ANSI/NETA ATS-2009

AMERICAN NATIONAL STANDARD

STANDARD FOR ACCEPTANCE TESTING SPECIFICATIONS for Electrical Power Equipment and Systems

Secretariat
InterNational Electrical Testing Association

Approved by
American National Standards Institute

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FOREWORD

(This Foreword is not part of American National Standard ANSI/NETA ATS-2009)

The InterNational Electrical Testing Association (NETA) was formed in 1972 to establish uniform testing procedures for electrical equipment and apparatus. NETA developed specifications for the acceptance of new electrical apparatus prior to energization and for the maintenance of existing apparatus to determine its suitability to remain in service. The first NETA *Acceptance Testing Specifications for Electrical Power Equipment and Systems* was produced in 1972. Upon completion of this project, the NETA Technical Committee began work on a maintenance document, and *Maintenance Testing Specifications for Electrical Power Equipment and Systems* was published in 1975.

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

The *NETA Acceptance Testing Specifications* was developed for use by those responsible for assessing the suitability for initial energization of electrical power equipment and systems and to specify field tests and inspections that ensure these systems and apparatus perform satisfactorily, minimizing downtime and maximizing life expectancy.

Since 1972, several revisions of the *Acceptance Testing Specifications* have been published; in 1989 the NETA Technical Committee, with approval of the Board of Directors, set a four-year review and revision schedule. Unless it involves a significant safety or urgent technical issue, each comment and suggestion for change is held until the appropriate review period. Each edition includes new and completely revised sections. The document uses the standard numbering system of ANSI and IEEE. Since 1989, revised editions of the *Acceptance Testing Specifications* have been published in 1991, 1995, 1999, 2003, and 2007.

On February 19, 2009, the American National Standards Institute approved the NETA *Acceptance Testing Specifications for Electrical Power Equipment and Systems* as an American National Standard.

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 acceptance 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:

Notation of Changes
Material included in this edition of the document but not part of the 2007 edition is marked with a black vertical line in the margin to the left of the insertion of text, deletion of text, or alteration of text.

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 acceptance testing of electrical power distribution equipment and systems. It is not intended that this document list how to test specific pieces of equipment or systems.

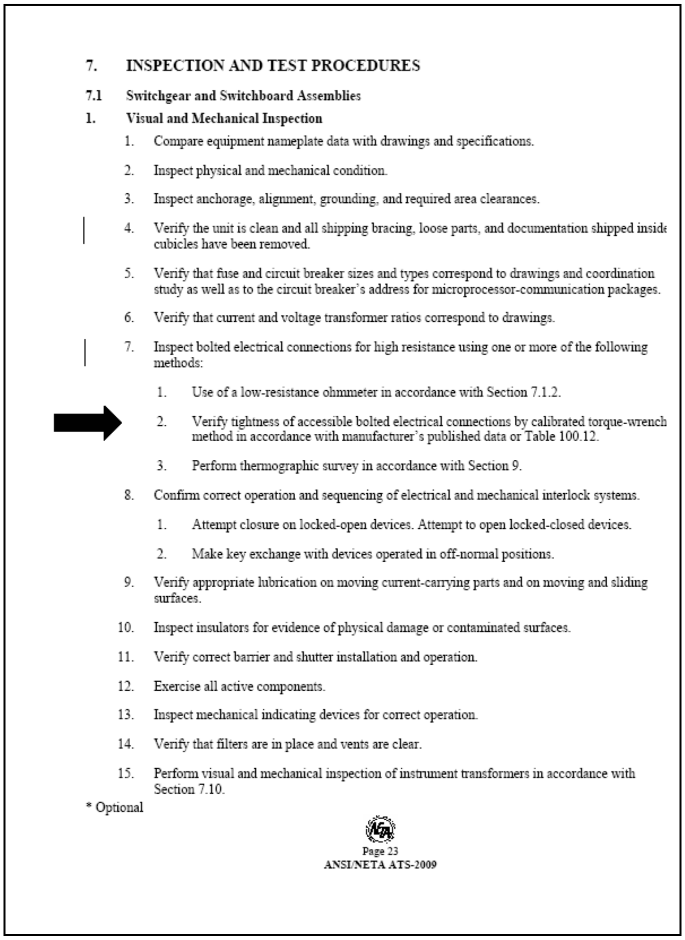
Expected Test Results
Section 7 consists of sections specific to each particular type of equipment. Within those sections there are, typically, three main bodies of information:

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

PREFACE (*Continued*)

Results of Visual and Mechanical Inspections

Some, but not all, visual and mechanical inspections have an associated test value or result. Those items with an expected result are referenced under Section 3.1 Test Values – Visual and Mechanical. For example, Section 7.1 Switchgear and Switchboard Assemblies, item 7.1.1.7.2 calls for verifying tightness of connections using a calibrated torque wrench method. Under the Test Values – Visual and Mechanical Section 7.1.3.1.2, the expected results for that particular task are listed within Section 3.1, with reference back to the original task description on item 7.1.1.7.2.



7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean and all shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.
5. Verify that fuse and 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 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 devices operated in off-normal positions.
9. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
10. Inspect insulators for evidence of physical damage or contaminated surfaces.
11. Verify correct barrier and shutter installation and operation.
12. Exercise all active components.
13. Inspect mechanical indicating devices for correct operation.
14. Verify that filters are in place and vents are clear.
15. Perform visual and mechanical inspection of instrument transformers in accordance with Section 7.10.

* Optional

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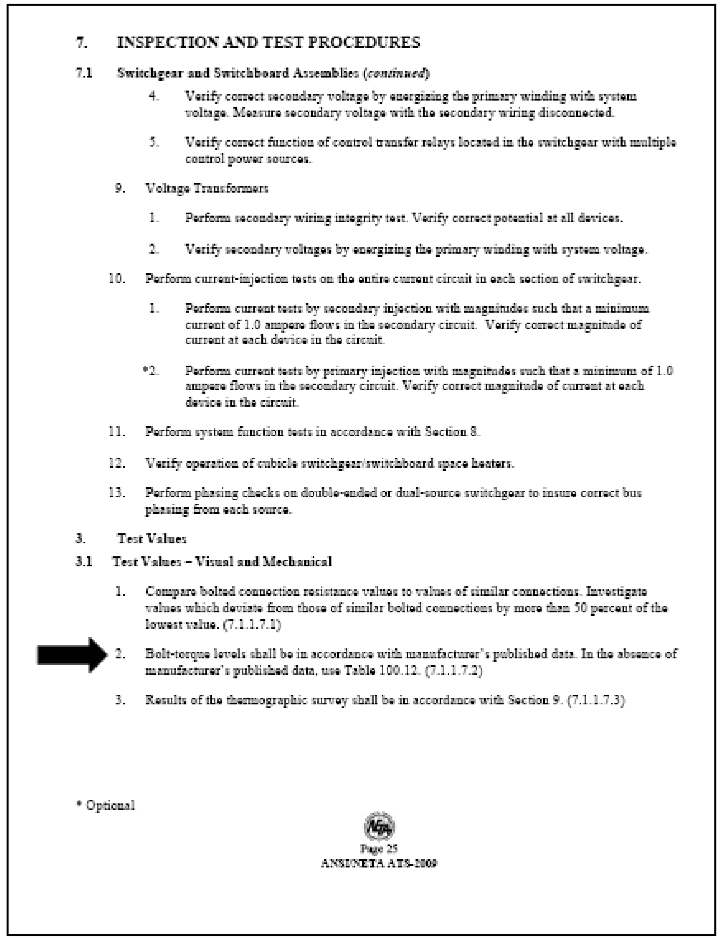

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (*continued*)

4. Verify correct secondary voltage by energizing the primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.
5. Verify correct function of control transfer relays located in the switchgear with multiple control power sources.

9. Voltage Transformers
   1. Perform secondary wiring integrity test. Verify correct potential at all devices.
   2. Verify secondary voltages by energizing the primary winding with system voltage.
10. Perform current-injection tests on the entire current circuit in each section of switchgear.
   1. Perform current tests by secondary injection with magnitudes such that a minimum current of 1.0 ampere flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.
   *2. Perform current tests by primary injection with magnitudes such that a minimum of 1.0 ampere flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.
11. Perform system function tests in accordance with Section 8.
12. Verify operation of cubicle switchgear/switchboard space heaters.
13. Perform phasing checks on double-ended or dual-source switchgear to insure correct bus phasing from each source.

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 shall 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)

* Optional

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PREFACE (*Continued*)

Results of Electrical Tests

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

7. INSPECTION AND TEST PROCEDURES

7.15.1 Rotating Machinery, AC Induction Motors and Generators

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Inspect air baffles, filter media, cooling fans, slip rings, brushes, and brush rigging.
5. Inspect bolted electrical connections for high resistance using one 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.
6. Perform special tests such as air-gap spacing and machine alignment, if applicable.
7. Verify the application of appropriate lubrication and lubrication systems.
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 ten minutes. Calculate polarization index.
    2. Machines 200 horsepower (150 kilowatts) and less: Test duration shall be one minute. Calculate 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.

7. INSPECTION AND TEST PROCEDURES

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

5. Air-gap spacing and machine alignment shall be in accordance with manufacturer's published data. (7.15.1.1.6).

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 index shall not be less than 1.0. The recommended minimum insulation resistance ($IR_{1\,min}$) test results in megohms shall 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 test, the test specimen is considered to have passed the test.
4. Investigate phase-to-phase stator resistance values that deviate by more than 10 percent.
5. Power-factor or dissipation-factor values shall be compared to manufacturer's published data. In the absence of manufacturer's published data these values will be compared with previous values of similar machines.
6. Tip-up values shall 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 shall be within manufacturer's published tolerances. In the absence of manufacturer's published tolerances, the comparison shall be made to similar machines.

* Optional

PREFACE (*Continued*)

Optional Tests

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

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

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

Manufacturer's Instruction Manuals

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

Summary

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

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

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

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CONTENTS (*continued*)

TABLES

CONTENTS (*continued*)

APPENDICES

1. GENERAL SCOPE

1. These specifications cover the suggested field tests and inspections that are available to assess the suitability for initial energization of electrical power equipment and systems.

2. The purpose of these specifications is to assure that tested electrical equipment and systems are operational, are within applicable standards and manufacturer's tolerances, and are installed in accordance with design specifications.

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 issues associated with their use. It is the responsibility of the user to review all applicable regulatory limitations prior to the use of these specifications

2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications

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

1. American National Standards Institute – ANSI

2. ASTM International - ASTM

ASTM D92	*Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*
ASTM D445	*Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)*
ASTM D664	*Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration*
ASTM D877	*Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids using Disk Electrodes*
ASTM D923	*Standard Practices for Sampling Electrical Insulating Liquids*
ASTM D924	*Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids*
ASTM D971	*Standard Test Method for Interfacial Tension of Oil against Water by the Ring Method*
ASTM D974	*Standard Test Method for Acid and Base Number by Color-Indicator Titration*
ASTM D1298	*Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*
ASTM D1500	*Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)*
ASTM D1524	*Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field*
ASTM D1533	*Standard Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration*
ASTM D1816	*Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes*

2. APPLICABLE REFERENCES

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

ASTM D2029	*Standard Test Methods for Water Vapor Content of Electrical Insulating Gases by Measurement of Dew Point*
ASTM D2129	*Standard Test Method for Color of Clear Electrical Insulating Liquids (Platinum-Cobalt Scale)*
ASTM D2284	*Standard Test Method of Acidity of Sulfur Hexafluoride*
ASTM D2285	*Standard Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin against Water by the Drop-Weight Method*
ASTM D2477	*Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies*
ASTM D2685	*Standard Test Method for Air and Carbon Tetrafluoride in Sulfur Hexafluoride by Gas Chromatography*
ASTM D2759	*Standard Practice for Sampling Gas from a Transformer under Positive Pressure*
ASTM D3284	*Standard Test Method for Combustible Gases in the Gas Space of Electrical Apparatus Using Portable Meters*
ASTM D3612	*Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography*
ASTM D3613	*Standard Practice for Sampling Electrical Insulating Oils for Gas Analysis and Determination of Water Content*

3. Association of Edison Illuminating Companies - AEIC

4. Canadian Standards Association - CSA

5. Electrical Apparatus Service Association - EASA

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

2. APPLICABLE REFERENCES

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

6. Institute of Electrical and Electronic Engineers - IEEE

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 C93.1	*Requirements for Power-Line Carrier Coupling Capacitors and Coupling Capacitor Voltage Transformers (CCVT)*
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 (IEEE Red Book)*
ANSI/IEEE 142	*IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE 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)*
ANSI/IEEE 400	*IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems*
ANSI/IEEE 400.2	*IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)*
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)*

2. APPLICABLE REFERENCES

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

ANSI/IEEE 1106	*IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Batteries for Stationary Applications*
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 Arc-Flash Hazard Calculations*

7. Insulated Cable Engineers Association – ICEA

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 - 46,000 Volts*
ANSI/ICEA S-97-682	*Standard for Utility Shielded Power Cables Rated 5,000 - 46,000 Volts*

8. InterNational Electrical Testing Association - NETA

ANSI/NETA ETT	*Standard for Certification of Electrical Testing Technicians*
ANSI/NETA MTS 7.2.1.1	*Standard for Electrical Maintenance Testing of Dry-Type Transformers*
ANSI/NETA MTS 7.2.1.2	*Standard for Electrical Maintenance Testing of Liquid-Filled Transformers*
NETA MTS	*Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*

9. National Electrical Manufacturers Association - NEMA

NEMA AB4	*Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications*
ANSI/NEMA 84.1	*Electrical Power Systems and Equipment Voltage Ratings (60 Hz)*
NEMA MG1	*Motors and Generators*

10. National Fire Protection Association - NFPA

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

ANSI/NFPA 70	*National Electrical Code*
ANSI/NFPA 70B	*Recommended Practice for Electric Equipment Maintenance*
ANSI/NFPA 70E	*Standard for Electrical Safety in the Workplace*
ANSI/NFPA 99	*Standard for Healthcare Facilities*
ANSI/NFPA 101	*Life Safety Code*
ANSI/NFPA 110	*Emergency and Standby Power Systems*
ANSI/NFPA 780	*Installation of Lightning Protection Systems*

11. Occupational Safety and Health Administration - OSHA

12. State and local codes and ordinances

13. Underwriters Laboratories, Inc. - UL

2. APPLICABLE REFERENCES

2.2 Other Publications

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

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

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

Paul Gill, *Electrical Power Equipment Maintenance and Testing*, New York: Marcel Dekker, Inc.

Kenneth G. Mastrullo, Ray A. Jones, Jane G. Jones, *The Electrical Safety Program Book*, NFPA

2.3 Contact Information

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

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

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

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

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

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

2. APPLICABLE REFERENCES

2.3 Contact Information (*continued*)

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

International Electrotechnical Commission – IEC
Contact through American National Standards Institute

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

Marcel Dekker, Inc.
PO Box 5005
Monticello, NY 12701
(800) 228-160
www.dekker.com

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

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

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

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

2. APPLICABLE REFERENCES

2.3 Contact Information (*continued*)

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

The Okonite Company
102 Hilltop Road
Ramsey, New Jersey 07446
(201) 825-0300 Fax 201-825-3524
www.okonite.com

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

3. QUALIFICATIONS OF TESTING ORGANIZATION AND PERSONNEL

3.1 Testing Organization

1. The testing organization shall be an independent, third party entity which can function as an unbiased testing authority, professionally independent of the manufacturers, suppliers, and installers of equipment or systems being evaluated.

2. The testing organization shall be regularly engaged in the testing of electrical equipment devices, installations, and systems.

3. The testing organization shall use technicians who are regularly employed for testing services.

4. An organization having a designation of “NETA Accredited Company” issued by the InterNational Electrical Testing Association meets the above criteria.

5. The testing organization shall submit appropriate documentation to demonstrate that it satisfactorily complies with these requirements.

3.2. Testing Personnel

1. 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 evaluate the test data and make a judgment on the serviceability of the specific equipment.

2. Technicians shall be certified in accordance with ANSI/NETA ETT-2000, *Standard for Certification of Electrical Testing Personnel*. Each on-site crew leader shall hold a current certification, Level III or higher, in electrical testing.

4. DIVISION OF RESPONSIBILITY

4.1 The Owner's Representative

The owner's representative shall provide the testing organization with the following:

1. A short-circuit analysis, a coordination study, and a protective device setting sheet as described in Section 6.

2. A complete set of electrical plans and specifications, including all change orders.

3. Drawings and instruction manuals applicable to the scope of work.

4. An itemized description of equipment to be inspected and tested.

5. A determination of who shall provide a suitable and stable source of electrical power to each test site.

6. A determination of who shall perform certain preliminary low-voltage insulation-resistance, continuity, and low-voltage motor rotation tests prior to and in addition to tests specified herein.

7. Notification of when equipment becomes available for acceptance tests. Work shall be coordinated to expedite project scheduling.

8. 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 that is found deficient based on the results of the acceptance tests.

5. A written 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 contain 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 qualified and 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 29 CFR Part 1910 and 29 CFR Part 1926.

    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 the 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 to be performed and the equipment to be tested.

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 better 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 and/or calibrations.
    4. Date of inspections, tests, maintenance, and/or calibrations.
    5. Identification of the testing technician.
    6. Indication of inspections, tests, maintenance, and/or calibrations to be performed and recorded.
    7. Indication of expected results when calibrations are to be performed.
    8. Indication of as-found and as-left results, as applicable.
    9. Sufficient spaces to allow all results and comments to be indicated.

3. The testing organization shall furnish a copy or copies of the complete report to the owner as specified in the acceptance 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 399 and the step-by-step procedures outlined in the short-circuit calculation chapters of IEEE 141 and ANSI/IEEE 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

   Determine protective device characteristics, settings, or sizes that provide a balance between equipment protection and selective device operation that is optimum for 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 coordination study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399 and ANSI/IEEE 242. Protective device selection and settings shall comply with requirements of NFPA 70 *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 demonstrating the coordination of time-overcurrent protective devices.

   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.

   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, and parallel generation.
   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.

6.3 Arc-Flash Hazard Analysis (*continued*)

10. Calculate the flash protection boundary at each fault location.

11. Document the assessment in reports and one-line diagrams. 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.

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.

2. Procedure

   The load-flow study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 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/IEEE C84.1, or other appropriate standards shall be clearly noted.

   6. Tabulations of system real and reactive power losses with areas of concern clearly noted.

   7. Conclusions and recommendations.

6. POWER SYSTEM STUDIES

6.5 Stability Studies

1. Scope of Study

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

2. Procedure

   The stability study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 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 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 ANSI/IEEE 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. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, grounding, and required area clearances.

4. Verify the unit is clean and all shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.

5. Verify that fuse and 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 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 devices operated in off-normal positions.

9. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

10. Inspect insulators for evidence of physical damage or contaminated surfaces.

11. Verify correct barrier and shutter installation and operation.

12. Exercise all active components.

13. Inspect mechanical indicating devices for correct operation.

14. Verify that filters are in place and vents are clear.

15. 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*)

16. 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 or circuit breaker ratings match drawings.

    3. Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.

2. Electrical Tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.1.1.

2. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground, for one minute in accordance with Table 100.1.

3. Perform a dielectric withstand voltage test on each bus section, each phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 100.2. The test voltage shall be applied for one minute.

*4. Perform insulation-resistance tests on control wiring with respect to ground. 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 can not tolerate the applied voltage, follow the manufacturer's recommendation.

5. Perform electrical tests on instrument transformers in accordance with Section 7.10.

6. Perform ground-resistance tests in accordance with Section 7.13.

7. Determine accuracy of all meters and calibrate watthour meters in accordance with Section 7.11. Verify multipliers.

8. Control Power Transformers

    1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with Table 100.1 unless otherwise specified by the manufacturer.

    2. Perform a turns-ratio test on all tap positions.

    3. Perform secondary wiring integrity test. Disconnect transformer at secondary terminals and connect secondary wiring to a rated secondary voltage source. Verify correct potential at all devices.

* Optional

7.1 Switchgear and Switchboard Assemblies (*continued*)

4. Verify correct secondary voltage by energizing the primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.

5. Verify correct function of control transfer relays located in the switchgear with multiple control power sources.

9. Voltage Transformers

   1. Perform secondary wiring integrity test. Verify correct potential at all devices.

   2. Verify secondary voltages by energizing the primary winding with system voltage.

10. Perform current-injection tests on the entire current circuit in each section of switchgear.

    1. Perform current tests by secondary injection with magnitudes such that a minimum current of 1.0 ampere flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.

    *2. Perform current tests by primary injection with magnitudes such that a minimum of 1.0 ampere flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.

11. Perform system function tests in accordance with Section 8.

12. Verify operation of cubicle switchgear/switchboard space heaters.

13. Perform phasing checks on double-ended or dual-source switchgear to insure correct bus phasing from each source.

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 shall 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)

* Optional

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (*continued*)

3.2 Test Values – Electrical

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

2. Insulation-resistance values of bus insulation shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.

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 test specimen is considered to have passed the test.

4. Minimum insulation-resistance values of control wiring shall not be less than two megohms.

5. Results of electrical tests on instrument transformers shall be in accordance with Section 7.10.

6. Results of ground-resistance tests shall be in accordance with Section 7.13.

7. Accuracy of meters shall be in accordance with Section 7.11.

8. Control Power Transformers

    1. Insulation-resistance values of control power transformers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

    2. Turns-ratio test results shall not deviate by more than one half percent from either the adjacent coils or the calculated ratio.

    3. Secondary wiring shall be in accordance with design drawings and specifications.

    4. Secondary voltage shall be in accordance with design specifications.

    5. Control transfer relays shall perform as designed.

9. Voltage transformers

    1. Secondary wiring shall be in accordance with design drawings and specifications.

    2. Secondary voltage shall be in accordance with design specifications

* Optional

10. Current-injection tests shall prove current wiring is in accordance with design specifications.

11. Results of system function tests shall be in accordance with Section 8.

12. Heaters shall be operational.

13. Phasing checks shall prove the switchgear or switchboard phasing is correct and in accordance with the system design.

* 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify that resilient mounts are free and that any shipping brackets have been removed.
5. Verify the unit is clean.
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 7.2.1.1.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
7. Verify that as-left tap connections are as specified.

2. Electrical Tests

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

*3. Perform turns-ratio tests at all tap positions.

4. Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.2.1.1.1.6.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.1.1.1.6.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.2.1.1.1.6.3)

4. Tap connections are left as found unless otherwise specified. (7.2.1.1.7)

3.2 Test Values – Electrical

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

2. Minimum insulation-resistance values of transformer insulation shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall not be less than 1.0.

3. Turns-ratio test results shall not deviate by more than one-half percent from either the adjacent coils or the calculated ratio.

4. Phase-to-phase and phase-to-neutral secondary voltages shall be in agreement with nameplate data.

* 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. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify that resilient mounts are free and that any shipping brackets have been removed.

5. Verify the unit is clean.

*6. Verify that control and alarm settings on temperature indicators are as specified.

7. Verify that cooling fans operate and that fan motors have correct overcurrent protection.

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 7.2.1.2.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

9. Perform specific inspections and mechanical tests as recommended by the manufacturer.

10. Verify that as-left tap connections are as specified.

11. Verify the presence of surge arresters.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.1.2.1.

2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.5. Calculate polarization index.

3. Perform power-factor or dissipation-factor tests on all windings in accordance with the test equipment manufacturer’s published data.

*4. Perform a power-factor or dissipation-factor tip-up test on windings greater than 2.5 kV.

* Optional

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

5. Perform turns-ratio tests at all tap positions.

*6. Perform an excitation-current test on each phase.

*7. Measure the resistance of each winding at each tap connection.

8. Measure core insulation resistance at 500 volts dc if the core is insulated and 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.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Control and alarm settings on temperature indicators shall operate within manufacturer's recommendations for specified settings. (7.2.1.2.1.6)

2. Cooling fans shall operate. (7.2.1.2.1.7)

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. (7.2.1.2.1.8.1)

4. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.1.2.1.8.2)

5. Results of the thermographic survey shall be in accordance with Section 9. (7.2.1.2.1.8.3)

6. Tap connections shall be left as found unless otherwise specified. (7.2.1.2.1.10)

3.2 Test Values – Electrical

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

2. Minimum insulation-resistance values of transformer insulation shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall not be less than 1.0.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

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 shall be expected on C_{HL} power factors:

   Power transformers: 2.0 percent or less
   Distribution transformers: 5.0 percent or less

   Consult transformer manufacturer's or test equipment manufacturer's data for additional information.

4. Power-factor or dissipation-factor tip-up exceeding 1.0 percent shall be investigated.

5. Turns-ratio test results shall 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.

7. Temperature-corrected winding-resistance values shall compare within one percent of previously-obtained results.

8. Core insulation-resistance values shall not be less than one megohm at 500 volts dc.

9. 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 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 test, the test specimen is considered to have passed the test.

10. Phase-to-phase and phase-to-neutral secondary voltages shall 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect impact recorder prior to unloading.
4. Test dew point of tank gases, if applicable.
5. Inspect anchorage, alignment, and grounding.
6. Verify the presence of PCB content labeling.
7. Verify removal of any shipping bracing after placement.
8. Verify the bushings are clean.
9. Verify that alarm, control, and trip settings on temperature and level indicators are as specified.
10. Verify operation of alarm, control, and trip circuits from temperature and level indicators, pressure relief device, gas accumulator, and fault pressure relay, if applicable.
11. Verify that cooling fans and pumps operate correctly and have appropriate overcurrent protection.
12. Inspect bolted electrical connections for high resistance using one or more of the following methods:
    1. Use of a low-resistance ohmmeter in accordance with Section 7.2.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
13. Verify correct liquid level in tanks and bushings.
14. Verify that positive pressure is maintained on gas-blanketed transformers.
15. Perform inspections and mechanical tests as recommended by the manufacturer.
16. Test load tap-changer in accordance with Section 7.12.
17. Verify presence of transformer surge arresters.
18. Verify de-energized tap-changer position is left as specified.

* Optional

7.2.2 Transformers, Liquid-Filled (*continued*)

2. Electrical Tests

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

2. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground. Apply in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.

3. Perform turns-ratio tests at all tap positions.

4. Perform insulation power-factor or dissipation-factor tests on all windings in accordance with test equipment manufacturer's published data.

5. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.

6. Perform excitation-current tests in accordance with test equipment manufacturer's published data.

7. Measure the resistance of each high-voltage winding in each de-energized tap-changer position. Measure the resistance of each low-voltage winding in each de-energized tap-changer position, if applicable.

*8. If core ground strap is accessible, remove and measure 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. 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

* Optional

7.2.2 Transformers, Liquid-Filled (*continued*)

*7. Water in insulating liquids: ASTM D 1533. (Required on 25 kV or higher voltages and on all silicone-filled units.)

*8. 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 instrument transformers in accordance with Section 7.10.

13. Test surge arresters in accordance with Section 7.19, if applicable.

14. Test transformer neutral grounding impedance device, if applicable.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Alarm, control, and trip circuits from temperature and level indicators as well as pressure relief device and fault pressure relay shall operate within manufacturer's recommendations for their specified settings. (7.2.2.1.10)

2. Cooling fans and pumps shall operate. (7.2.2.1.11)

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. (7.2.2.1.12.1)

4. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.2.1.12.2)

5. Results of the thermographic survey shall be in accordance with Section 9. (7.2.2.1.12.3)

6. Liquid levels in the transformer tanks and bushings shall be within indicated tolerances. (7.2.2.1.13)

7. Positive pressure shall be indicated on pressure gauge for gas-blanketed transformers. (7.2.2.1.14)

3.2 Test Values – Electrical

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

* Optional

7.2.2 Transformers, Liquid-Filled (*continued*)

2. Minimum insulation-resistance values of transformer insulation shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall not be less than 1.0.

3. Turns-ratio test results shall not deviate by more than one-half percent from either the adjacent coils or the calculated ratio.

4. Maximum winding insulation power-factor/dissipation-factor values of liquid-filled transformers shall be in accordance with the manufacturer's published data. In the absence of manufacturer's published data use 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 shall compare within one percent of previously obtained results.

8. Core insulation values shall be compared to the factory test value 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 shall 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 manufacturer's published data.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.3.1 Cables, Low-Voltage, Low-Energy

— RESERVED —

* Optional

7. INSPECTION AND TEST PROCEDURES

7.3.2 Cables, Low-Voltage, 600-Volt Maximum

1. Visual and Mechanical Inspection

1. Compare cable data with drawings and specifications.

2. Inspect exposed sections of cable for physical damage and correct connection in accordance with the single-line diagram.

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 7.3.2.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

4. Inspect compression-applied connectors for correct cable match and indentation.

5. Inspect for correct identification and arrangements.

6. Inspect cable jacket insulation and condition.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.3.2.1.

2. Perform insulation-resistance test on each conductor with respect to ground and adjacent conductors. 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.

3. Perform continuity tests to insure correct cable connection.

*4. Verify uniform resistance of parallel conductors.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.3.2.1.3.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.3.2.1.3.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.3.2.1.3.3)

* Optional

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

3.2 Test Values – Electrical

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

2. Insulation-resistance values shall 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 shall be investigated.

3. Cable shall exhibit continuity.

4. 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. Compare cable data with drawings and specifications.

2. Inspect exposed sections of cables for physical damage.

3. Inspect bolted electrical connections for high resistance using one or more of the following methods:

    1. Use of a low-resistance ohmmeter in accordance with Section 7.3.3.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

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

4. Inspect compression-applied connectors for correct cable match and indentation.

5. Inspect shield grounding, cable supports, and terminations.

6. Verify that visible cable bends meet or exceed ICEA and manufacturer's minimum published 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.

9. Inspect for correct identification and arrangements.

10. Inspect cable jacket and insulation condition.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.3.3.1.

2. Perform an insulation-resistance test individually on each conductor with all other conductors and shields grounded. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

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

* Optional

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

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 baseline diagnostic tests such as partial discharge analysis, and power factor or dissipation factor. The selection shall be made after an evaluation of the available test methods and a review of the installed cable system. Some of the available test methods are listed below.

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. Baseline 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. Off-line partial discharge
    1. Power frequency (50/60 Hz)
    2. Very low frequency (VLF)

3. Test Values

3.1 Test Values – Visual and Mechanical

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

* Optional

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

3.2 Test Values – Electrical

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

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Shielding shall exhibit continuity. Investigate resistance values in excess of ten ohms per 1000 feet of cable.

4.1 If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.

4.2 Based on the test methodology chosen, refer to applicable standards or manufacturer's literature for acceptable values.

* Optional

7.4 Metal-Enclosed Busways

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify correct connection in accordance with single-line diagram.

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 7.4.2.

    2. Verify tightness of accessible bolted electrical connections and bus joints by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

6. Confirm physical orientation in accordance with manufacturer's labels to insure adequate cooling.

7. Examine outdoor busway for removal of "weep-hole" plugs, if applicable, and the correct installation of joint shield.

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. Measure insulation resistance of each busway, phase-to-phase and phase-to-ground for one minute, in accordance with Table 100.1.

3. Perform a dielectric withstand voltage test on each busway, phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. In the absence of manufacturer's published data, use 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 adjacent phases.

5. Perform phasing test on each busway tie section energized by separate sources. Tests must be performed from their permanent sources.

* Optional

7.4 Metal-Enclosed Busways (*continued*)

6. Verify operation of busway space heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.4.1.5.1)

2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.4.1.5.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.4.1.5.3)

3.2 Test Values – Electrical

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

2. Insulation-resistance test voltages and resistance values shall be in accordance with manufacturer's published. In the absence of manufacturer's published data, use Table 100.1. Minimum resistance values are for a nominal 1000-foot busway run. Use the following formula to convert the measured resistance value to the 1000-foot nominal value:

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

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

3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.

4. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values which deviate from those of similar bus connections and sections by more than 50 percent of the lowest value.

5. Phasing test results shall indicate the phase relationships are in accordance with system design.

6. Heaters shall be operational.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.5.1.1 Switches, Air, Low-Voltage

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required clearances.
4. Verify the unit is clean.
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 studies, 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 thermographic survey in accordance with Section 9.
9. Verify operation and sequencing of interlocking systems.
10. Verify correct phase barrier installation.
11. Verify correct operation of all indicating and control devices.
12. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.1.1.1.
2. Measure contact resistance across each switchblade and fuseholder.
3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

4. Measure fuse resistance.

5. Verify cubicle space heater operation.

6. Perform ground fault test in accordance with Section 7.14, if applicable.

7. Perform tests on other protective devices in accordance with Section 7.9, if applicable.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.1.1.1.8.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.1.1.1.8.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.1.1.1.8.3)

3.2 Test Values – Electrical

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

2. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

3. Insulation-resistance values shall 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 shall be investigated.

4. Investigate fuse-resistance values that deviate from each other by more than 15 percent.

5. Heaters shall be operational.

6. Ground fault tests shall be in accordance with Section 7.14.

7. Results of protective device tests shall 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required clearances.
4. Verify the unit is clean.
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 study, and coordination study.
7. Verify that expulsion-limiting devices are in place on all holders having expulsion-type elements.
8. Verify that each fuseholder has adequate mechanical support and contact integrity.
9. Inspect bolted electrical connections for high resistance using one or more of the following methods:
    1. Use of a low-resistance ohmmeter in accordance with Section 7.5.1.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
10. Verify operation and sequencing of interlocking systems.
11. Verify correct phase barrier installation.
12. Verify correct operation of all indicating and control devices.
13. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

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 and fuseholder.

* Optional

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

3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

4. Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.2.

5. Measure fuse resistance.

6. Verify cubicle space heater operation.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.1.2.1.9.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.1.2.1.9.2)

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

3.2 Test Values – Electrical

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

2. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's published data, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

3. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.

4. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.

* Optional

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

5. Investigate fuse resistance values that deviate from each other by more than 15 percent.

6. Heaters shall be operational.

* Optional

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

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required clearances.
4. Verify the unit is clean.
5. Perform mechanical operator tests in accordance with manufacturer's published data, if applicable.
6. Verify correct operation and adjustment of motor operator limit switches and mechanical interlocks, if applicable.
7. Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation.
8. Verify operation and sequencing of interlocking systems.
9. Verify that each fuse has adequate mechanical support and contact integrity, if applicable.
10. Verify that fuse sizes and types are in accordance with drawings, short-circuit study, and coordination study.
11. 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 7.5.1.3.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
12. Verify correct operation of all indicating and control devices, if applicable.
13. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
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 contact-resistance test across each switchblade and fuseholder.

3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

*4. Perform insulation-resistance tests on all control wiring with respect to ground. 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 can not tolerate the applied voltage, follow manufacturer's recommendation.

5. Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.1.3.1.11.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.1.3.1.11.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.1.3.1.11.3)

4. Operation counter should advance one digit per close-open cycle.(7.5.1.3.1.14)

3.2 Test Values – Electrical

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

2. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's published data, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

* Optional

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

3. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.

4. Minimum insulation-resistance values of control wiring shall not be 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 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required clearances.
4. Verify the unit is clean.
5. Perform mechanical operator tests in accordance with manufacturer's published data, if applicable.
6. Verify correct operation and adjustment of motor operator limit switches and mechanical interlocks, if applicable.
7. Verify operation and sequencing of interlocking systems.
8. Verify that each fuse has adequate mechanical support and contact integrity, if applicable.
9. Verify that fuse sizes and types are in accordance with drawings, short-circuit study, and coordination study.
10. 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 7.5.1.3.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
11. Verify that insulating oil level is correct.
12. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Record as-found and as-left operation counter readings.

* Optional

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

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.2.1

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 switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

*4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.

5. Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19.

*6. Remove a sample of insulating liquid in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.

    1. Dielectric breakdown voltage: ASTM D 877.

    2. Color: ANSI/ASTM D 1500

    3. Visual condition: ASTM D 1524

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.2.1.10.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.2.1.10.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.2.1.10.3)

4. Operation counter shall advance one digit per close-open cycle. (7.5.2.1.13)

* Optional

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

3.2 Test Values – Electrical

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

2. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

3. Insulation-resistance values shall 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 shall 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 shall not be 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 test, the test specimen is considered to have passed the test.

6. Insulating liquid test results shall 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required clearances.
4. Verify the unit is clean.
5. Perform mechanical operator tests in accordance with manufacturer's published data, if applicable.
6. Verify correct operation and adjustment of motor operator limit switches and mechanical interlocks, if applicable.
7. Verify critical distances on operating mechanism as recommended by the manufacturer.
8. Verify operation and sequencing of interlocking systems.
9. Verify that each fuse has adequate support and contact integrity.
10. Verify that fuse sizes and types are in accordance with drawings, the short-circuit study, and the coordination study.
11. Inspect bolted electrical connections for high resistance using one or more of the following methods:
    1. Use of a low-resistance ohmmeter. See Section 7.5.3.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
12. Verify that insulating oil level is correct, if applicable.
13. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
14. Record as-left operation counter reading, if applicable.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

2. Electrical Tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. See Section 7.5.3.1

2. Perform a contact/pole-resistance test.

3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

4. Perform vacuum bottle integrity (dielectric withstand voltage) test across each vacuum bottle with the contacts in the open position in strict accordance with manufacturer's published data.

5. Remove a sample of insulating liquid, if applicable, in accordance with ASTM D 923. 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. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

7. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Critical distances of the operating mechanism shall be in accordance with manufacturer's published data. (7.5.3.1.7)

2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.3.1.11.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.3.1.11.2)

* Optional

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

4. Results of the thermographic survey shall be in accordance with Section 9. (7.5.3.1.11.3)

5. Operation counter shall advance one digit per close-open cycle. (7.5.3.1.14)

3.2 Test Values – Electrical

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

2. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

3. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.

4. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the vacuum bottle integrity test, the test specimen is considered to have passed the test.

5. Insulating liquid test results shall be in accordance with Table 100.4.

6. Insulation-resistance values of control wiring shall not be 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 test, the test specimen is considered to have passed the test.

8. Results of open and close operation from control devices shall 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required clearances.
4. Verify the unit is clean.
5. Inspect and service mechanical operator and SF_6 gas insulated system in accordance with the manufacturer's 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. Verify operation and sequencing of interlocking systems.
9. Verify that each fuse holder has adequate mechanical support and contact integrity.
10. Verify that fuse sizes and types are in accordance with drawings, short-circuit study, and coordination study.
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 7.5.4.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
12. Verify appropriate contact lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Test for SF_6 gas leaks in accordance with manufacturer's published data.
14. Record as-found and as-left operation counter readings.

* 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/pole-resistance test.

3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

*4. Remove a sample of SF_6 gas if provisions are made for sampling and test in accordance with Table 100.13.

5. Perform a dielectric withstand voltage test across each gas bottle with the switch in the open position in accordance with manufacturer's published data.

*6. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

7. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Critical distances of operating mechanism shall be in accordance with manufacturer's published data. (7.5.4.1.7)

2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.4.1.11.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.4.1.11.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.5.4.1.11.3)

5. Operation counter shall advance one digit per close-open cycle. (7.5.4.1.14)

* Optional

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

3.2 Test Values – Electrical

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

2. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's published data, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

3. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.

4. Results of SF_6 gas tests shall 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 gas bottle dielectric withstand test, the test specimen is considered to have passed the test.

6. Insulation-resistance values of control wiring shall not be 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 test, the test specimen is considered to have passed the test.

8. Results of open and close operation from control devices shall be in accordance with system design.

7. INSPECTION AND TEST PROCEDURES

7.5.5 Switches, Cutouts

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required clearances.
4. Verify the unit is clean.
5. Verify correct blade alignment, blade penetration, travel stops, latching mechanism, and mechanical operation.
6. Verify that each fuseholder has adequate mechanical support and contact integrity.
7. Verify that fuse size and types are in accordance with drawings, short-circuit study, and coordination study.
8. 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 7.5.5.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.

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. Test voltage shall be in accordance with manufacturer’s published data or Table 100.1.
4. Perform a dielectric withstand voltage test on each pole, phase-to-ground with cutout closed. Ground adjacent cutouts, if applicable. Test voltage shall be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.5.5 Switches, Cutouts (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.5.1.8.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.5.1.8.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.5.1.8.3)

3.2 Test Values – Electrical

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

2. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values which deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

3. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.

4. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage and alignment.
4. Verify the unit is clean.
5. Operate the circuit breaker to insure smooth operation.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
    1. Use of a low-resistance ohmmeter in accordance with Section 7.6.1.1.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform 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 the coordination study.

2. Electrical Tests

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

*4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

5. Determine long-time pickup and delay by primary current injection.
6. Determine short-time pickup and delay by primary current injection.

* Optional

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

7. Determine ground-fault pickup and time delay by primary current injection.

8. Determine instantaneous pickup by primary current injection.

*9. Test functions of the trip unit by means of secondary injection.

10. Perform minimum pickup voltage tests on shunt trip and close coils in accordance with manufacturer's published data.

11. Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, anti-pump function, and trip unit battery condition. Reset all trip logs and indicators.

12. Verify operation of charging mechanism.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.6.1.1.1.6.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.1.1.1.6.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.6.1.1.1.6.3)

4. Settings shall comply with coordination study recommendations. (7.6.1.1.1.8)

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 shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.

4. Insulation-resistance values of control wiring shall not be less than two megohms.

* Optional

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

5. Long-time pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current characteristic tolerance band, including adjustment factors. If manufacturer's curves are not available, trip times shall not exceed the value shown in Table 100.7.

6. Short-time pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current tolerance band.

7. Ground fault pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current tolerance band.

8. Instantaneous pickup values shall be as specified and within manufacturer's published tolerances. In the absence of manufacturer's published data, refer to Table 100.8.

9. Pickup values and trip characteristics shall be within manufacturer's published tolerances.

10. Minimum pickup voltage of the shunt trip and close coils shall conform to the manufacturer's published data. In the absence of the manufacturer's published data, refer to Table 100.20.

11. Breaker open, close, trip, trip-free, anti-pump, and auxiliary features shall function as designed.

12. The charging mechanism shall operate in accordance with manufacturer's published data.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.6.1.2 Circuit Breakers, Air, Low-Voltage Power

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify that all maintenance devices are available for servicing and operating the breaker.
5. Verify the unit is clean.
6. Verify the arc chutes are intact.
7. Inspect moving and stationary contacts for condition and alignment.
8. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
9. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism in accordance with manufacturer's published data.
10. Inspect bolted electrical connections for high resistance using one or more of the following methods:
    1. Use of a low-resistance ohmmeter in accordance with Section 7.6.1.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform a thermographic survey in accordance with Section 9.
11. Verify cell fit and element alignment.
12. Verify racking mechanism operation.
13. Verify 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. Record as-found and as-left operation counter readings.

* 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. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

3. Perform a contact/pole-resistance test.

*4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

5. Determine long-time pickup and delay by primary current injection.

6. Determine short-time pickup and delay by primary current injection.

7. Determine ground-fault pickup and delay by primary current injection.

8. Determine instantaneous pickup value by primary current injection.

*9. Test functions of the trip unit by means of secondary injection.

10. Perform minimum pickup voltage tests on shunt trip and close coils in accordance with manufacturer's published data.

11. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, antipump function, and trip unit battery condition. Reset all trip logs and indicators.

12. Verify operation of charging mechanism.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.6.1.2.1.10.1).

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.1.2.1.10.2)

* Optional

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

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. (7.6.1.2.1.14)

5. Operations counter shall advance one digit per close-open cycle. (7.6.1.2.1.15)

3.2 Test Values – Electrical

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

2. Insulation-resistance values of circuit breakers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's 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 shall not be less than two megohms.

5. Long-time pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current characteristic tolerance band, including adjustment factors. If manufacturer's curves are not available, trip times shall not exceed the value shown in Table 100.7.

6. Short-time pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current tolerance band.

7. Ground fault pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current tolerance band.

8. Instantaneous pickup values shall be as specified and within manufacturer's published tolerances. In the absence of manufacturer's published data, refer to Table 100.8.

9. Pickup values and trip characteristic shall be as specified and within manufacturer's published tolerances.

10. Minimum pickup voltage of the shunt trip and close coils shall conform to the manufacturer's published data. In the absence of the manufacturer's published data, refer to Table 100.20.

11. Auxiliary features shall operate in accordance with manufacturer's published data.

* Optional

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

12. The charging mechanism shall operate in accordance with manufacturer's published data.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.6.1.3 Circuit Breakers, Air, Medium-Voltage

1. Visual and Mechanical Inspection

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

*15. Perform time-travel analysis.

16. Record as-found and as-left operation-counter readings.

* Optional

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

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 circuit breaker closed, and across each open pole. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.

3. Perform a contact/pole-resistance test.

*4. Perform insulation-resistance tests on all control wiring with respect to ground. 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 can not tolerate the applied voltage, follow manufacturer’s recommendation.

5. With breaker in the 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 mechanism charge, trip-free, and antipump functions.

6. Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer’s published data.

*7. Perform power-factor or dissipation-factor tests with breaker in both the open and closed positions.

*8. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer’s published data.

9. Perform a dielectric withstand voltage test on each phase with the circuit breaker closed and the poles not under test grounded. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.19.

10. Measure blowout coil circuit resistance.

11. Verify operation of cubicle space heaters.

12. Test instrument transformers in accordance with Section 7.10.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Mechanical operation and contact alignment shall be in accordance with manufacturer's published data. (7.6.1.3.1.9)

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. (7.6.1.3.1.10.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.1.3.1.10.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.6.1.3.1.10.3)

5. Travel and velocity values shall be in accordance with manufacturer's published data. (7.6.1.3.1.15)

6. Operations counter shall advance one digit per close-open cycle. (7.6.1.3.1.16)

3.2 Test Values – Electrical

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

2. Insulation-resistance values of circuit breakers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's 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 shall not be less than two megohms.

5. Breaker mechanism charge, close, open, trip, trip-free, and antipump features shall function as designed.

6. Minimum pickup voltage of the trip and close coils shall conform to the manufacturer's published data. In the absence of the manufacturer's published data, refer to Table 100.20.

* Optional

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

7. Power-factor or dissipation-factor values shall be compared with previous test results of similar breakers or manufacturer's published data.

8. Power-factor or dissipation-factor and capacitance values shall be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/milliwatt loss basis, and the results shall 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 test, the circuit breaker is considered to have passed the test.

10. The blowout coil circuit shall exhibit continuity.

11. Heaters shall be operational.

12. The results of instrument transformer tests shall be in accordance with Section 7.10.

7. INSPECTION AND TEST PROCEDURES

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

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, grounding, and required clearances.

4. Verify that all maintenance devices such as special tools and gauges specified by the manufacturer are available for servicing and operating the breaker.

5. Verify correct oil level in all tanks and bushings.

6. Verify that breather vents are clear.

7. Verify the unit is clean.

8. Inspect hydraulic system and air compressor in accordance with manufacturer's published data.

9. Test alarms and pressure-limit switches for pneumatic and hydraulic operators as recommended by the manufacturer.

10. Perform mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.

11. While performing internal inspection:

    1. Remove oil. Lower tanks or remove manhole covers as necessary. Inspect bottom of tank for broken parts and debris.

    2. Inspect lift rod and toggle assemblies, contacts, interrupters, bumpers, dashpots, bushing current transformers, tank liners, and gaskets.

    3. Verify that contact sequence is in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to ANSI/IEEE C37.04.

    4. Fill tank(s) with filtered oil.

* Optional

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

12. 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 7.6.2.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

13. Verify cell fit and element alignment, if applicable.

14. Verify racking mechanism operation, if applicable.

15. Perform time-travel analysis.

16. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

17. 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 7.6.2.1.

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. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

3. Perform a contact/pole resistance test.

*4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

5. 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. Power factor: ASTM D 924

   *4. Interfacial tension: ANSI/ASTM D 971 or ANSI/ASTM D 2285

   5. Visual condition: ASTM D 1524

6. Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer's published data.

7. Verify correct operation of any auxiliary features such as electrical close and trip operation, trip-free, antipump function.

8. Trip circuit breaker by operation of each protective device. Reset all trip logs and indicators.

9. Perform power-factor or dissipation-factor tests on each pole with breaker open and each phase with breaker closed. Determine tank loss index.

10. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.

*11. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.

12. Verify operation of heaters.

13. Test instrument transformers in accordance with Section 7.10.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Settings for alarm, pressure, and limit switches shall be in accordance with owner's specifications. In the absence of owner's specifications use manufacturer's published data. (7.6.2.1.9)

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. (7.6.2.1.12.1)

* Optional

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

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.2.1.12.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.6.2.1.12.3)

5. Travel and velocity values shall be in accordance with manufacturer's published data. (7.6.2.1.15)

6. Operations counter shall advance one digit per close-open cycle. (7.6.2.1.17)

3.2 Test Values – Electrical

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

2. Insulation-resistance values of circuit breakers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.

4. Insulation-resistance values of control wiring shall not be less than two megohms.

5. Insulating liquid test results shall be in accordance with Table 100.4.

6. Minimum pickup voltage of the trip and close coils shall conform to the manufacturer's published data. In the absence of the manufacturer's published data, refer to Table 100.20.

7. Auxiliary features shall operate in accordance with manufacturer's published data.

8. Protective devices shall operate the breaker per system design.

9. Power-factor or dissipation-factor values and tank loss index shall be compared to manufacturer's published data. In the absence of manufacturer's published data, the comparison shall be made to test data from similar breakers or data from test equipment manufacturers.

10. Power-factor or dissipation-factor and capacitance values shall 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

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

11. 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 test specimen is considered to have passed the test.

12. Heaters shall be operational.

13. Results of electrical tests on instrument transformers shall be in accordance with Section 7.10.

7. INSPECTION AND TEST PROCEDURES

7.6.3 Circuit Breakers, Vacuum, Medium-Voltage

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify that all maintenance devices such as special tools and gauges specified by the manufacturer are available for servicing and operating the breaker.

5. Verify the unit is clean.

6. Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.

7. Measure critical distances such as contact gap as recommended by manufacturer.

8. 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 7.6.3.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

9. Verify cell fit and element alignment.

10. Verify racking mechanism operation.

*11. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

*12. Perform time-travel analysis.

13. Record as-found and as-left operation counter readings.

* Optional

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

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.3.1.

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. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

*3. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

4. Perform a contact/pole-resistance test.

5. Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer's published data.

6. Verify correct operation of any auxiliary features such as electrical close and trip operation, trip-free, and antipump function.

7. Trip circuit breaker by operation of each protective device. Reset all trip logs and indicators.

*8. Perform power-factor or dissipation-factor tests on each pole with the breaker open and each phase with the breaker closed.

*9. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.

10. Perform vacuum bottle integrity (dielectric withstand voltage) test across each vacuum bottle with the breaker in the open position in strict accordance with manufacturer's published data.

11. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.

12. Verify operation of heaters.

13. Test instrument transformers in accordance with Section 7.10.

* Optional

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Critical distance measurements such as contact gap shall be in accordance with the manufacturer's published data. (7.6.3.1.7)

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. (7.6.3.1.8.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.3.1.8.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.6.3.1.8.3)

5. Travel and velocity values shall be in accordance with manufacturer's published data. (7.6.3.1.12)

6. Operation counter shall advance one digit per close-open cycle. (7.6.3.1.13)

3.2 Test Values – Electrical

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

2. Insulation-resistance values of circuit breakers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Insulation-resistance values of control wiring shall not be less than two megohms.

4. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's published data, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.

5. Minimum pickup voltage of the trip and close coils shall conform to the manufacturer's published data. In the absence of the manufacturer's published data, refer to Table 100.20.

6. Auxiliary features shall operate in accordance with manufacturer's published data.

7. Protective devices shall operate the breaker per system design.

* Optional

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

8. Power-factor or dissipation-factor values shall be compared to manufacturer's published data. In the absence of manufacturer's published data the comparison shall be made to similar breakers.

9. Power-factor or dissipation-factor and capacitance values shall 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.

10. 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.

11. 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 test specimen is considered to have passed the test.

12. Heaters shall be operational.

13. 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. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify that all maintenance devices such as special tools and gauges specified by the manufacturer are available for servicing and operating the breaker.

5. Verify the unit is clean.

*6. 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.

7. Inspect operating mechanism and/or hydraulic or pneumatic system and SF_6 gas-insulated system in accordance with manufacturer’s published data.

8. Test for SF_6 gas leaks in accordance with manufacturer’s published data.

9. Verify correct operation of alarms and pressure-limit switches for pneumatic, hydraulic, and SF_6 gas pressure in accordance with manufacturer’s published data.

10. If recommended by manufacturer, slow close/open breaker and check for binding, friction, contact alignment, and penetration. Verify that contact sequence is in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, refer to ANSI/IEEE C37.04.

11. Perform all mechanical operation tests on the operating mechanism in accordance with the manufacturer’s published data.

12. Inspect all bolted electrical connections for high resistance using one or more of the following methods:

    1. Use of a low-resistance ohmmeter in accordance with Section 7.6.4.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

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

13. Verify the appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

14. Perform time-travel analysis.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.6.4 Circuit Breakers, SF_6 (*continued*)

15. 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 in accordance with Table 100.1 from each pole-to-ground with breaker closed and across open poles at each phase. For single-tank breakers, perform insulation resistance tests in accordance with Table 100.1 from pole-to-pole.

3. Perform a contact/pole-resistance test.

*4. Perform insulation-resistance tests on all control wiring with respect to ground. 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 can not tolerate the voltage, follow manufacturer's recommendation.

5. Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer's published data.

6. Verify correct operation of any auxiliary features such as electrical close and trip operation, trip-free, and antipump function. Reset all trip logs and indicators.

7. Trip circuit breaker by operation of each protective device.

8. Perform power-factor or dissipation-factor tests on each pole with the breaker open and on each phase with the breaker closed.

9. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.

*10. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.

11. Verify operation of heaters.

12. Test instrument transformers in accordance with Section 7.10.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. SF_6 gas shall have values in accordance with Table 100.13. (7.6.4.1.6)

2. Results of the SF_6 gas leak test shall confirm that no SF_6 gas leak exists. (7.6.4.1.8)

* Optional

7. INSPECTION AND TEST PROCEDURES

7.6.4 Circuit Breakers, SF_6 (*continued*)

3. Settings for alarm, pressure, and limit switches shall be in accordance with manufacturer's published data. (7.6.4.1.9)

4. 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. (7.6.4.1.12.1)

5. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.4.1.12.2)

6. Results of the thermographic survey shall be in accordance with Section 9. (7.6.4.1.12.3)

7. Circuit breaker travel and velocity values shall be in accordance with manufacturer's published data. (7.6.4.1.14)

8. Operations counter shall advance one digit per close-open cycle. (7.6.4.1.15)

3.2 Test Values – Electrical

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

2. Insulation-resistance values of circuit breakers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's 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 shall not be less than two megohms.

5. Minimum pickup voltage of the trip and close coils shall conform to the manufacturer's published data. In the absence of the manufacturer's published data, refer to Table 100.20.

6. Auxiliary features shall operate in accordance with manufacturer's published data.

7. Protective devices shall operate the breaker per the system design.

8. Power-factor or dissipation-factor values shall be compared to manufacturer's published data. In the absence of manufacturer's published data, the comparison shall be made to test data from similar breakers or data from test equipment manufacturers.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.6.4 Circuit Breakers, SF_6 (*continued*)

9. Power-factor or dissipation-factor and capacitance test values shall be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/milliwatt loss basis, and the results shall be compared to values of similar bushings.

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 test, the test specimen is considered to have passed the test.

11. Heaters shall be operational.

12. Results of electrical tests on instrument transformers shall be in accordance with Section 7.10.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.7 Circuit Switchers

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the bushings and insulators are clean.
5. Verify both the circuit switcher and its operating mechanism mechanically operate in accordance with the manufacturer's published data.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
    1. Use of low-resistance ohmmeter. See Section 7.7.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
7. Verify operation of SF_6 interrupters is in accordance with manufacturer's published data.
8. Verify SF_6 pressure is in accordance with manufacturer's published data.
9. Verify operation of isolating switch is in accordance with system design and manufacturer's published data.
10. Verify all interlocking systems operate and sequence per system design and manufacturer's published data.
11. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
12. Record as-found and as-left operation counter readings.

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 test of interrupters and isolating switches.
3. Perform insulation-resistance tests on each pole phase-to-ground.

* Optional

*4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

5. Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer's published data.

6. Verify correct operation of any auxiliary features such as electrical close and trip operation, trip-free, and anti-pump 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 the manufacturer's published data.

10. Verify operation of heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.7.1.6.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.7.1.6.2)

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

4. SF_6 interrupters shall operate in accordance with manufacturer's published data. (7.7.1.7)

5. SF_6 pressure shall be in accordance with manufacturer's published data. (7.7.1.8)

6. Isolating switch shall operate in accordance with system and manufacturer's design. (7.7.1.9)

7. Interlocking systems shall operate in accordance with system and manufacturer's design. (7.7.1.10)

8. Operation counter shall advance one digit per close-open cycle. (7.7.1.12)

* Optional

7.7 Circuit Switchers (*continued*)

3.2 Test Values – Electrical

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

2. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's published data, 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 shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

4. Insulation-resistance values of control wiring shall not be less than two megohms.

5. Minimum pickup voltage of the trip and close coils shall conform to the manufacturer's published data. In the absence of the manufacturer's published data, refer to Table 100.20.

6. Auxiliary features shall operate in accordance with manufacturer's published data.

7. Protective devices shall operate the circuit switcher in accordance with the system design.

8. Electrical trip interrupters shall function as designed.

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 test, the circuit switcher is considered to have passed the test.

10. Heaters shall be operational.

* Optional

7.8 Network Protectors, 600-Volt Class

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Verify arc chutes are intact.
6. Inspect moving and stationary contacts for condition and alignment.
7. Verify that maintenance devices are available for servicing and operating the network protector.
8. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the network protector are correct.
9. Perform mechanical operator and contact alignment tests on both the network protector and its operating mechanism.
10. 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 7.8.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
11. Verify cell fit and element alignment.
12. Verify racking mechanism operation.
13. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
14. Record as-found and as-left operation counter readings.
15. Perform a leak test on submersible enclosure in accordance with manufacturer's published data.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.8.1.

* Optional

2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with network protector closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

3. Perform a contact/pole-resistance test.

*4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

5. Verify current transformer ratios in accordance with Section 7.10.

6. Measure the resistance of each network 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.

12. Verify phase rotation, phasing, and synchronized operation as required by the application.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.8.1.10.1)

* Optional

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

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.8.1.10.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.8.1.10.3)

4. Operations counter shall advance one digit per close-open cycle. (7.8.1.14)

3.2 Test Values – Electrical

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

2. Insulation resistance of the network protector shall 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 shall be investigated.

3. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's published data, 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 shall not be 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 shall be in accordance with manufacturer's published data, but not more than 75 percent of rated control circuit voltage.

8. Minimum operating voltage of the motor on the closing mechanism shall not exceed 75 percent of rated control circuit voltage.

9. Trip actuator minimum pickup voltage shall not exceed 7.5 percent of rated control circuit voltage.

10. Results of network protector relay calibrations shall be in accordance with Section 7.9.

11. Network protector operation shall be in accordance with design requirements.

12. Phase rotation, phasing, and synchronizing shall be in accordance with system design requirements.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.9.1 Protective Relays, Electromechanical and Solid-State

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect relays and cases for physical damage. Remove shipping restraint material.

3. Verify the unit is clean.

4. Relay Case

    1. Tighten case connections.

    2. Inspect cover for correct gasket seal.

    3. Clean cover glass. Inspect shorting hardware, connection paddles, and 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 pivots.

6. Set relays in accordance with coordination study.

2. Electrical Tests

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

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.

* Optional

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.

5. 27 Undervoltage Relay

    1. Determine dropout voltage.

    2. Determine time delay.

    3. Determine time delay at a second point on the timing curve for inverse time relays.

6. 32 Directional Power Relay

* Optional

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

1. Determine minimum pickup at maximum torque angle.
2. Determine closing zone.
3. Determine maximum torque angle.
4. Determine time delay.
5. Verify 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.
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).

* Optional

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

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.

15. 55 Power Factor Relay

 1. Determine tripping angle.

 2. Determine time delay.

16. 59 Overvoltage Relay

 1. Determine overvoltage pickup.

* Optional

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

2. Determine time delay to close the contact with sudden application of 120 percent of pickup.

17. 60 Voltage Balance Relay

    1. Determine voltage difference to close the contacts with one source at rated voltage.

    *2. Plot the operating curve for the relay.

18. 63 Transformer Sudden Pressure Relay

    1. Determine rate-of-rise or the pickup level of suddenly applied pressure in accordance with manufacturer's published data.

    2. Verify operation of the 63 FPX seal-in circuit.

    3. Verify trip circuit to remote operating device.

19. 64 Ground Detector Relay

    1. 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.

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.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

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.

4. Control Verification

1. Functional tests

   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. Refer to Section 8.0.

2. In-service monitoring

   After the equipment is initially energized, measure magnitude and phase angle of all inputs and compare to expected values.

5. Test Values

1. When not otherwise specified, use manufacturer's recommended tolerances.

* Optional

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

2. When critical test points are specified, the relay shall be calibrated to those points even though other test points may be out of tolerance.

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. Verify operation of light-emitting diodes, display, and targets.

3. Record passwords for all access levels.

4. Clean the front panel and remove foreign material from the case.

5. Check tightness of connections.

6. Verify that the frame is grounded in accordance with manufacturer's instructions.

7. Set the relay in accordance with the coordination study.

8. Download settings from the relay. Print a copy of the settings for the report and compare the settings to those specified in the coordination study.

2. Electrical Tests

1. Perform insulation-resistance tests from each circuit to the grounded frame in accordance with manufacturer's published data.

2. Apply voltage or current to all analog inputs and verify correct registration of the relay meter functions.

3. Functional Operation

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

4. Control Verification

   1. Functional tests

      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 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, communications statistics, fault counters, sequence of events recorder, and all event records.

2. In-service monitoring

After the equipment is initially energized, measure magnitude and phase angle of all inputs and compare to expected values.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Verify correct connection of transformers with system requirements.

4. Verify that adequate clearances exist between primary and secondary circuit wiring.

5. Verify the unit is clean.

6. 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 7.10.2.1 and 7.10.2.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

7. Verify that all required grounding and shorting connections provide contact.

8. Verify correct operation of transformer withdrawal mechanism and grounding operation.

9. Verify correct primary and secondary fuse sizes for voltage transformers.

10. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

2.1 Electrical Tests - Current Transformers

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.

2. Perform insulation-resistance test of each current transformer and its secondary wiring with respect to ground at 1000 volts dc for one minute. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.

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.

* Optional

7.10 Instrument Transformers (*continued*)

6. Measure current circuit burdens at transformer terminals in accordance with ANSI/IEEE C57.13.1.

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 tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.9.

9. Perform power-factor or dissipation-factor tests in accordance with test equipment manufacturer's published data.

10. Verify that current transformer secondary circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. That grounding point should be located as specified by the engineer in the project drawings.

2.2 Electrical Tests - Voltage Transformers

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.

2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Test voltages shall be applied for one minute in accordance with Table 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.

3. Perform a polarity test on each transformer to verify the polarity marks or H_1- X_1 relationship as applicable.

4. Perform a turns-ratio test on all tap positions.

5. Measure voltage circuit burdens at transformer terminals.

*6. Perform a dielectric withstand 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.

7. Perform power-factor or dissipation-factor tests in accordance with test equipment manufacturer's published data.

8. Verify that voltage transformer secondary circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. The grounding point should be located as specified by the engineer in the project drawings.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

2.3 Electrical Tests - Coupling-Capacitor Voltage Transformers

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.

2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Test voltages shall be applied for one minute in accordance with Table 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.

3. Perform a polarity test on each transformer to verify the polarity marking. See ANSI/IEEE C93.1 for standard polarity marking.

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 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.

7. Measure capacitance of capacitor sections.

8. Perform power-factor or dissipation-factor tests in accordance with test equipment manufacturer's published data.

9. Verify that the coupling-capacitor voltage transformer circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. That grounding point should be located as specified by the engineer in the project drawings.

2.4 Electrical Tests – High-Accuracy Instrument Transformers (Reserved)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.10.1.6.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.10.1.6.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.10.1.6.3)

* Optional

7.10 Instrument Transformers (*continued*)

3.2.1 Test Values – Current Transformers – Electrical

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

2. Insulation-resistance values of instrument transformers shall not be less than values shown in Table 100.5.

3. Polarity results shall agree with transformer markings.

4. Ratio errors shall be in accordance with C57.13.

5. Excitation results shall match the curve supplied by the manufacturer or be in accordance with ANSI C57.13.1.

6. Measured burdens shall be compared to instrument transformer ratings.

7. Insulation-resistance values of instrument transformers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use 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 test, the primary winding is considered to have passed the test.

9. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.

10. Test results shall indicate that the circuits have only one grounding point.

3.2.2 Test Values –Voltage Transformers – Electrical

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

2. Insulation-resistance values of instrument transformers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5.

3. Polarity results shall agree with transformer markings.

4. Ratio errors shall be in accordance with C57.13.

5. Measured burdens shall be compared to instrument transformer ratings.

* Optional

7.10 Instrument Transformers (*continued*)

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 test, the primary windings are considered to have passed the test.

7. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.

8. Test results shall indicate that the circuits are grounded at only one point.

3.2.3 Test Values – Coupling Capacitor Voltage Transformers

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

2. Insulation-resistance values of instrument transformers shall not be less than values shown in Table 100.5.

3. Polarity results shall agree with transformer markings.

4. Ratio errors shall be in accordance with C57.13.

5. Measured burdens shall be compared 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 test, the test specimen is considered to have passed the test.

7. Capacitance of capacitor sections of coupling-capacitor voltage transformers shall be in accordance with manufacturer's published data.

8. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.

9. Test results shall indicate that the circuits are grounded at only one point.

3.2.4 Test Values – High-Accuracy Instrument Transformers (Reserved)

* Optional

7. INSPECTION AND TEST PROCEDURES

7.11.1 Metering Devices

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

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 7.11.1.2.

    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 thermographic survey in accordance with Section 9.

4. Inspect cover gasket, cover glass, condition of spiral spring, disk clearance, contacts, and case-shorting contacts, as applicable.

5. Verify the unit is clean.

6. Verify freedom of movement, end play, and alignment of rotating disk(s).

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.11.1.1.

2. Verify accuracy of meters at all cardinal points.

3. Calibrate meters in accordance with manufacturer's published data.

4. Verify all instrument multipliers.

5. Verify that current transformer and voltage transformer secondary circuits are intact.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.11.1.1.3.1)

2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.11.1.1.3.2)

* Optional

7.11.1 Metering Devices (*continued*)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.11.1.3.3)

3.2 Test Values - Electrical

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

2. Meter accuracy shall be in accordance with manufacturer's published data.

3. Calibration results shall be within manufacturer's published tolerances.

4. Instrument multipliers shall be in accordance with system design specifications.

5. Test results shall confirm the integrity of the secondary circuits of current and voltage transformers.

* Optional

7.11.2 Metering Devices, Microprocessor-Based

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect meters and cases for physical damage.
3. Clean front panel and remove shipping restraint material.
4. Check tightness of electrical connections.
5. Record model number, serial number, firmware revision, software revision, and rated control voltage.
6. Verify operation of display and indicating devices.
7. Record passwords.
8. Verify unit is grounded in accordance with manufacturer's instructions.
9. Verify unit is connected in accordance with manufacturer's instructions and project drawings.
10. Set all required parameters including instrument transformer ratios, system type, frequency, power demand methods/intervals, and communications requirements.

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 including mechanical relay, digital, and analog.
3. After initial system energization, confirm measurements and indications are consistent with loads present.

* Optional

7.11.2 Metering Devices, Microprocessor-Based (c*ontinued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Nameplate data shall be per drawings and specifications. (7.11.2.1.1)

2. Tightness of electrical connections shall assure a low resistance connection. (7.11.2.1.4)

3. Display and indicating devices shall operate per manufacturer's published data. (7.11.2.1.6)

3.2 Test Values – Electrical

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

2. All auxiliary input/output features shall operate per settings and manufacturer's published data.

3. Measurements and indications shall 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect impact recorder prior to unloading regulator, if applicable.
4. Inspect anchorage, alignment, and grounding.
5. Verify removal of any shipping bracing and vent plugs after final placement.
6. Verify the unit is clean.
7. Verify auxiliary device operation.
8. 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 7.12.1.1.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
9. Verify correct operation of motor and drive train and automatic motor cutoff at maximum lower and raise positions.
10. Verify appropriate lubrication on drive motor components..
11. Verify correct liquid level in all tanks and bushings.
12. Perform specific inspections and mechanical tests as recommended by the manufacturer.
13. Record as-found and as-left operation counter readings.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.12.1.1.1.
2. Perform insulation-resistance tests on each winding-to-ground in any off-neutral position. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.

* Optional

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

3. Perform insulation power-factor or dissipation-factor tests on windings in accordance with test equipment manufacturer's published data.

4. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.

5. Measure winding resistance of source windings in the neutral position. Measure the resistance of all taps on load windings.

6. Perform special tests and adjustments as recommended by manufacturer.

*7. If the regulator has a separate tap-changer compartment, test for the presence of oxygen in the gas blanket in the main tank.

8. Perform turns-ratio test on each voltage step position. Verify that the 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 functions of regulator control device.

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.

* Optional

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

*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 in accordance with ANSI/IEEE C57.104 or ASTM D 3612.

15. Verify operation of heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Auxiliary devices should operate in accordance with system design. (7.12.1.1.1.7)

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. (7.12.1.1.1.8.1)

3. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12. (7.12.1.1.1.8.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.12.1.1.1.8.3)

5. Motor, drive train, and automatic cutoff should operate in accordance with manufacturer’s design. (7.12.1.1.1.9)

6. Liquid level in tanks and bushings should be within indicated tolerances. (7.12.1.1.1.10)

7. The operation counter shall move incrementally for each operation performed. (7.12.1.1.1.13)

3.2 Test Values – Electrical

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

* Optional

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

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Resistance values shall be temperature corrected in accordance with Table 100.14. The polarization index shall be compared to manufacturer's factory test results. If manufacturer's test results are not available the polarization index value shall not be less than 1.0.

3. Maximum power-factor or dissipation-factor values of liquid-filled regulators shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, compare to test equipment manufacturer's published data. Representative values are indicated in Table 100.3.

4. Power-factor or dissipation-factor and capacitance values shall be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/milliwatt loss basis, and the results shall 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 shall meet manufacturer's published requirements.

7. Investigate presence of oxygen in nitrogen gas blanket.

8. Turns-ratio test results shall maintain a normal deviation between each voltage step and shall not deviate more than one-half percent from the calculated voltage ratio.

9. Voltage range limiter shall operate within manufacturer's recommendations.

10. Operation and accuracy of bandwidth, time-delay, voltage, and live drop compensation functions shall 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 of regulators having a separate tap-changer compartment or the common tank of single tank voltage regulators shall 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 shall be in accordance with Table 100.4.

14. Results of dissolved gas analysis shall be evaluated in accordance with ANSI/IEEE C57.104 or ASTM D 3612.

.
* Optional

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

15. Heaters shall be operational.

* Optional

7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Inspect impact recorder prior to unloading regulator, if applicable.
5. Verify removal of any shipping bracing and vent plugs after final placement.
6. Verify the unit is clean.
7. Verify correct auxiliary device operation.
8. 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 7.12.1.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
9. Verify correct operation of motor and drive train and automatic motor cutoff at maximum lower and raise positions.
10. Verify appropriate lubrication on drive motor components.
11. Verify appropriate liquid level in all tanks and bushings, if applicable.
12. Perform specific inspections and mechanical tests as recommended by the manufacturer.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.12.1.2.1.
2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data useTable 100.5. Calculate polarization index.
3. Perform winding insulation power-factor or dissipation-factor tests on windings in accordance with test equipment manufacturer’s published data.

* Optional

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

4. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.

5. Verify voltage regulation.

6. Verify that the indicator correctly identifies neutral position.

7. Perform winding-resistance tests on each winding.

8. Sample insulating liquid, if applicable, in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.

    1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816

    2. Acid neutralization number: ANSI/ASTM D 974

    *3. Specific gravity: ANSI/ASTM D 1298

    4. Interfacial tension: ANSI/ASTM D 971 or ASTM D 2285

    5. Color: ANSI/ASTM D 1500

    6. Visual condition: ASTM D 1524

    *7. Power factor: ASTM D 924
    Required when the regulator voltage is 46 kV or higher.

    *8. Water content: ASTM D 1533
    Required when the regulator voltage is 25 kV or higher.

*9. Remove a sample of insulating liquid, if applicable, in accordance with ASTM D 3613 and perform dissolved gas analysis 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

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Auxiliary devices shall operate in accordance with system design. (7.12.1.2.1.7)

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. (7.12.1.2.1.8.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.12.1.2.1.8.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.12.1.2.1.8.3)

5. Motor, drive train, and automatic cutoff shall operate in accordance with manufacturer's design intent. Automatic motor cutoff should operate at maximum lower and maximum raise positions. (7.12.1.2.1.9)

6. Liquid level in tanks and bushings shall be within indicated tolerances. (7.12.1.2.1.11)

3.2 Test Values – Electrical

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

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations shall be investigated. The polarization index shall be compared to manufacturer's factory test results. In the absence of factory test results the polarization index value shall not be less than 1.0.

3. Maximum power-factor or dissipation-factor values of liquid-filled regulators shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, compare to test equipment manufacturer's published data. Representative values are indicated in Table 100.3.

4. Power-factor or dissipation-factor and capacitance values shall be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/milliwatt loss basis, and the results shall be compared to values of similar bushings.

5. The regulation shall be a linear ratio throughout the range between the maximum raise and the maximum lower positions.

6. Indicator shall 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 shall be in accordance with Table 100.4.

9. Results of dissolved-gas analysis shall be evaluated in accordance with ANSI/IEEE C57.104.

10. Investigate presence of oxygen in nitrogen gas blanket.

11. Heaters shall be operational.

* Optional

7.12.2 Regulating Apparatus, Current

— RESERVED —

* Optional

7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Inspect impact recorder, if applicable.
5. Verify removal of any shipping bracing and vent plugs.
6. Verify the unit is clean.
7. 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 7.12.3.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
8. Verify correct auxiliary device operation.
9. Verify correct operation of motor and drive train and automatic motor cutoff at maximum lower and maximum raise positions.
10. Verify appropriate liquid level in all tanks.
11. Perform specific inspections and mechanical tests as recommended by the manufacturer.
12. Verify appropriate lubrication on motor components.
13. 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 accordance with Section 7.2.2.

*4. Perform winding-resistance test at each tap position.

* Optional

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

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

    2. Color: ANSI/ASTM D 1500

    3. Visual condition: ASTM D 1524

8. Remove a sample of insulating liquid in accordance with ASTM D 3613 and perform dissolved gas analysis in accordance with ANSI/IEEE C57.104 or ASTM D 3612.

*9. Perform vacuum bottle integrity tests (dielectric withstand voltage) across each vacuum bottle with the contacts in the open position in strict accordance with manufacturer’s published data.

10. Verify operation of heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.12.3.1.7.1)

2. Bolt-torque levels shall be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12. (7.12.3.1.7.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.12.3.1.7.3)

4. Auxiliary device operation shall be in accordance with design intent. (7.12.3.1.8)

5. Motor, drive train, and automatic cutoff shall operate in accordance with manufacturer’s design intent and automatic motor cutoff shall operate at maximum lower and maximum raise positions.(7.12.3.1.9)

6. Liquid level in tanks shall be within indicated tolerances. (7.12.3.1.10)

7. Operation counter shall have had an incremental change in accordance with tap-changer operation. (7.12.3.1.13)

3.2 Test Values – Electrical

* Optional

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

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 shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations shall be investigated.

3. Maximum winding insulation power-factor/dissipation-factor values of liquid-filled transformers shall be in accordance with the transformer manufacturer's published data. In the absence of manufacturer's published data, use Table 100.3.

4. Consult the manufacturer if winding-resistance values vary by more than one percent from measurements of adjacent windings.

5. Special tests and adjustments shall be in accordance with manufacturer's published data.

6. Turns-ratio test results shall maintain a normal deviation between each voltage step and shall not deviate more than one-half percent from the calculated voltage ratio.

7. Results of insulating liquid tests shall be in accordance with Table 100.4.

8. Results of dissolved-gas analysis shall be evaluated 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 test, the test specimen is considered to have passed the test.

10. Heaters shall 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 drawings, specifications, and NFPA 70 *National Electrical Code Article 250.*

2. Inspect physical and mechanical condition.

3. Inspect bolted electrical connections for high resistance using one or more of the following methods:

    1. Use of low-resistance ohmmeter in accordance with Section 7.13.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

4. Inspect anchorage.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with section 7.13.1.

2. Perform fall-of-potential or alternative test in accordance with ANSI/IEEE 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 derived neutral points.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Grounding system electrical and mechanical connections shall 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 shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.13.1.3.2)

3.2 Test Values – Electrical

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

* Optional

7.13 Grounding Systems (*continued*)

2. The resistance between the main grounding electrode and ground shall 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 that exceed 0.5 ohm.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.14 Ground-Fault Protection Systems, Low-Voltage

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect the components for damage and errors in polarity or conductor routing.

    1. Verify that ground connection is made on the source side of the neutral disconnect link and 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 the zero sequence sensors.

    5. Verify that the grounded conductor is solidly grounded.

3. Verify the unit is clean.

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 7.14.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

5. Verify correct operation of all functions of the self-test panel, if applicable.

6. Verify that the control power transformer has adequate capacity for the system.

7. Set pickup and time-delay settings in accordance with the settings provided in the owner's specifications. Record appropriate operation and test sequences as required by NFPA 70, *National Electrical Code*, Article 230.95.

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 the neutral disconnect link after testing.

* Optional

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

*3. Perform insulation resistance test on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.

4. Perform ground fault protective device pickup tests using primary 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 reduced control voltage tripping capability is 55 percent for ac systems and 80 percent for dc systems.

8. Verify blocking capability of zone interlock systems.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.14.1.4.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.14.1.4.2)

3.2 Test Values – Electrical

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

2. System neutral-to-ground insulation resistance shall be a minimum of one megohm.

3. Insulation-resistance values of control wiring shall not be less than two megohms.

4. Results of pickup test shall 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 shall operate when current direction is the same relative to polarity marks in the two current transformers. The ground fault protective device shall not operate when current direction is opposite relative to polarity marks in the two current transformers.

6. Relay timing shall be in accordance with manufacturer's published data but must be no longer than one second at 3000 amperes in accordance with ANSI/NFPA 70, *National Electrical Code,* Article 230.95.

7. The circuit interrupting device shall 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 shall be in accordance with manufacturer's published data and design specifications.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.15.1 Rotating Machinery, AC Induction Motors and Generators

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Inspect air baffles, filter media, cooling fans, slip rings, brushes, and brush rigging.

5. 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 or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

6. Perform special tests such as air-gap spacing and machine alignment, if applicable.

7. Verify the application of appropriate lubrication and lubrication systems.

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 ten minutes. Calculate polarization index.

    2. Machines 200 horsepower (150 kilowatts) and less:
       Test duration shall be one minute. Calculate 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

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

*6. Perform power-factor tip-up tests.

*7. Perform surge comparison tests.

8. Perform insulation-resistance test on insulated bearings in accordance with manufacturer's published data.

9. Test surge protection devices in accordance with Section 7.19 and Section 7.20.

10. Test motor starter in accordance with Section 7.16.

11. Perform resistance tests on resistance temperature detector (RTD) circuits.

12. Verify operation of machine space heater, if applicable.

*13. Perform vibration test.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Inspection (7.15.1.4)

    1. Air baffles shall be clean and installed in accordance with manufacturer's published data.

    2. Filter media shall be clean and installed in accordance with manufacturer's published data.

    3. Cooling fans shall operate.

    4. Slip ring alignment shall be within manufacturer's published tolerances.

    5. Brush alignment shall be within manufacturer's published tolerances.

    6. Brush rigging shall be in accordance with manufacturer's published data.

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. (7.15.1.1.5.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.15.1.1.5.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.15.1.1.5.3)

* Optional

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

5. Air-gap spacing and machine alignment shall be in accordance with manufacturer's published data. (7.15.1.1.6)

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 index shall not be less than 1.0. The recommended minimum insulation resistance ($IR_{1\ min}$) test results in megohms shall 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 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 to manufacturer's published data. In the absence of manufacturer's published data these values will be compared with previous values of similar machines.

6. Tip-up values shall 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 shall be within manufacturer's published tolerances. In the absence of manufacturer's published tolerances, the comparison shall be made to similar machines.

* Optional

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

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

10. Test results of motor starter equipment shall be in accordance with Section 7.16.

11. RTD circuits shall conform to design intent and machine protection device manufacturer's published data.

12. Heaters shall be operational.

13. Vibration amplitudes of the uncoupled and unloaded machine shall 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Inspect air baffles, filter media, cooling fans, slip rings, brushes, and brush rigging.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
    1. Use of low-resistance ohmmeter in accordance with Section 7.15.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
6. Perform special tests such as air-gap spacing and machine alignment.
7. Verify the application of appropriate lubrication and lubrication systems.
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 dielectric-absorption ratio.
3. Perform dc dielectric withstand voltage tests on machines rated at 2300 volts and greater in accordance with ANSI/IEEE Standard 95.
4. Perform phase-to-phase stator resistance test on machines 2300 volts and greater.

*5. Perform insulation power-factor or dissipation-factor tests.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

*6. Perform power-factor tip-up tests.

*7. Perform surge comparison tests.

8. Perform insulation-resistance test on insulated bearings in accordance with manufacturer's published data, if applicable.

9. Test surge protection devices in accordance with Section 7.19 and Section 7.20.

10. Test motor starter in accordance with Section 7.16.

11. Perform resistance tests on resistance temperature detector (RTD) circuits.

12. Verify operation of machine space heater, if applicable.

*13. Perform vibration test.

14. Perform insulation-resistance tests on the main rotating field winding, the exciter-field winding, and the exciter-armature winding in accordance with ANSI/IEEE Standard 43.

*15. Perform an ac voltage-drop test on all rotating field poles.

*16. Perform a high-potential test on the excitation system in accordance with ANSI/IEEE Standard 421.3.

17. Measure resistance of machine-field winding, exciter-stator winding, exciter-rotor windings, and field discharge resistors.

*18. Perform front-to-back resistance tests on diodes and gating tests of silicon-controlled rectifiers for field application semiconductors.

19. Prior to re-energizing, apply voltage to the exciter supply and adjust exciter-field current to nameplate value.

20. Verify that the field application timer and the enable timer for the power-factor relay have been tested and set to the motor drive manufacturer's recommended values.

*21. Record stator current, stator voltage, and field current for the complete acceleration period including stabilization time for a normally loaded starting condition. From the recording determine the following information:

    1. Bus voltage prior to start.

    2. Voltage drop at start.

    3. Bus voltage at machine full-load.

* Optional

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

4. Locked-rotor current.

5. Current after synchronization but before loading.

6. Current at maximum loading.

7. Acceleration time to near synchronous speed.

8. Revolutions per minute (RPM) just prior to synchronization.

9. Field application time.

10. Time to reach stable synchronous operation.

*22. Plot a V-curve of stator current versus excitation current at approximately 50 percent load to check correct exciter operation.

*23. If the range of exciter adjustment and machine loading permit, reduce excitation to cause power factor to fall below the trip value of the power-factor relay. Verify relay operation.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Inspection (7.15.2.1.4)

    1. Air baffles shall be clean and installed in accordance with manufacturer's published data.

    2. Filter media shall be clean and installed in accordance with manufacturer's published data.

    3. Cooling fans shall operate.

    4. Slip ring alignment shall be within manufacturer's published tolerances.

    5. Brush alignment shall be within manufacturer's published tolerances.

    6. Brush rigging shall be in accordance with manufacturer's published data.

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. (7.15.2.1.5.1)

3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.15.2.1.5.2)

4. Results of thermographic survey shall be in accordance with Section 9. (7.15.2.1.5.3)

* Optional

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

5. Air-gap spacing and machine alignment shall be in accordance with manufacturer's published data. (7.15.2.1.6)

3.2 Test Values – Electrical

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

2. The dielectric absorption ratio or polarization index shall not be less than 1.0. The recommended minimum insulation resistance ($IR_{1\ min}$) test results in megohms shall 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 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 to manufacturer's published data. In the absence of manufacturer's published data these values will be compared with previous values of similar machines.

6. Tip-up values shall 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 shall be within manufacturer's published tolerances. In the absence of manufacturer's published tolerances, the comparison shall be made to similar machines.

* Optional

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

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

10. Test results of motor starter equipment shall be in accordance with Section 7.16.

11. RTD circuits shall be in accordance with system design intent and machine protection device manufacturer's published data.

12. Heaters shall be operational.

13. Vibration amplitudes of the uncoupled and unloaded machine shall 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 shall 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-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 test, the winding is considered to have passed the test.

17. The measured resistance values of motor-field windings, exciter-stator windings, exciter-rotor windings, and field-discharge resistors shall be compared to manufacturer's published data. In the absence of manufacturer's published data, the comparison shall be made to similar machines.

18. Resistance test results of diodes and gating tests of silicon-controlled rectifiers shall be in accordance with industry standards and system design requirements.

19. Exciter power supply shall allow exciter-field current to be adjusted to nameplate value.

* Optional

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

20. Application timer and enable timer for power-factor relay test results shall comply with manufacturer's recommended values.

21. Recorded values shall be in accordance with system design requirements.

22. Plotted V-curve shall indicate correct exciter operation.

23. When reduced excitation falls below trip value for the power-factor relay, the relay shall operate.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.15.3 Rotating Machinery, DC Motors and Generators

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Inspect air baffles, field media, cooling fans, brushes, and brush rigging.

5. Inspect bolted electrical connections for high resistance using one of the following methods:

    1. Use of low-resistance ohmmeter in accordance with Section 7.15.3.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

6. Inspect commutator and tachometer generator.

7. 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 dielectric absorption ratio.

3. Perform high-potential test in accordance with NEMA MG 1, Section 3.1.

*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

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Inspection (7.15.3.1.4)

    1. Air baffles shall be clean and installed in accordance with manufacturer's published data.

    2. Filter media shall be clean and installed in accordance with manufacturer's published data.

    3. Cooling fans shall operate.

    4. Slip ring alignment shall be within manufacturer's published tolerances.

    5. Brush alignment shall be within manufacturer's published tolerances.

    6. Brush rigging shall be in accordance with manufacturer's published data.

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. (7.15.3.1.5.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.15.3.1.5.2)

4. Results of thermographic survey shall be in accordance with Section 9. (7.15.3.1.5.3)

5. Commutator and tachometer generator shall be in accordance with manufacturer's published data and system design. (7.15.3.1.6)

6. Air-gap spacing and machine alignment shall be in accordance with manufacturer's published data. (7.15.3.1.7)

3.2 Test Values – Electrical

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

7. INSPECTION AND TEST PROCEDURES

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

2. The dielectric absorption ratio or polarization index shall not be less than 1.0. The recommended minimum insulation resistance ($IR_{1\ min}$) test results in megohms shall 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 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 shall be comparable to nameplate data.

6. Vibration amplitudes of the uncoupled and unloaded machine shall 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. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify the unit is clean.

5. Inspect contactors.

    1. Verify mechanical operation.

    2. Verify contact gap, wipe, alignment, and pressure are in accordance with manufacturer's published data.

*6. Motor-Running Protection

    1. Verify overload element rating is correct for its application.

    2. If motor-running protection is provided by fuses, verify correct fuse rating.

7. 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 7.16.1.1.2.

    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 thermographic survey in accordance with Section 9.

8. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

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 on each pole, phase-to-phase and phase-to-ground with starter closed, and across each open pole for one minute. Test voltage shall be in accordance with manufacturer's published data or Table 100.1.

* Optional

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

*3. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

4. Test motor protection devices in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Section 7.9.

5. Test circuit breakers in accordance with Section 7.6.

6. Perform operational tests by initiating control devices.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.16.1.1.1.7.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.16.1.1.1.7.2)

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

3.2 Test Values – Electrical

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

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Insulation-resistance values of control wiring shall not be less than two megohms.

4. Motor protection parameters shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Section 7.9.

5. Circuit breaker test results shall be in accordance with Section 7.6.1.1.

6. Control devices shall perform in accordance with system design requirements.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.16.1.2 Motor Control, Motor Starters, Medium-Voltage

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. 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 7.16.1.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
6. Test all electrical and mechanical interlock systems for correct operation and sequencing.
7. Verify correct barrier and shutter installation and operation.
8. Exercise all active components and confirm correct operation of all indicating devices.
9. Inspect contactors.
    1. Verify mechanical operation.
    2. Verify contact gap, wipe, alignment, and pressure are in accordance with manufacturer's published data.
10. Verify overload protection rating is correct for its application. Set adjustable or programmable devices according to the protective device coordination study.
11. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

* Optional

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), phase-to-ground, phase-to-phase, and across the open contacts for one minute in accordance with Table 100.1.

*3. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

*4. Perform a dielectric withstand voltage test in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.9.

5. Perform vacuum bottle integrity test (dielectric withstand voltage), if applicable, across each vacuum bottle with the contacts in the open position in strict accordance with manufacturer's published data. Do not exceed maximum voltage stipulated for this test.

6. Perform contact resistance tests.

7. Measure blowout coil circuit resistance.

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.

11. Test starting transformers, if applicable, in accordance with Section 7.2.1.

12. Test starting reactors, if applicable, in accordance with 7.20.3.

13. Test motor protection devices in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Section 7.9.

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

15. Verify operation of cubicle space heater.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.16.1.2.1.5.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.16.1.2.1.5.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.16.1.2.1.5.3)

4. Electrical and mechanical interlocks shall operate in accordance with system design. (7.16.1.2.1.6)

5. Barrier and shutter installation and operation shall be in accordance with manufacturer's design. (7.16.1.2.1.7)

6. Indicating devices shall operate in accordance with system design. (7.16.1.2.1.8)

3.2 Test Values – Electrical

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

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Insulation-resistance values of control wiring shall not be 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 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 shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values which deviate from those of similar connections by more than 50 percent of the lowest value.

7. Resistance values of blowout coils shall be in accordance with manufacturer's published data.

* Optional

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

8. Resistance values shall not deviate by more than 15 percent between identical fuses.

9. Contactor coil shall operate with minimal vibration and noise.

10. Control power transformer rest results shall be in accordance with Section 7.1.2.8.

11. Starting transformer test results shall be in accordance with Section 7.2.1.

12. Starting reactor test results shall be in accordance with Section 7.20.3.

13. Motor protection parameters shall be in accordance with manufacturer's published data.

14. System function test results shall be in accordance with manufacturer's published data and system design.

15. Heaters shall be operational.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.16.2.1 Motor Control, Motor Control Centers, Low-Voltage

1. Refer to Section 7.1 for appropriate inspections and tests of the motor control center bus.

2. Refer to Section 7.5.1.2 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

7.16.2.2 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 7.5.1.1 for appropriate inspections and tests of the motor control center switches.

3. Refer to Section 7.6.1.1 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.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.17 Adjustable Speed Drive Systems

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Ensure vent path openings are free from debris and that heat transfer surfaces are clean.
6. Verify correct connections of circuit boards, wiring, disconnects, and ribbon cables.
7. Motor running protection
    1. Verify drive overcurrent setpoints are correct for their application.
    2. If drive is used to operate multiple motors, verify individual overload element ratings are correct for their application.
    3. Apply minimum and maximum speed setpoints. Verify setpoints 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 low-resistance ohmmeter in accordance with Section 7.17.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
9. Verify correct fuse sizing in accordance with manufacturer's published data.

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.

* Optional

7.17 Adjustable Speed Drive Systems (*continued*)

*4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

5. Test for the following parameters in accordance with relay calibration procedures outlined in Section 7.9 or as recommended by the manufacturer:

   1. Input phase loss protection (Section 7.9.3.10)
   2. Input overvoltage protection (Section 7.9.3.16)
   3. Output phase rotation (Section 7.9.3.10)
   4. Overtemperature protection (Section 7.9.3.11)
   5. DC overvoltage protection (Section 7.9.3.16)
   6. Overfrequency protection (Section 7.9.3.22)
   7. Drive overload protection (Section 7.9.3.14 or 7.6.1.1)
   8. Fault alarm outputs (Section 7.9.3 or 7.9.4)

6. Perform continuity tests on bonding conductors in accordance with Section 7.13.

7. Perform startup of drive in accordance with manufacturer's published data. Calibrate drive to the system's minimum and maximum speed control signals.

8. 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.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.17.1.8.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.17.1.8.2)

* Optional

7.17 Adjustable Speed Drive Systems (*continued*)

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

3.2 Test Values – Electrical

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

2. Overload test trip times at 300 percent of overload element rating shall be in accordance with manufacturer's published time-current curve.

3. Input circuit breaker test results shall be in accordance with Section 7.6.

4. Insulation-resistance values of control wiring shall not be 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 shall perform in accordance with system requirements.

8. Operational tests shall conform to system design requirements.

* Optional

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

1. Visual and Mechanical Inspection

1. Verify that batteries are adequately located.
2. Verify that battery area ventilation system is operable.
3. Verify existence of suitable eyewash equipment.
4. Compare equipment nameplate data with drawings and specifications.
5. Inspect physical and mechanical condition.
6. Verify adequacy of battery support racks, mounting, anchorage, alignment, grounding and clearances.
7. Verify electrolyte level. Measure electrolyte specific gravity and temperature levels.
8. Verify presence of flame arresters.
9. Verify the units are clean.
10. Inspect spill containment installation.
11. Verify application of an oxide inhibitor on battery terminal connections.
12. 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 7.18.1.1.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.

2. Electrical Tests

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

* Optional

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

5. Measure intercell connection resistances.

6. Perform internal ohmic measurement tests.

7. Perform a load test in accordance with manufacturer's published data or ANSI/IEEE 450.

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Electrolyte level and specific gravity shall be within normal limits. (7.18.1.1.1.7)

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. (7.18.1.1.1.12.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.18.1.1.1.12.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.1.1.12.3)

3.2 Test Values – Electrical

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

2. Charger float and equalize voltage levels shall be in accordance with battery manufacturer's published data.

3. The results of charger functions and alarms shall be in accordance with manufacturer's published data.

4. Cell voltages shall be within 0.05 volt of each other or in accordance with manufacturer's published data.

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

6. Cell internal ohmic values (resistance, impedance, or conductance) shall not vary by more than 25 percent between identical cells that are in a fully charged state.

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

* Optional

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

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

7. INSPECTION AND TEST PROCEDURES

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

1. Visual and Mechanical Inspection

1. Verify that batteries are adequately located.

2. Verify that battery area ventilation system is operable.

3. Verify existence of suitable eyewash equipment.

4. Compare equipment nameplate data with drawings and specifications.

5. Inspect physical and mechanical condition.

6. Verify adequacy of battery support racks or cabinets, mounting, anchorage, alignment, grounding, and clearances.

7. Verify electrolyte level. Measure pilot-cell electrolyte temperature.

8. Verify the units are clean.

9. Verify application of an oxide inhibitor on battery terminal connections.

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 7.18.1.2.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.18.1.2.1.

2. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer’s recommended settings.

3. Verify all charger functions and alarms.

4. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.

5. Measure intercell connection resistances.

* Optional

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

6. Perform internal ohmic measurement tests.

7. Perform a load test in accordance with manufacturer's published data or ANSI/IEEE 1106.

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Electrolyte level shall be within normal limits. (7.18.1.2.1.7)

2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.18.1.2.1.10.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.18.1.2.1.10.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.2.1.10.3)

3.2 Test Values – Electrical

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

2. Charger float and equalize voltage levels shall be in accordance with battery manufacturer's published data.

3. The results of charger functions and alarms shall be in accordance with manufacturer's published data.

4. Cell voltages shall be within 0.05 volt of each other or in accordance with manufacturer's published data.

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

6. Cell internal ohmic values (resistance, impedance, or conductance) shall not vary by more than 25 percent between identical cells that are in a fully charged state, or shall be in accordance with manufacturer's published data.

7. Results of load tests shall be in accordance with manufacturer's published data or ANSI/IEEE 1106.

* Optional

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

8. Voltage measured from positive-to-ground shall 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 that batteries are adequately located.
2. Verify that battery area ventilation system is operable.
3. Verify existence of suitable eyewash equipment.
4. Compare equipment nameplate data with drawings and specifications.
5. Inspect physical and mechanical condition.
6. Verify adequacy of battery support racks or cabinets, mounting, anchorage, alignment, grounding, and clearances.
7. Verify the units are clean.
8. Verify the 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 low-resistance ohmmeter in accordance with Section 7.18.1.3.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.

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.

* Optional

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

7. Perform internal ohmic measurement tests.

8. Perform a load test in accordance with manufacturer's published data or ANSI/IEEE 1188.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.18.1.3.9.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.18.1.3.9.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.3.9.3)

3.2 Test Values – Electrical

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

2. Negative post temperature shall be within manufacturer's published data or IEEE 1188.

3. Charger float and equalize voltage levels shall be in accordance with the battery manufacturer's published data.

4. Results of charger functions and alarms shall be in accordance with manufacturer's published data.

5. Monoblock/cell voltages shall be in accordance with manufacturer's published data.

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

7. Monoblock/cell internal ohmic values (resistance, impedance, or conductance) shall not vary by more than 25 percent between identical monoblocks/cells in a fully charged state.

8. Results of load tests shall be in accordance with manufacturer's published data or IEEE 1188.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.18.2 Direct-Current Systems, Chargers

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect for physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Inspect all bolted electrical connections for high resistance using one or more of the following methods:
    1. Use of low-resistance ohmmeter in accordance with Section 7.18.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey under load in accordance with Section 9.
6. Inspect filter and tank capacitors.
7. Verify operation of cooling fans and presence of filters.

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 voltage imposed on the battery.

*9. Perform full-load testing of charger.

* Optional

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.18.2.1.5.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.18.2.1.5.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.18.2.1.5.3)

3.2 Test Values – Electrical

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

2. Float and equalize voltage settings shall be in accordance with the battery manufacturer's published data.

3. Current limit shall be within manufacturer's recommended maximum.

4. Results of load sharing between parallel chargers shall be in accordance with system design specifications.

5. Results of meter calibration shall be in accordance with Section 7.11.

6. Results of alarm operation shall be in accordance with manufacturer's published data and system design.

7. Input and output voltage shall be in accordance with manufacturer's published data.

8. AC ripple current and voltage imposed on the battery shall be in accordance with manufacturer's published data.

9. Charger shall be capable of manufacturer's specified full load.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.18.3 Direct-Current Systems, Rectifiers

— RESERVED —

* Optional

7. INSPECTION AND TEST PROCEDURES

7.19.1 Surge Arresters, Low-Voltage

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, grounding, and clearances.

4. Verify the arresters are clean.

5. 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 7.19.1.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.

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 an insulation-resistance test on each arrester, phase terminal-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

3. Test grounding connection in accordance with Section 7.13.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.19.1.1.5.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.19.1.1.5.2)

3.2 Test Values – Electrical

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

* Optional

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

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Resistance between the arrester ground terminal and the ground system shall be less than 0.5 ohm and in accordance with Section 7.13.

7.19.2 Surge Arresters, Medium- and High-Voltage

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, grounding, and clearances.

4. Verify the arresters are clean.

5. 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 7.19.2.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.

7. Verify that the stroke counter is correctly mounted and electrically connected, if applicable.

8. Record the stroke counter reading.

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 an insulation-resistance test on each arrester, phase terminal-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

3. Test grounding connection in accordance with Section 7.13.

*4. Perform a watts-loss test.

* Optional

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.19.2.1.5.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.19.2.1.5.2)

3.2 Test Values – Electrical

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

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated

3. Resistance between the arrester ground terminal and the ground system shall be less than 0.5 ohm and in accordance with Section 7.13.

4. Watts-loss values are evaluated on a comparison basis with similar units and test equipment manufacturer's published data.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.20.1 Capacitors and Reactors, Capacitors

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and clearances.
4. Verify the unit is clean.
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 low-resistance ohmmeter in accordance with Section 7.20.1.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.

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. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Measure the capacitance of all terminal combinations.
4. Measure resistance of the internal discharge resistors.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.20.1 Capacitors and Reactors, Capacitors (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.20.1.1.6.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.20.1.1.6.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.20.1.1.6.3)

3.2 Test Values – Electrical

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

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated

3. Investigate capacitance values differing from manufacturer's published data.

4. Investigate discharge resistor values differing from manufacturer's published data. In accordance with ANSI/NFPA 70 *National Electrical Code,* Article 460, residual voltage of a capacitor shall be reduced to 50 volts in the following time intervals after being disconnected from the source of supply:

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

* Optional

7. INSPECTION AND TEST PROCEDURES

7.20.2 Capacitors and Reactors, Capacitor Control Devices

— RESERVED —

* Optional

7. INSPECTION AND TEST PROCEDURES

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

1. Visual and Mechanical Inspections

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify the unit is clean.

5. 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 7.20.3.1.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

6. Verify that tap connections are as specified, if applicable.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.20.3.1.1.

2. Perform winding-to-ground insulation-resistance tests. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

3. Measure winding resistance.

*4. Perform dielectric withstand voltage tests on each winding-to-ground.

* Optional

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.20.3.1.1.5.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.20.3.1.1.5.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.20.3.1.1.5.3)

3.2 Test Values – Electrical

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

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

3. Winding-resistance test results shall be within one percent of factory results.

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 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. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect impact recorder prior to unloading, if applicable.
4. Verify removal of any shipping bracing after final placement.
5. Inspect anchorage, alignment, and grounding.
6. Verify the unit is clean.
7. Verify settings and operation of all temperature devices, if applicable.
8. Verify that cooling fans and pumps operate correctly and that fan and pump motors have correct overcurrent protection, if applicable.
9. Verify operation of all alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relay, if applicable.
10. 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 7.20.3.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
11. Verify correct liquid level in all tanks and bushings.
12. Verify that positive pressure is maintained on nitrogen-blanketed reactors.
13. Perform specific inspections and mechanical tests as recommended by the manufacturer.
14. Verify that tap connections are as specified, if applicable.

* Optional

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

2. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.20.3.2.1.

2. Perform winding-to-ground insulation-resistance tests. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Calculate polarization index.

3. Perform insulation power-factor or dissipation-factor tests on windings in accordance with the test equipment manufacturer's published data.

4. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.

5. Measure winding resistance.

6. Measure the percentage of oxygen in the nitrogen gas blanket, if applicable.

7. Remove a sample of insulating liquid in accordance with ASTM D-923. Sample shall be tested for the following:

    1. Dielectric breakdown voltage: ASTM D-877 and/or ASTM D-1816.

    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 in accordance with ANSI/IEEE C57.104 or ASTM D-3612.

* Optional

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Operation of temperature devices shall be in accordance with system requirements. (7.20.3.2.1.7)

2. Operation of pumps and fans shall be in accordance with manufacturer's recommendations and system design. (7.20.3.2.1.8)

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. (7.20.3.2.1.10.1)

4. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.20.3.2.1.10.2)

5. Results of the thermographic survey shall be in accordance with Section 9. (7.20.3.2.1.10.3)

6. Liquid levels shall be in accordance with manufacturer's published tolerances. (7.20.3.2.1.11)

7. Positive pressure shall be indicated on the pressure gauge for gas-blanketed reactors. (7.20.3.2.1.12)

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 shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall be greater than 1.0.

3. Maximum power-factor or dissipation-factor values of liquid-filled reactors shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, compare to test equipment manufacturer's published data. Representative values are indicated in Table 100.3.

4. Power-factor or dissipation-factor and capacitance values shall be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/ milliwatt-loss basis, and the results shall be compared to values of similar bushings.

5. Consult the manufacturer if winding-resistance values vary more than one percent from factory tests.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

6. Investigate presence of oxygen in the nitrogen gas blanket.

7. Insulating liquid values shall be in accordance with Table 100.4.

8. Results of dissolved-gas analysis shall be evaluated in accordance with IEEE Standard C57.104.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.21 Outdoor Bus Structures

1. Visual and Mechanical Inspection

1. Compare bus arrangement with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify the support insulators are clean.

5. 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 7.21.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.21.1.

*2. Measure insulation resistance of each bus, phase-to-ground with other phases grounded. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

3. Perform dielectric withstand voltage test on each bus phase, phase-to-ground with other phases grounded. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19. Potential application shall be for one minute.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.21.1.5.1)

2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.21.1.5.2)

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

* Optional

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 shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use 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 test, the test specimen is considered to have passed the test.

* Optional

7.22.1 Emergency Systems, Engine Generator

NOTE: Other than protective shutdowns, the prime mover is not addressed in these specifications.

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.

2. Electrical and Mechanical Tests

1. Perform insulation-resistance tests in accordance with ANSI/IEEE Standard 43.
    1. Machines larger than 200 horsepower (150 kilowatts):
    Test duration shall be ten minutes. Calculate polarization index.
    2. Machines 200 horsepower (150 kilowatts) and less:
    Test duration shall be one minute. Calculate the dielectric-absorption ratio.
2. Test protective relay devices in accordance with Section 7.9.
3. Verify phase rotation, phasing, and synchronized operation as required by the application.
4. Functionally test engine shutdown for low oil pressure, overtemperature, overspeed, and other protection features as applicable.

*5. Perform vibration test for each main bearing cap.

6. Conduct performance test in accordance with ANSI/NFPA 110.
7. Verify correct functioning of the governor and regulator.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Anchorage, alignment, and grounding should be in accordance with manufacturer's published data and system design. (7.22.1.1.3)

* Optional

3.2 Test Values – Electrical

1. 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 shall 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.

2. Protective relay device test results shall be in accordance with Section 7.9.

3. Phase rotation, phasing, and synchronizing shall be in accordance with system design requirements.

4. Low oil pressure, overtemperature, overspeed, and other protection features shall operate in accordance with manufacturer's published data and system design requirements.

5. Vibration levels shall be in accordance with manufacturer's published data and shall be compared to baseline data.

6. Performance tests shall conform to manufacturer's published data and ANSI/NFPA Standard 110.

7. Governor and regulator shall operate in accordance with manufacturer's published data and system design requirements.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.22.2 Emergency Systems, Uninterruptible Power Systems

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

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, grounding, and required clearances.

4. Verify that fuse sizes and types correspond to drawings.

5. Verify the unit is clean.

6. Test all electrical and mechanical interlock systems for correct operation and sequencing.

7. Inspect bolted electrical connections for high resistance using one or more of the following methods:

    1. Use of low-resistance ohmmeter in accordance with Section 7.22.2.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

8. Verify operation of forced ventilation.

9. Verify that filters are in place and vents are clear.

* Optional

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

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.22.2.1.
2. Test static transfer from inverter to bypass and back. Use normal load, if possible.
3. Set free running frequency of oscillator.
4. Test dc undervoltage trip level on inverter input breaker. Set according to manufacturer's published data.
5. Test alarm circuits.
6. Verify synchronizing indicators for static switch and bypass switches.
7. Perform electrical tests for UPS system breakers in accordance with Section 7.6.
8. Perform electrical tests for UPS system automatic transfer switches in accordance with Section 7.22.3.
9. Perform electrical tests for UPS system batteries in accordance with Section 7.18.
10. Perform electrical tests for UPS rotating machinery in accordance with Section 7.15.

3. Test Values

3.1 Test Values – Visual and Mechanical

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

* Optional

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

3.2 Test Values – Electrical

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

2. Static transfer shall function in accordance with manufacturer's published data.

3. Oscillator free running frequency shall be within manufacturer's published tolerances.

4. DC undervoltage shall trip inverter input breaker.

5. Alarm circuits shall operate in accordance with design requirements.

6. Synchronizing indicators shall operate in accordance with design requirements.

7. Breaker performance shall be in accordance with Section 7.6.1.

8. Automatic transfer switch performance shall be in accordance with Section 7.22.3.

9. Battery test results shall be in accordance with Section 7.18.

10. Rotating machinery performance shall be in accordance with Section 7.15.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.22.3 Emergency Systems, Automatic Transfer Switches

1. Visual and Mechanical Inspection

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

* Optional

7. INSPECTION AND TEST PROCEDURES

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

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.22.3.1.

*2. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or for control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.

3. Perform a contact/pole-resistance test.

4. Verify settings and operation of control devices.

5. Calibrate and set all relays and timers in accordance with Section 7.9.

6. Verify phase rotation, phasing, and synchronized operation as required by the application.

7. Perform automatic transfer tests:

   1. Simulate loss of normal power.
   2. Return to normal power.
   3. Simulate loss of emergency power.
   4. Simulate all forms of single-phase conditions.

8. Verify correct operation and timing of the following functions:

   1. Normal source voltage-sensing and frequency-sensing relays.
   2. Engine start sequence.
   3. Time delay upon transfer.
   4. Alternate source voltage-sensing and frequency-sensing relays.
   5. Automatic transfer operation.
   6. Interlocks and limit switch function.
   7. Time delay and retransfer upon normal power restoration.
   8. Engine cool down and shutdown feature.

* Optional

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.22.3.1.8.1)

2. Bolt-torque levels shall be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12. (7.22.3.1.8.2)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.22.3.1.8.3)

3.2 Test Values – Electrical

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

2. Insulation-resistance values of control wiring shall not be less than two meghoms.

3. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer’s published data. If manufacturer’s published data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

4. Control devices shall operate in accordance with manufacturer’s published data.

5. Relay test results shall be in accordance with Section 7.9.

6. Phase rotation, phasing, and synchonization shall be in accordance with system design specifications.

7. Automatic transfers shall operate in accordance with manufacturer’s design.

8. Operation and timing shall be in accordance with manufacturer’s and system design requirements.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.23 Communications

— RESERVED —

* Optional

7. INSPECTION AND TEST PROCEDURES

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

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify the unit is clean.

5. Perform all mechanical operation and contact alignment tests on both the recloser and its operating mechanism in accordance with manufacturer's published data.

6. Inspect bolted electrical connections for high resistance using one or more of the following methods:

    1. Use of low-resistance ohmmeter in accordance with Section 7.24.1.2.

    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 thermographic survey in accordance with Section 9.

7. Verify appropriate insulating liquid level.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.24.1.1.

2. Perform insulation-resistance tests on each pole, phase–to–phase and phase–to–ground with recloser closed, and across each open pole for one minute. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

3. Perform a contact/pole-resistance test.

*4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

5. Remove a sample of insulating liquid, if applicable, in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.

    1. Dielectric breakdown voltage: ASTM D 877

    2. Color: ANSI/ASTM D 1500

    3. Visual condition: ASTM D 1524

6. Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer’s published data.

*7. Perform power-factor or dissipation-factor tests on each pole with the recloser open and each phase with the recloser closed.

8. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer’s published data.

9. Perform vacuum bottle integrity test (dielectric withstand voltage), if applicable, across each vacuum bottle with the contacts in the open position in strict accordance with manufacturer’s published data.

10. Perform dielectric withstand voltage tests on each pole-to-ground and pole-to-pole with recloser in closed position.

11. Verify operation of heaters, if applicable.

12. Test all protective functions in accordance with Section 7.9.

13. Test all metering and instrumentation in accordance with Section 7.11.

14. Test instrument transformers in accordance with Section 7.10.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Mechanical operation and contact alignment shall be in accordance with manufacturer's published data. (7.24.1.1.5)

2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.24.1.1.6.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.24.1.1.6.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.24.1.1.6.3)

5. Insulating liquid level shall be in accordance with manufacturer's recommended tolerances. (7.24.1.1.7)

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 shall 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 shall be investigated.

3. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values that deviate from adjacent poles or similar reclosers by more than 50 percent of the lowest value.

4. Insulation-resistance values of control wiring shall not be less than two megohms.

5. Insulating liquid test results shall be in accordance with Table 100.4.

6. Minimum pickup voltage of the trip and close coils shall conform to the manufacturer's published data. In the absence of the manufacturer's published data, refer to Table 100.20.

7. Power-factor or dissipation-factor values and tank loss-index shall be compared to manufacturer's published data. In the absence of manufacturer's published data, the comparison shall be made to test data from similar circuit reclosers, sectionalizers, or data from test equipment manufacturers.

* Optional

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

8. Power-factor or dissipation-factor and capacitance values shall be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/milliwatt loss basis, and the results shall 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 test, the test specimen is considered to have passed the test.

11. Heaters shall be operational.

12. Protective device function test results shall be in accordance with Section 7.9.

13. Metering and instrumentation test results shall be in accordance with Section 7.11.

14. Instrument transformer test results shall be in accordance with Section 7.10.

* Optional

7. INSPECTION AND TEST PROCEDURES

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

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify the unit is clean.

5. Perform all mechanical operation and contact alignment tests on both the sectionalizer and its operating mechanism in accordance with manufacturer's published data.

6. Inspect bolted electrical connections for high resistance using one or more of the following methods:

    1. Use of low-resistance ohmmeter in accordance with Section 7.24.2.2.

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.

    3. Perform thermographic survey in accordance with Section 9.

7. Verify appropriate insulating liquid level.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.24.2.1.

2. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with sectionalizer closed, and across each open pole for one minute. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

3. Perform a contact/pole-resistance test.

4. Remove a sample 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. Visual condition: ASTM D 1524

* Optional

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

5. Perform dielectric withstand voltage tests on each pole-to-ground and pole-to-pole with recloser in closed position.

6. Test sectionalizer counting function by application of simulated fault current (greater than 160 percent of continuous current rating).

7. Test sectionalizer lockout function for all counting positions.

8. Test for reset timing on trip actuator.

*9. Perform power-factor or dissipation-factor tests on each pole with the recloser open and each phase with the recloser closed.

*10. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Mechanical operation and contact alignment shall be in accordance with manufacturer's published data. (7.24.2.1.5)

2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.24.2.1.6.1)

3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.24.2.1.6.2)

4. Results of the thermographic survey shall be in accordance with Section 9. (7.24.2.1.6.3)

5. Insulating liquid level shall be in accordance with manufacturer's recommended tolerances. (7.24.2.1.7)

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 shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

* Optional

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

3. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's published data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

4. Insulating liquid test results shall be in accordance with Table 100.4.

5. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.

6. Operations counter shall advance one digit per close-open cycle.

7. Lockout function shall operate in accordance with manufacturer's published data.

8. Reset timing of trip actuator shall operate in accordance with manufacturer's published data.

9. Power-factor or dissipation-factor values and tank loss-index shall be compared to manufacturer's published data. In the absence of manufacturer's published data, the comparison shall be made to test data from similar circuit reclosers, sectionalizers, or data from test equipment manufacturers.

10. Power-factor or dissipation-factor and capacitance values shall be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.25 Fiber-Optic Cables

1. Visual and Mechanical Inspection

1. Compare cable, connector, and splice data with drawings and specifications.

2. Inspect cable and connections for physical and mechanical damage.

3. Verify that all connectors and splices are correctly installed.

2. Optical Tests

1. Perform cable length measurement, fiber fracture inspection, and construction defect inspection using an optical time domain reflectometer.

2. Perform connector and splice integrity test using an optical time domain reflectometer.

3. Perform cable attenuation loss measurement with an optical power loss test set.

4. Perform connector and splice attenuation loss measurement from both ends of the optical cable with an optical power loss test set.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Cable and connections shall not have been subjected to physical or mechanical damage. (7.25.1.1)

2. Connectors and splices shall be installed in accordance with industry standards. (7.25.1.2)

3.2 Test Values – Optical

1. The optical time domain reflectometer signal shall be analyzed for excessive connection, splice, or cable backscatter by viewing the reflected power/distance graph.

2. The optical time domain reflectometer signal shall be analyzed for excessive connection, splice, or cable backscatter by viewing the reflected power/distance graph.

3. Attenuation loss measurement shall be expressed in dB/km. Losses shall be within the manufacturer's recommendations when no local site specifications are available.

4. Attenuation loss measurement shall be expressed in dB/km. Losses shall be within the manufacturer's recommendations when no local site specifications are available.

* Optional

8. SYSTEM FUNCTION TESTS

NOTE: It is the purpose of system function tests to prove the correct interaction of all sensing, processing, and action devices. Perform system function tests upon completion of the acceptance tests on specified equipment.

1. Develop test parameters and perform tests for the purpose of evaluating performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

2. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.

3. Verify the correct operation of all sensing devices, alarms, and indicating devices.

9. THERMOGRAPHIC SURVEY

1. Visual and Mechanical Inspection

1. Perform thermographic survey when load is applied to the system.

2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.

*3. Perform a follow-up thermographic survey within 12 months of final acceptance by the owner.

2. Report

Provide a report which includes the following:

1. Description of equipment to be tested.

2. Discrepancies.

3. Temperature difference between the area of concern and the reference area.

4. Probable cause of temperature difference.

5. Areas inspected. Identify inaccessible and unobservable areas and equipment.

6. Identify load conditions at time of inspection.

7. Provide photographs and/or thermograms of the deficient area.

8. Recommended action.

3. Test Parameters

1. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.

2. Equipment shall detect emitted radiation and convert detected radiation to visual signal.

3. Thermographic surveys should be performed during periods of maximum possible loading. Refer to ANSI/NFPA 70B, 2006 Edition, Section 21.17.

4. Test Results

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

10. ELECTROMAGNETIC FIELD TESTING

1. Scope of Services

Determine the vector-valued quantity of magnetic flux density for power frequency magnetic fields over a predetermined space or area.

2. Procedure

1. Take detailed measurements of the magnetic flux density, vector direction, and temporal variations at the locations or over the area, as necessary.

    1. Perform spot measurements of the magnetic fields (40 to 800 Hertz) at grid intervals one meter above the floor throughout the office. Record x, y, z, and resultant magnetic flux density values for each measurement point.

    2. Take additional detailed spot measurements directly at floor level and at two meters above the floor at grid point locations directly on the wall surface separating measured area from suspected magnetic field source.

    3. If measured magnetic flux densities at any perimeter wall appear to be above 3.0 to 5.0 mG, take additional spot measurements of the adjoining space utilizing the same measurement grid spacing at one meter above floor.

    4. Take a benchmark magnetic flux density reading at a specific point in the immediate area of the suspected magnetic field source.

    5. Determine magnetic field temporal variations as required by positioning the Gaussmeter at or near the location of highest magnetic flux density for 24 to 48 hours.

2. Obtain and record other related electrical system information including current measurements for each phase, neutral, and net current as available for the involved electrical system for use in correcting any wiring deficiencies and in completing the design of a shielding installation or other suitable mitigation proposal.

3. The magnetic field evaluation shall be performed in accordance with the recommended practices and procedures in accordance with IEEE 644.

3. Survey Report

1. Results of the survey shall be summarized in a report containing the following items:

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

11.0 CORONA STUDIES

— RESERVED —

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Tables

Standard for Acceptance Testing Specifications
for
Electrical Power
Equipment and Systems

TABLE 100.1

Insulation Resistance Test Values
Electrical Apparatus and Systems

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

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

See Table 100.14 for temperature correction factors.

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

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

TABLE 100.2

Switchgear Withstand Test Voltages

Type of Switchgear	Rated Maximum Voltage (kV) (rms)	Maximum Test Voltage kV	
		AC	DC
Low-Voltage Power Circuit Breaker Switchgear	.254/.508/.635	1.6	2.3
Metal-Clad Switchgear	4.76	14	20
	8.25	27	37
	15.0	27	37
	27.0	45	†
	38.0	60	†
Station-Type Cubicle Switchgear	15.5	37	†
	38.0	60	†
	72.5	120	†
Metal Enclosed Interrupter Switchgear	4.76	14	20
	8.25	19	27
	15.0	27	37
	15.5	37	52
	25.8	45	†
	38.0	60	†

Derived from ANSI/IEEE C37.20.1-1993, Paragraph 5.5, *Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear*, C37.20.2-1993, Paragraph 5.5, *Standard for Metal-Clad and Station-Type Cubicle Switchgear* and C37.20.3-1987 (R1992), Paragraph 5.5, *Standard for Metal-Enclosed Interrupter Switchgear*, and includes 0.75 multiplier with fraction rounded down.

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

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

TABLE 100.3

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

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 100.4

Insulating Fluid Limits

Table 100.4.1
Test Limits for New Insulating Oil Received in New Equipment

Mineral Oil

Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2
Test Limits for Silicone Insulating Liquid in New Transformers

Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2.

TABLE 100.4 (*continued*)

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid
Received in New Equipment

ASTM Method	Test	Results: Minimum		Results: Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0 X 10^2 (100)		1.3 X 10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

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

TABLE 100.5

Transformer Insulation Resistance
Acceptance Testing

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

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

See Table 100.14 for temperature correction factors.

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

TABLE 100.6

Medium-Voltage Cables
Acceptance Test Values

Table 100.6.1 DC Test Voltages					
		Nominal Insulation Thickness mils (mm)		Maximum DC Field Test Voltages, kV During/After Installation	
Rated Voltage Phase-to-Phase kV	**Conductor Size AWG or kcmil (mm)**	**100% Insulation Level**	**133% Insulation Level**	**100% Insulation Level**	**133% Insulation Level**
5	8-1000 (8.4-507) Above 1000 (507)	90 (2.29) 140 (3.56)	115 (2.92) 140 (3.56)	28 28	36 36
8	6-1000 (13.3-507) Above 1000 (507)	115 (2.92) 175 (4.45)	140 (3.56) 175 (4.45)	36 36	44 44
15	2-1000 (33.6-507) Above 1000 (507)	175 (4.45) 220 (5.59)	220 (5.59) 220 (5.59)	56 56	64 64
25	1-2000 (42.4-1013)	260 (6.60)	320 (8.13)	80	96
28	1-2000 (42.4-1013)	280 (7.11)	345 (8.76)	84	100
35	1/0-2000 (53.5-1013)	345 (8.76)	420 (10.7)	100	124
46	4/0-2000 (107.2-1013)	445 (11.3)	580 (14.7)	132	172
69	4/0-2000 (107.2-1013)		650		195

Tables derived from ANSI/ICEA S 93-639/NEMA WC 74-2000, *5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*; ANSI/ICEA S-94-649-2000, *Standard for Concentric Neutral Cables Rated 5,000 - 46,000 Volts*; ANSI/ICEA S-97-682-2000, *Standard for Utility Shielded Power Cables Rated 5,000 - 46,000 Volts;* and The Okonite Company, *High-Voltage Proof Testing.*

DC test voltages are applied to discover gross problems such as incorrectly installed accessories or mechanical damage.

The dc field test voltages listed above are intended for cable designed in accordance with ICEA specifications. When older cables or other types/classes of cables or accessories are connected to the system, voltages lower than those shown may be necessary. Consult the manufacturers of the cables and accessories before applying the test voltage.

TABLE 100.6 (*continued*)

Medium-Voltage Cables
Acceptance Test Values

Table 100.6.2 AC Test Voltages					
		Nominal Insulation Thickness Mils (mm)		AC Test Voltage, kV	
Rated Voltage Phase-to-Phase kV	**Conductor Size AWG or kcmil**	**100% Insulation Level**	**133% Insulation Level**	**100% Insulation Level**	**133% Insulation Level**
5 kV	8-1000 1001-3000	90 (2.29) 140 (3.56)	115 (2.92) 140 (3.56)	18 28	23 28
8 kV	6-1000 1001-3000	115 (2.92) 175 (4.45)	140 (3.56) 175 (4.45)	23 35	28 35
15 kV	2-1000 1001-3000	175 (4.45) 220 (5.59)	220 (5.59) 220 (5.59)	35 44	44 44
25 kV	1-3000	260 (6.60)	320 (8.13)	52	64
28 kV	1-3000	280 (7.11)	345 (8.76)	56	69
35 kV	1/0-3000	345 (8.76)	420 (10.7)	69	84
46 kV	4/0-3000	445 (11.3)	580 (14.7)	89	116

Tables derived from ANSI/ICEA S 93-639/NEMA WC 74-2000, *5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*; ANSI/ICEA S-94-649-2000, *Standard for Concentric Neutral Cables Rated 5,000 - 46,000 Volts*; ANSI/ICEA S-97-682-2000, *Standard for Utility Shielded Power Cables Rated 5,000 - 46,000 Volts.*

All ac voltages are rms values.

TABLE 100.6 (*continued*)

Medium-Voltage Cables
Acceptance Test Values

Table 100.6.3 Partial Discharge Requirements for Semiconduction Coating and Semiconducting, Nonmetalic Tape Designs Only		
Rated Circuit Voltage Phase-to-Phase Volts	**Minimum Partial Discharge Extinction Level, kV**	
	100% Insulation Level	**133% Insulation Level**
2001-5000	4	5
5001-8000	6	8
8001-15000	11	15

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

ANSI/ICEA S 93-639/NEMA WC 74-2000, 5-*46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*.

Table 100.6.4 Very Low Frequency Testing Levels 0.1 Hz Test Voltage (rms)	
System Voltage Phase-to-Phase (kV) (rms)	**Proof Phase-to-Ground (kV) (rms)**
5	10
15	22
25	33
35	47

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

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TABLE 100.7

Inverse Time Trip Test
at 300% of Rated Continuous Current of Circuit Breaker
Molded-Case Circuit Breakers

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

Derived from Table 5-3, NEMA Standard AB 4-1996, *Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications*.

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

TABLE 100.8

Instantaneous Trip Tolerances for Field Testing of Circuit Breakers

		Tolerances of Manufacturer's Published Trip Range	
Breaker Type	**Tolerance of Settings**	**High Side**	**Low Side**
Adjustable	+40% -30%	- - - - -	- - - - -
Nonadjustable	- - - - -	+25%	-25%

Reproduction of Table 5-4 from NEMA publication AB4-1996.

For circuit breakers with nonadjustable instantaneous trips, tolerances apply to the manufacturer's published trip range, i.e., +40 percent on high side, -30 percent on low side.

TABLE 100.9

Instrument Transformer Dielectric Tests
Field Acceptance

Nominal System Voltage (kV)	BIL (kV)	Periodic Dielectric Withstand Test Field Test Voltage (kV)	
		AC	DC*
0.60	10	3.0	4
1.20	30	7.5	10
2.40	45	11.25	15
5.00	60	14.25	19
8.70	75	19.5	26
15.00	95	25.5	34
15.00	110	25.5	34
25.00	125	30.0	40
25.00	150	37.5	50
34.50	200	52.5	70
46.00	250	71.2	+
69.00	350	105	+
115.00	450	138	+
115.00	550	172	+
138.00	650	206	+
161.00	750	243	+
230.00	900	296	+
230.00	1050	345	+
345.00	1300	431	+
500.00	1675	562	+
500.00	1800	600	+
765.00	2050	690	+

Table 100.9 is derived from Paragraph 8.8.2 and Tables 2 of ANSI/IEEE C57.13-1993, *Standard Requirements for Instrument Transformers*.

+ Periodic dc potential tests are not recommended for transformers rated higher than 34.5 kV.

* DC potential tests are not recommended for transformers rated higher than 200 kV BIL. DC tests may prove beneficial as a reference for future testing. In such cases the test direct voltage shall not exceed the original factory test rms alternating voltages.

TABLE 100.10

Maximum Allowable Vibration Amplitude

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

Derived from NEMA publication MG 1–2006, Section 7.8.1, Table 7–1. Table is unfiltered vibration limits for resiliently mounted machines. For machines with rigid mounting multiply the limiting values by 0.8.

TABLE 100.11

— RESERVED —

TABLE 100.12.1

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

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

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

TABLE 100.12.2

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

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

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 100.12.3

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

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

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 100.12.4

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

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

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

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

TABLE 100.13

SF_6 Gas Tests

Test	Method	Serviceability Limits [a]
Moisture	Hygrometer	Per manufacturer or ≥ 200 ppm[b]
SF_6 decomposition byproducts	ASTM D 2685	≥ 500 ppm
Air	ASTM D 2685	≥ 5000 ppm[c]
Dielectric breakdown hemispherical contacts	0.10 inch gap at atmospheric pressure	11.5 - 13.5 kV[d]

a. In the absence of consensus standards dealing with SF_6 circuit breaker gas tests, the NETA Standards Review Council suggests the above representative values.

b. According to some manufacturers.

c. Dominelli, N. and Wylie, L., *Analysis of SF_6 Gas as a Diagnostic Technique for GIS*, Electric Power Research Institute, Substation Equipment Diagnostics Conference IV, February 1996.

d. Per Even, F.E., and Mani, G. Sulfur Fluorides, Kirk, *Othmer Encyclopedia of Chemical Technology*, 4th ed., 11,428, 1994.

Reference: IEC 61634 High-Voltage Switchgear and Controlgear - *Use and Handling of Sulfur Hexafluoride (SF_6) in High-Voltage Switchgear and Controlgear*.

TABLE 100.14

Insulation Resistance Conversion Factors (20° C)

Table 100.14.1 Test Temperatures to 20° C			
Temperature		**Multiplier**	
° C	**° F**	**Apparatus Containing Immersed Oil Insulation**	**Apparatus Containing Solid Insulation**
-10	14	0.125	0.25
-5	23	0.180	0.32
0	32	0.25	0.40
5	41	0.36	0.50
10	50	0.50	0.63
15	59	0.75	0.81
20	68	1.00	1.00
25	77	1.40	1.25
30	86	1.98	1.58
35	95	2.80	2.00
40	104	3.95	2.50
45	113	5.60	3.15
50	122	7.85	3.98
55	131	11.20	5.00
60	140	15.85	6.30
65	149	22.40	7.90
70	158	31.75	10.00
75	167	44.70	12.60
80	176	63.50	15.80
85	185	89.789	20.00
90	194	127.00	25.20
95	203	180.00	31.60
100	212	254.00	40.00
105	221	359.15	50.40
110	230	509.00	63.20

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

Formula:
$R_c = R_a \times K$
Where: R_c is resistance corrected to 20° C
R_a is measured resistance at test temperature
K is applicable multiplier

Example: Resistance test on oil-immersion insulation at 104°
R_a = 2 megohms @ 104° F
K = 3.95
$R_c = R_a \times K$
$R_c = 2.0 \times 3.95$
R_c = 7.90 megohms @ 20° C

TABLE 100.14 (*continued*)

Insulation Resistance Conversion Factors (40° C)

Table 100.14.2 Test Temperature to 40° C			
Temperature		**Multiplier**	
° C	**° F**	**Apparatus Containing Immersed Oil Insulation**	**Apparatus Containing Solid Insulation**
-10	14	0.03	0.10
-5	23	0.04	0.13
0	32	0.06	0.16
5	41	0.09	0.20
10	50	0.13	0.25
15	59	0.18	0.31
20	68	0.25	0.40
25	77	0.35	0.50
30	86	0.50	0.63
35	95	0.71	0.79
40	104	1.00	1.00
45	113	1.41	1.26
50	122	2.00	1.59
55	131	2.83	2.00
60	140	4.00	2.52
65	149	5.66	3.17
70	158	8.00	4.00
75	167	11.31	5.04
80	176	16.00	6.35
85	185	22.63	8.00
90	194	32.00	10.08
95	203	45.25	12.70
100	212	64.00	16.00
105	221	90.51	20.16
110	230	128.00	25.40

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

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

Formula:
$R_c = R_a \times K$
Where: R_c is resistance corrected to 40° C
R_a is measured resistance at test temperature
K is applicable multiplier

Example: Resistance test on oil-immersion insulation at 68° F/20° C
R_a = 2 megohms @ 68° F/20° C
K = 0.40
$R_c = R_a \times K$
R_c = 2.0 x 0.40 = 0.8 megohms @ 40° C

TABLE 100.15

High-Potential Test Voltage
Automatic Circuit Reclosers

Nominal Voltage Class, kV	Maximum Voltage, kV	Rated Impulse Withstand Voltage, kV	Maximum Field Test Voltage, kV, AC
14.4	15.0	95	35
14.4	15.5	110	50
24.9	27.0	150	60
34.5	38.0	150	70
46.0	48.3	250	105
69.0	72.5	350	160

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

TABLE 100.16

High-Potential Test Voltage for Acceptance Testing of Line Sectionalizers

Nominal Voltage Class kV	Maximum Voltage kV	Rated Impulse Withstand Voltage kV	Maximum Field Test Voltage kV, AC	DC 15 Minute Withstand (kV)
14.4 (1 ø)	15.0	95	35	53
14.4 (1 ø)	15.0	125	42	53
14.4 (3 ø)	15.5	110	50	53
24.9 (1 ø)	27.0	125	60	78
34.5 (3 ø)	38.0	150	70	103

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

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

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

TABLE 100.17

Dielectric Withstand Test Voltages
Metal-Enclosed Bus

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

Derived from ANSI/IEEE C37.23-1987, Tables 3A, 3B, 3C, 3D and paragraph 6.4.2. The table includes a 0.75 multiplier with fractions rounded down.

NOTE:

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

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

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

TABLE 100.18

Thermographic Survey
Suggested Actions Based on Temperature Rise

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

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

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

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

TABLE 100.19

Dielectric Withstand Test Voltages
Electrical Apparatus Other than Inductive Equipment

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

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

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

TABLE 100.20

Rated Control Voltages and their Ranges for Circuit Breakers

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

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

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

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 100.20 (*continued*)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2

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

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

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

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

TABLE 100.21

Accuracy of IEC Class TP Current Transformers
Error Limit

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

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

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

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

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

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

x = applicable, – = not applicable
*The factor construction is determined from the following ratio:

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

where
V_{alc} is the mts value of sinusoidal voltage of rated frequency, with, if applied to the secondary winding of a ct, would result in an exciting current corresponding to the maximum permissible error current appropriate to ct class
E_{alc} is the equivalent rms emf of rated frequency determined during test observed error current corresponds to the appropriate limit for the class
Derived from C37.110

TABLE 100.22

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

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

ANSI/ICEA S-93-639/NEMA WC 74-2000, 5-46 *kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy, Appendix I – Recommended Bending Radii for Cables and Table I1 – Minimum Radii for Power Cable*.

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

TABLE 100.22

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

Notes

Specific references from Appendix I:

1. Interlocked-Armor and Metallic-Sheathed Cables

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

2. Flat-Tape Armored or Wire-Armored Cables

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

3. Tape-Shielded Cables

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

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

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

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

4. Wire-Shielded Cables

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

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

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

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APPENDIX A

Definitions

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

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

As-found
Condition of the equipment when taken out of service, prior to testing.

As-left
Condition of equipment at the completion of inspection and testing. As-left values refer to test values obtained after any corrective action or design change has been performed on the device under test.

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

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

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

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

Extra-high voltage
A class of nominal system voltages greater than 230,000 volts.

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

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

Interim amendment
A interim amendment is made by NETA's Standards Review Council when there is a potential hazard prior to review by the Section Panel or the public.

APPENDIX A

Definitions (*continued*)

Low voltage
A class of nominal system voltages 1000 volts or less.

Manufacturer's published data
Data provided by the manufacturer concerning a specific piece of equipment.

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

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

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

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

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

Should
Indicates that a provision is not mandatory but is recommended as good practice.

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

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

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

APPENDIX B

— RESERVED —

APPENDIX C

About the InterNational Electrical Testing Association

(This appendix is not part of American National Standard ANSI/NETA ATS-2009)

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

CERTIFICATION

Certification of competency is particularly important in the electrical testing industry. Inherent in the determination of the equipment's serviceability is the prerequisite that individuals performing the tests be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must also evaluate the test data and make an informed judgement on the continued serviceability, deterioration, or nonserviceability of the specific equipment. NETA, a nationally-recognized certification agency, provides recognition of four levels of competency within the electrical testing industry in accordance with *ANSI/NETA ETT-2000 Standard for Certification of Electrical Testing Technicians.*

QUALIFICATIONS OF THE TESTING ORGANIZATION

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

- The NETA Technician has broad-based knowledge -- this person is trained to inspect, test, maintain, and calibrate all types of electrical equipment in all types of industries.
- NETA Technicians meet stringent educational and experience requirements in accordance with *ANSI/NETA ETT-2000 Standard for Certification of Electrical Testing Technicians*.
- A Registered Professional Engineer will review all engineering reports.
- All tests will be performed objectively, according to NETA specifications, using calibrated instruments traceable to the National Institute of Science and Technology (NIST).
- The firm is a well-established, full-service electrical testing business.

APPENDIX C

About the InterNational Electrical Testing Association (*continued*)

(This appendix is not part of American National Standard ANSI/NETA ATS-2009)

SPECIFICATIONS AND PUBLICATIONS

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

ANSI/NETA ETT-2000	*Standard for Certification of Electrical Testing Technicians*
ANSI/NETA MTS-2007	*Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*
ANSI/NETA ATS-2009	*Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*

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

EDUCATIONAL PROGRAMS

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

APPENDIX D

Form for Comments

(This appendix is not part of American National Standard ANSI/NETA ATS-2009)

Anyone may comment on this document using this form:

Type of Comment (Check one) ❑ Technical ❑ Editorial
Paragraph Number ______________________________
Recommend (Check One) ❑ *New Text ❑ *Revised Text ❑ *Deleted Text
❑This Comment is original material (Note: Original material is considered to be the submitter's own idea based on or as a result of his/her own experience, thought, or research and to the best of his/her knowledge is not copied from another source.)
❑This Comment is not original material; its source (if known) is ______________________________
Please Check One: ❑User ❑Producer ❑General Interest ❑Section Panel
Date ______________________________
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Signature (required) ______________________________

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

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

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

Send to: Standards Review Council
3050 Old Centre Avenue, Suite 102, Portage, MI 49024
Phone: 888.300.6382 FAX: 269.488.6383 Email: neta@netaworld.org

APPENDIX E

Form for Proposals

(This appendix is not part of American National Standard ANSI/NETA ATS-2009)

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

When drafting a proposed section:
Use the most recent edition of the specifications as a guideline for format and wording.
Remember that NETA specifications are "what to do" documents and do not include "how to do" information.
Include references.
When applicable, use the standard base format:

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

Date ____________________

Name ____________________ Tel No. ____________________

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Address ____________________ E-Mail ____________________

Please indicate organization represented (if any) ____________________

NETA document title ____________________ Year ____________________

Section/Number ____________________

Note 1: Type or print legibly in black ink.
Note 2: If supplementary material (photographs, diagrams, reports, etc.) is included, you may be required to submit sufficient copies for all Members and Alternates of the Section Panel.

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