



ANSI/NETA ATS-2017

# ATS

STANDARD FOR

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**ACCEPTANCE**  
TESTING SPECIFICATIONS

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FOR ELECTRICAL POWER EQUIPMENT & SYSTEMS

**2017** **NETA**  
STANDARDS

ANSI/NETA ATS-2017

AMERICAN NATIONAL STANDARD

**STANDARD FOR**  
**ACCEPTANCE TESTING SPECIFICATIONS** for  
Electrical Power Equipment  
and Systems

Secretariat  
**InterNational Electrical Testing Association**



American National Standards Institute



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- 5. General
  - 5.1 Safety and Precautions
  - 5.2 Suitability of Test Equipment
  - 5.3 Test Instrument Calibration
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## FOREWORD

(This Foreword is not part of American National Standard ANSI/NETA ATS-2017)

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, 2007, 2009, and 2013.

On February 2, 2017, 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, or emailed to [neta@netaworld.org](mailto:neta@netaworld.org).



# PREFACE

(This Preface is not part of American National Standard ANSI/NETA ATS-2017)

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 2013 edition is marked with a black vertical line to the left of the insertion of text, deletion of text, or alteration of text.

## The Document Structure

The document is divided into thirteen separate and defined sections:

<b>Section</b>	<b>Description</b>
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 Tests and Commissioning
Section 9	Thermographic Survey
Section 10	Electromagnetic Field Testing
Section 11	Corona Studies (Reserved)
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.

## Sequence of Tests and Inspections

The tests and inspections specified in this document are not necessarily presented in chronological order and may be performed in a different sequence.

## Expected Test Results

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

- A. Visual and Mechanical Inspection
- B. Electrical Tests
- C. Test Values – Visual and Mechanical
- D. Test Values – Electrical

# PREFACE (Continued)

(This Preface is not part of American National Standard ANSI/NETA ATS-2017)

## 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 C., *Test Values – Visual and Mechanical*. For example, Section 7.1 *Switchgear and Switchboard Assemblies*, item 7.1.A.8.2 calls for verifying tightness of connections using a calibrated torque wrench method. Under the *Test Values – Visual and Mechanical* Section 7.1.C.2, the expected results for that particular task are listed within Section C., with reference back to the original task description on item 7.1.A.8.2.

<p>7. INSPECTION AND TEST PROCEDURES</p> <p>7.1 Switchgear and Switchboard Assemblies</p> <p>A. Visual and Mechanical Inspection</p> <ol style="list-style-type: none"><li>1. Compare equipment nameplate data with drawings and specifications.</li><li>2. Inspect physical and mechanical condition.</li><li>3. Inspect anchorage, alignment, grounding, and required area clearances.</li><li>4. Verify the unit is clean and all shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.</li><li>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.</li><li>6. Verify that current and voltage transformer ratios correspond to drawings.</li><li>7. Verify that wiring connections are tight and that wiring is secure to prevent damage during routine operation of moving parts.</li><li>8. Inspect bolted electrical connections for high resistance using one or more of the following methods:<ol style="list-style-type: none"><li>1. Use of a low-resistance ohmmeter in accordance with Section 7.1.B.1.</li><li>2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.</li><li>3. Perform thermographic survey in accordance with Section 9.</li></ol></li><li>9. Verify operation and sequencing of interlocking systems.</li><li>10. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.</li><li>11. Inspect insulators for evidence of physical damage or contaminated surfaces.</li><li>12. Verify correct barrier and shutter installation and operation.</li><li>13. Exercise all active components.</li><li>14. Inspect mechanical indicating devices for correct operation.</li><li>15. Verify that filters are in place and vents are clear.</li><li>16. Perform visual and mechanical inspection of instrument transformers in accordance with Section 7.10.</li></ol> <p>* Optional</p> <p><b>NETA</b> Page 24 ANSI/NETA ATS-2017</p>	<p>7. INSPECTION AND TEST PROCEDURES</p> <p>7.1 Switchgear and Switchboard Assemblies (continued)</p> <p>C. Test Values – Visual and Mechanical</p> <ol style="list-style-type: none"><li>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.A.8.1)</li><li>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.A.8.2)</li><li>3. Results of the thermographic survey shall be in accordance with Section 9. (7.1.A.8.3)</li></ol> <p>D. Test Values – Electrical</p> <ol style="list-style-type: none"><li>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.</li><li>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.</li><li>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.</li><li>4. Minimum insulation-resistance values of control wiring shall not be less than two megohms.</li><li>5. Results of electrical tests on instrument transformers shall be in accordance with Section 7.10.</li><li>6. Results of ground-resistance tests shall be in accordance with Section 7.13.</li><li>7. Accuracy of metering devices shall be in accordance with Section 7.14.</li></ol> <p>* Optional</p> <p><b>NETA</b> Page 27 ANSI/NETA ATS-2017</p>
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## Results of Electrical Tests

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

A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
- \*6. Perform special tests such as air-gap spacing and machine alignment.
- \*7. Manually rotate the rotor and check for problems with the bearings or shaft.
- \*8. Rotate the shaft and measure and record the shaft extension runout.
9. Verify the application of appropriate lubrication and lubrication systems.
10. Verify that resistance temperature detector (RTD) circuits conform to drawings.

B. Electrical Tests – AC Induction

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, in accordance with Section 7.15.1.A.5.1.
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 for 60/30 second periods.

\* Optional

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7. INSPECTION AND TEST PROCEDURES

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

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.A.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.A.5.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.15.1.A.5.3)
5. Air-gap spacing and machine alignment shall be in accordance with manufacturer's published data. (7.15.1.A.6)

D. 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.
  1. The polarization index value shall not be less than 2.0.
  2. The dielectric absorption ratio shall not be less than 1.4.
2. The recommended minimum insulation resistance ( $IR_{min}$ ) test results in megohms shall be in accordance with Table 100.11.
  1. The polarization index value shall not be less than 2.0.
  2. The dielectric absorption ratio shall not be less than 1.4.
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

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## **PREFACE (*Continued*)**

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### **Optional Tests**

The purpose of these specifications is to assure that all tested electrical equipment and systems supplied by either contractor or owner are 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 and calibration 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.

### **Standards Review Council InterNational Electrical Testing Association**

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## **1. GENERAL SCOPE**

1. These specifications cover the suggested field tests and inspections that are available to assess the suitability for initial energization and final acceptance 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, 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 Liquids 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 Liquids Using VDE Electrodes*



## 2. APPLICABLE REFERENCES

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

- |            |                                                                                                                                          |
|------------|------------------------------------------------------------------------------------------------------------------------------------------|
| ASTM D2029 | <i>Standard Test Methods for Water Vapor Content of Electrical Insulating Gases by Measurement of Dew Point</i>                          |
| ASTM D2129 | <i>Standard Test Method for Color of Clear Electrical Insulating Liquids (Platinum-Cobalt Scale)</i>                                     |
| ASTM D2284 | <i>Standard Test Method of Acidity of Sulfur Hexafluoride</i>                                                                            |
| ASTM D2472 | <i>Standard Specification for Sulphur Hexafluoride</i>                                                                                   |
| ASTM D2477 | <i>Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies</i> |
| ASTM D2685 | <i>Standard Test Method for Air and Carbon Tetrafluoride in Sulfur Hexafluoride by Gas Chromatography</i>                                |
| ASTM D2759 | <i>Standard Practice for Sampling Gas from a Transformer under Positive Pressure</i>                                                     |
| ASTM D3284 | <i>Standard Practice for Combustible Gases in the Gas Space of Electrical Apparatus Using Portable Meters</i>                            |
| ASTM D3612 | <i>Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography</i>                           |
| ASTM D4052 | <i>Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter</i>                           |
| ASTM D5837 | <i>Standard Test Method for Furanic Compounds in Electrical Insulating Liquids by High-Performance Liquid Chromatography (HPLC)</i>      |
3. Association of Edison Illuminating Companies - AEIC
  4. Canadian Standards Association - CSA
  5. Electrical Apparatus Service Association - EASA
- |            |                                                                             |
|------------|-----------------------------------------------------------------------------|
| EASA AR100 | <i>Recommended Practice for the Repair of Rotating Electrical Apparatus</i> |
|------------|-----------------------------------------------------------------------------|

## 2. APPLICABLE REFERENCES

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

#### 6. Institute of Electrical and Electronic Engineers - IEEE

IEEE C2	<i>National Electrical Safety Code</i>
IEEE C37 Compilation	<i>Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses</i>
IEEE C57 Compilation	<i>Distribution, Power, and Regulating Transformers</i>
IEEE C62 Compilation	<i>Surge Protection</i>
IEEE C93.1	<i>Requirements for Power-Line Carrier Coupling Capacitors and Coupling Capacitor Voltage Transformers (CCVT)</i>
IEEE 43	<i>IEEE Recommended Practice for Testing Insulation Resistance of Electric Machinery</i>
IEEE 48	<i>IEEE Standard for Test Procedures and Requirements for Alternating- Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV</i>
IEEE 81	<i>IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System</i>
IEEE 95	<i>IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage</i>
IEEE 100	<i>The Authoritative Dictionary of IEEE Standards Terms</i>
IEEE 141	<i>IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants (IEEE Red Book)</i>
IEEE 142	<i>IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)</i>
IEEE 241	<i>IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book)</i>
IEEE 242	<i>IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)</i>

## 2. APPLICABLE REFERENCES

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

IEEE 386	<i>IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems above 600 V</i>
IEEE 399	<i>IEEE Recommended Practice for Power Systems Analysis (Brown Book)</i>
IEEE 400	<i>IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems Rated 5 kV and Above</i>
IEEE 400.1	<i>IEEE Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above with High Direct Current Voltage</i>
IEEE 400.2	<i>IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)(less than 1 Hz)</i>
IEEE 400.3	<i>IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment</i>
IEEE 400.4	<i>IEEE Guide for Field Testing of Shielded Power Cable Systems Rated 5 kV and Above with Damped Alternating Current (DAC) Voltage</i>
IEEE 421.3	<i>IEEE Standard for High-Potential-Test Requirements for Excitation Systems for Synchronous Machines</i>
IEEE 446	<i>IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)</i>
IEEE 450	<i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications</i>
IEEE 493	<i>IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)</i>
IEEE 519	<i>IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems</i>
IEEE 602	<i>IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book)</i>
IEEE 637	<i>IEEE Guide for the Reclamation of Insulating Oil and Criteria for Its Use</i>
IEEE 644	<i>Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines</i>

## 2. APPLICABLE REFERENCES

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

IEEE 739	<i>IEEE Recommended Practice for Energy Management in Commercial and Industrial Facilities (Bronze Book)</i>
IEEE 1015	<i>IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)</i>
IEEE 1100	<i>IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)</i>
IEEE 1106	<i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Batteries for Stationary Applications</i>
IEEE 1159	<i>IEEE Recommended Practice on Monitoring Electrical Power Quality</i>
IEEE 1188	<i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications</i>
IEEE 1584	<i>IEEE Guide for Arc-Flash Hazard Calculations</i>
IEEE 3007.3	<i>Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems</i>

### 7. Insulated Cable Engineers Association – ICEA

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

### 8. InterNational Electrical Testing Association - NETA

ANSI/NETA ECS	<i>Standard for Electrical Commissioning of Electrical Power Equipment and Systems</i>
ANSI/NETA ETT	<i>Standard for Certification of Electrical Testing Technicians</i>
ANSI/NETA MTS	<i>Maintenance Testing Specifications for Electrical Power Equipment and Systems</i>



## 2. APPLICABLE REFERENCES

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

9. National Electrical Manufacturers Association - NEMA

NEMA AB4 *Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications*

NEMA 84.1 *Electrical Power Systems and Equipment Voltage Ratings (60 Hz)*

NEMA MG1 *Motors and Generators*

10. National Fire Protection Association - NFPA

NFPA 70 *National Electrical Code*

NFPA 70B *Recommended Practice for Electric Equipment Maintenance*

NFPA 70E *Standard for Electrical Safety in the Workplace*

NFPA 99 *Health Care Facilities Code*

NFPA 101 *Life Safety Code*

NFPA 110 *Emergency and Standby Power Systems*

NFPA 111 *Standard on Stored Electrical Energy Emergency Systems and Standby Power Systems*

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 References**

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

John L. 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.

### **2.3 Contact Information**

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

Association of Edison Illuminating Companies – AEIC  
600 N. 18<sup>th</sup> Street; PO Box 2641  
Birmingham, AL 35291  
(205) 257-2530  
[www.aeic.org](http://www.aeic.org)

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

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

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

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



## 2. APPLICABLE REFERENCES

### 2.3 Contact Information (*continued*)

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](http://www.netaworld.org)

Megger  
4271 Bronze Way  
Dallas, TX 75237  
(800) 723-2861  
[www.megger.com](http://www.megger.com)

National Electrical Manufacturers Association– NEMA  
1300 N. 17<sup>th</sup> St. Suite 1847  
Rosslyn, VA 22209  
(703) 841-3200  
[www.nema.org](http://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](http://www.nfpa.org)

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

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

Underwriters Laboratories, Inc. – UL  
333 Pfingsten Road  
Northbrook, IL 60062  
(847) 272-8800  
[www.ul.com](http://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, *Standard for Certification of Electrical Testing Technicians*. Each on-site crew leader shall hold a current certification, Level 3 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. Applicable state and local safety operating procedures.
  4. Owner's safety practices.
2. The testing organization shall have a designated safety lead person on site to supervise operations with respect to safety.
3. A job hazard analysis and 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. Device settings.
  5. Test data.
  6. Analysis and recommendations.
2. Test data records shall include the following minimum requirements:
  1. Identification of the testing organization.
  2. Equipment identification.
  3. Nameplate data.
  4. Humidity, temperature, and other conditions that may affect the results of the tests and/or calibrations.
  5. Date of inspections, tests, maintenance, and/or calibrations.
  6. Identification of the testing technician.
  7. Indication of inspections, tests, maintenance, and/or calibrations to be performed and recorded.
  8. Indication of expected results when calibrations are to be performed.
  9. Indication of as-found and as-left results, as applicable.
  10. Identification of all test results outside of specified tolerances.
  11. Sufficient spaces to allow all results and comments to be indicated.
3. The testing organization shall furnish a copy or copies of the complete report as specified in the acceptance testing contract.

## 5. GENERAL

### 5.5 Test Decal

1. The testing organization shall affix a test decal on the exterior of equipment or equipment enclosure of protective devices after performing electrical tests.
2. The test decal shall be color-coded to communicate the condition of maintenance for the protective device. Color scheme for condition of maintenance of overcurrent protective device shall be:
  1. White: electrically and mechanically acceptable.
  2. Yellow: minor deficiency not affecting fault detection and operation, but minor electrical or mechanical condition exists.
  3. Red: deficiency exists affecting performance, not suitable for service.
3. The decal shall include:
  1. Testing organization
  2. Project identifier
  3. Test date
  4. Technician identifier



## 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 current ratings.
4. Tabulations of equipment short-circuit current ratings versus available fault duties. The tabulation shall identify percentage of rated short circuit current and clearly note equipment with insufficient ratings.
5. Conclusions and recommendations.

\* Optional

## 6. POWER SYSTEM STUDIES

### 6.2 Coordination Studies

#### 1. Scope of Study

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

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, selective coordination ratios of fuses, or selective coordination tables of circuit breakers demonstrating the coordination of overcurrent protective devices to the scope.
3. Tabulations of protective devices identifying circuit location, manufacturer, type, range of adjustment, IEEE device number, current transformer ratios, recommended settings or device size, and referenced time-current curve.
4. Conclusions and recommendations.

\* Optional

## 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 in accordance with NFPA 70E, IEEE 1584, OSHA 1910.269, or other applicable 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 arc-flash hazard PPE category for the calculated incident energy level.
10. Calculate the flash protection boundary at each fault location.
11. Document the assessment in reports and one-line diagrams.
- \*12. Fabricate and install appropriate labels on the equipment.

\* Optional

## 6. POWER SYSTEM STUDIES

### 6.3 Arc-Flash Hazard Analysis (*continued*)

#### 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 develop incident-energy levels and arc-flash boundaries.
4. Tabulations of equipment incident energies, arc-flash hazard PPE categories, and arc-flash boundaries. The tabulation shall identify and clearly note equipment that exceeds  $40 \text{ cal/cm}^2$ .
5. List of required arc-flash labels and locations.
6. Conclusions and recommendations.

\* Optional

## 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.

\* Optional

## 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.

\* Optional

## 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.

\* Optional

## **7. INSPECTION AND TEST PROCEDURES**

### **7.1 Switchgear and Switchboard Assemblies**

#### **A. 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. Verify that wiring connections are tight and that wiring is secure to prevent damage during routine operation of moving parts.
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 7.1.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
9. Verify operation and sequencing of interlocking systems.
10. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
11. Inspect insulators for evidence of physical damage or contaminated surfaces.
12. Verify correct barrier and shutter installation and operation.
13. Exercise all active components.
14. Inspect mechanical indicating devices for correct operation.
15. Verify that filters are in place and vents are clear.
16. 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*)

17. Perform visual and mechanical inspection of surge arresters in accordance with Section 7.19.
18. 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 contacts, grounding contacts, and interlocks.

#### B. Electrical Tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.1.A.8.1.
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. Test metering devices in accordance with Section 7.11.
8. Control Power Transformers
  1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with 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. 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 ANSI/NETA ECS.
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.
14. Perform electrical tests of surge arresters in accordance with Section 7.19.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.1 Switchgear and Switchboard Assemblies (*continued*)

#### C. 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.A.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. (7.1.A.8.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.1.A.8.3)

#### D. 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 metering devices shall be in accordance with Section 7.11.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.1 Switchgear and Switchboard Assemblies (*continued*)

#### 8. Control Power Transformers

1. Insulation-resistance values of control power transformers 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.
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
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 ANSI/NETA ECS.
  12. Heaters shall be operational.
  13. Phasing checks shall prove the switchgear or switchboard phasing is correct and in accordance with the system design.
  14. Results of electrical tests on surge arresters shall be in accordance with Section 7.19.

\* 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.

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
7. Verify that as-left tap connections are as specified.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.1.1.A.6.1.
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*)

#### C. 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.A.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.A.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.2.1.1.A.6.3)
4. Tap connections are left as found unless otherwise specified. (7.2.1.1.A.7)

#### D. 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.

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.1.2.A. 8.1.
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. INSPECTION AND TEST PROCEDURES

### 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.

#### C. 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.A.6)
2. Cooling fans shall operate. (7.2.1.2.A.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.A.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.A.8.2)
5. Results of the thermographic survey shall be in accordance with Section 9. (7.2.1.2.A.8.3)
6. Tap connections shall be left as found unless otherwise specified. (7.2.1.2.A.10)

#### D. 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. The following values are typical for insulation power factor tests:
  1.  $C_{HL}$  Power transformers: 2.0 percent or less
  2.  $C_{HL}$  Distribution transformers: 5.0 percent or less
  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. 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

#### A. 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
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.
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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
13. Verify correct liquid level in tanks and bushings.
14. Verify valves are in the correct operating position.
15. Verify that positive pressure is maintained on gas-blanketed transformers.
16. Perform inspections and mechanical tests as recommended by the manufacturer.
17. Test load tap-changer in accordance with Section 7.12.3.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.2.2 Transformers, Liquid-Filled (*continued*)

18. Verify presence of transformer surge arresters.
19. Verify de-energized tap-changer position is left as specified.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter if applicable, in accordance with Section 7.2.2.A.12.1.
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 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. Perform sweep frequency response analysis tests.
8. 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.
- \*9. Perform leakage reactance three phase equivalent and per phase tests.
- \*10. If core ground strap is accessible, remove and measure core insulation resistance at 500 volts dc.
- \*11. Measure the percentage of oxygen in the gas blanket.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.2.2 Transformers, Liquid-Filled (*continued*)

12. 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
  5. Color: ANSI/ASTM D 1500
  6. Visual Condition: ASTM D 1524
  7. Water in insulating liquids: ASTM D 1533.
  - \*8. Power factor or dissipation factor in accordance with ASTM D 924.
13. Remove a sample of insulating liquid in accordance with ASTM D923 and perform dissolved-gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D3612.
14. Test instrument transformers in accordance with Section 7.10.
15. Test surge arresters in accordance with Section 7.19, if present.
16. Test transformer neutral grounding impedance device, if present.
17. Verify operation of cubicle or air terminal compartment space heaters.

### C. 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.A.10)
2. Cooling fans and pumps shall operate. (7.2.2.A.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.A.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.A.12.2)
5. Results of the thermographic survey shall be in accordance with Section 9. (7.2.2.A.12.3)

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.2.2 Transformers, Liquid-Filled (*continued*)

6. Liquid levels in the transformer tanks and bushings shall be within indicated tolerances. (7.2.2.A.13)
7. Positive pressure shall be indicated on pressure gauge for gas-blanketed transformers. (7.2.2.A.15)

#### D. 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.
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. Distribution transformer power factor results shall compare to previously obtained results.
5. Investigate bushing power-factor values that vary from nameplate values by more than 150 percent. Investigate bushing capacitance values that vary from nameplate values by more than five percent. Investigate bushing hot-collar test values that exceed 0.1 Watts.
6. Typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.
7. Sweep frequency response analysis test results should compare to factory and previous test results.
8. Consult the manufacturer if winding-resistance test values vary by more than two percent from factory test values or between adjacent phases.
9. Investigate leakage reactance per phase test results that deviate from the average of the three readings by more than 3%. The three phase equivalent test results serve as a benchmark for future tests.
10. Core insulation values shall be compared to the factory test value but not less than one megohm at 500 volts dc.
11. Investigate the presence of oxygen in the nitrogen gas blanket.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.2.2 Transformers, Liquid-Filled (*continued*)

12. Insulating liquid values shall be in accordance with Table 100.4.
13. Evaluate results of dissolved-gas analysis in accordance with ANSI/IEEE Standard C57.104.
14. Results of electrical tests on instrument transformers shall be in accordance with Section 7.10.
15. Results of surge arrester tests shall be in accordance with Section 7.19.
16. Compare grounding impedance device values to manufacturer's published data.
17. Heaters shall be operational.

\* 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**

#### **A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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.

#### **B. Electrical Tests**

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.3.2.A.3.1.
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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### C. 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.A.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.A.3.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.3.2.A.3.3)

#### D. 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform a thermographic survey in accordance with Section 9.
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.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.3.3.A.3.1.
2. Perform an insulation-resistance test individually on each conductor and each shield 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. INSPECTION AND TEST PROCEDURES

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

4. Perform cable time domain reflectometer (TDR) measurements on each conductor.
5. 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, very low frequency alternating current, or damped alternating current (DAC). 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.

#### 5.1. 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. Damped alternating current (DAC) voltage

#### 5.2. 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. Partial discharge
  1. Online (50/60 Hz)
  2. Off line
    1. Power Frequency (50/60 Hz)
    2. Very low frequency (VLF)

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### C. 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.A.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.A.3.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.3.3.A.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.A.6)

#### D. 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. TDR graphical measurements should clearly identify the cable length and characteristic should be consistent with other phases.
- 5.1 If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the test, the test specimen is considered to have passed the test.
- 5.2 Based on the test methodology chosen, refer to applicable standards or manufacturer's literature for acceptable values.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.4 Metal-Enclosed Busways

#### A. 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.B.
  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.

#### B. 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.A.
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, an ac value shall be used. The test voltage shall be applied for one minute.
4. Measure resistance of assembled busway sections on insulated busway 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.
6. Verify operation of busway space heaters.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.4 Metal-Enclosed Busways (*continued*)

#### C. 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.A.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.A.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.4.A.5.3)

#### D. 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 data or Table 100.1. In the absence of manufacturer's published data, minimum resistance values are for a nominal 1000-foot busway run. Use the following formula to convert the measured resistance value to the 1000-foot nominal value:

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

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

3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand 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

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## 7. INSPECTION AND TEST PROCEDURES

### 7.5.1.1 Switches, Air, Low-Voltage

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.1.1.A.8.1.
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.

#### C. 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.A.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.A.8.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.1.1.A.8.3)

#### D. 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.1.2.A.9.1.
2. Measure contact resistance across each switchblade and fuseholder.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 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.

#### C. 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.A.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.A.9.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.1.2.A.9.3)

#### D. 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. INSPECTION AND TEST PROCEDURES

### 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



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## 7. INSPECTION AND TEST PROCEDURES

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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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. INSPECTION AND TEST PROCEDURES

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

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.1.3.A.11.1.
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.
6. Measure fuse resistance.

#### C. 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.A.11.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.1.3.A.11.3)
4. Operation counter should advance one digit per close-open cycle.(7.5.1.3.A.14)

#### D. 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. INSPECTION AND TEST PROCEDURES

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

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.5.2 Switches, Oil, Medium-Voltage

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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. INSPECTION AND TEST PROCEDURES

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

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.2.A.10.1.
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
7. Measure fuse resistance.

#### C. 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.A.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.A.10.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.2.A.10.3)
4. Operation counter shall advance one digit per close-open cycle. (7.5.2.A.13)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### D. 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.
7. Investigate fuse resistance values that deviate from each other by more than 15 percent.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.5.3 Switches, Vacuum, Medium-Voltage

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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*)

#### B. Electrical Tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. See Section 7.5.3.A.11.1.
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 magnetron atmospheric condition (MAC) test on each vacuum interrupter.
5. 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.
6. 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
- \*7. 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.
8. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
9. Verify open and close operation from control devices, if applicable.
10. Measure fuse resistance.

#### C. Test Values – Visual and Mechanical

1. Critical distances of the operating mechanism shall be in accordance with manufacturer's published data. (7.5.3.A.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.A.11.1)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.5.3 Switches, Vacuum, Medium-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. (7.5.3.A.11.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.5.3.A.11.3)
5. Operation counter shall advance one digit per close-open cycle. (7.5.3.A.14)

#### D. 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. Evaluate each vacuum interrupter in accordance with test equipment manufacturer's instructions.
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 test specimen is considered to have passed the test.
6. Insulating liquid test results shall be in accordance with Table 100.4.
7. Insulation-resistance values of control wiring shall not be less than two megohms.
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 test specimen is considered to have passed the test.
9. Results of open and close operation from control devices shall be in accordance with system design.
10. Investigate fuse resistance values that deviate from each other by more than 15 percent.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.5.4 Switches, SF<sub>6</sub>, Medium-Voltage

#### A. 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<sub>6</sub> gas insulated system in accordance with the manufacturer's published data.
6. Verify correct operation of SF<sub>6</sub> 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.B.1.
  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<sub>6</sub> 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<sub>6</sub>, Medium-Voltage (*continued*)

#### B. Electrical Tests

1. Perform resistance measurements through accessible bolted electrical connections with a low-resistance ohmmeter, if applicable. See Section 7.5.4.A.11.1.
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<sub>6</sub> 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.
9. Measure fuse resistance.

#### C. Test Values – Visual and Mechanical

1. Critical distances of operating mechanism shall be in accordance with manufacturer's published data. (7.5.4.A.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.A.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.A.11.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.5.4.A.11.3)
5. Operation counter shall advance one digit per close-open cycle. (7.5.4.A.14)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.5.4 Switches, SF<sub>6</sub>, Medium-Voltage (*continued*)

#### D. 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<sub>6</sub> 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.
9. Investigate fuse resistance values that deviate from each other by more than 15 percent.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.5.5 Switches, Cutouts

#### A. 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.B.1.
  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.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.5.A.8.1.
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.
5. Measure fuse resistance.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.5.5 Switches, Cutouts (*continued*)

#### C. 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.A.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.A.8.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.5.A.8.3)

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

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.1.1.A.6.1.
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. INSPECTION AND TEST PROCEDURES

### 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.

#### C. 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.A.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.A.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.6.1.1.A.6.3)
4. Settings shall comply with coordination study recommendations. (7.6.1.1.A.8)

#### D. 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. INSPECTION AND TEST PROCEDURES

### 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, Low-Voltage Power

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform a thermographic survey in accordance with Section 9.
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. INSPECTION AND TEST PROCEDURES

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

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.1.2.A.10.1.
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.

#### C. 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.A.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.A.10.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.6.1.2.A.10.3)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

4. Settings shall comply with coordination study recommendations. (7.6.1.2.A.14)
5. Operations counter shall advance one digit per close-open cycle. (7.6.1.2.A.15)

#### D. 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.
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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform a thermographic survey in accordance with Section 9.
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 contact-timing test.
- \*16. Perform mechanism-motion analysis.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

- \*17. Perform trip/close coil current signature analysis.
- 18. Record as-found and as-left operation-counter readings.

#### B. Electrical Tests

- 1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. See Section 7.6.1.3.A.10.1.
- 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 heaters.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

12. Test instrument transformers in accordance with Section 7.10.

#### C. Test Values – Visual and Mechanical

1. Mechanical operation and contact alignment shall be in accordance with manufacturer's published data. (7.6.1.3.A.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.A.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.A.10.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.6.1.3.A.10.3)
5. Contact timing values shall be in accordance with manufacturer's published data. (7.6.1.3.A.15).
6. Travel and velocity values shall be in accordance with manufacturer's published data. (7.6.1.3.A.16)
7. Trip/close coil current values shall be in accordance with manufacturer's published data. (7.6.1.3.A.17).
6. Operations counter shall advance one digit per close-open cycle. (7.6.1.3.A.18)

#### D. 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

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 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### A. 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. INSPECTION AND TEST PROCEDURES

### 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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 contact-timing test.
16. Perform mechanism-motion analysis.
- \*17. Perform trip/close coil current signature analysis.
18. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
19. Record as-found and as-left operation counter readings.

#### **B. Electrical Tests**

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.2.A.12.1
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with circuit-breaker closed, and across each open pole. 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 static contact/pole resistance test.
- \*4. Perform a dynamic contact/pole resistance test.
- \*5. 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*)

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. Power factor: ASTM D 924
  4. Interfacial tension: ASTM D 971
  5. Visual condition: ASTM D 1524
  6. Neutralization number (acidity): ASTM D974
  7. Water content: ASTM D1533
7. Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer's published data.
8. Verify correct operation of any auxiliary features such as electrical close and trip operation, trip-free, antipump function.
9. Trip circuit breaker by operation of each protective device. Reset all trip logs and indicators.
10. Perform power-factor or dissipation-factor tests on each pole with breaker open and each phase with breaker closed. Determine tank loss index.
11. 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.
- \*12. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
13. Verify operation of heaters.
14. Test instrument transformers in accordance with Section 7.10.

### C. 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.A.9)

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

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.A.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. (7.6.2.A.12.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.6.2.A.12.3)
5. Contact timing values shall be in accordance with manufacturer's published data. (7.6.2.A.15).
6. Travel and velocity values shall be in accordance with manufacturer's published data. (7.6.2.A.16)
7. Trip/close coil current values shall be in accordance with manufacturer's published data. (7.6.2.A.17).
8. Operations counter shall advance one digit per close-open cycle. (7.6.2.A.19)

#### D. 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. Dynamic contact resistance values shall be in accordance with manufacturer's published data.
5. Insulation-resistance values of control wiring shall not be less than two megohms.
6. Insulating liquid test results shall be in accordance with Table 100.4.
7. 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.
8. Auxiliary features shall operate in accordance with manufacturer's published data.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

9. Protective devices shall operate the breaker per system design.
10. 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.
11. 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 milliamperere/milliwatt loss basis, and the results should be compared to values of similar bushings.
12. 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.
13. Heaters shall be operational.
14. Results of electrical tests on instrument transformers shall be in accordance with Section 7.10.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.6.3 Circuit Breakers, Vacuum, Medium-Voltage

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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 contact-timing test.
- \*13. Perform trip/close coil current signature analysis.
- \*14. Perform mechanism motion analysis.
15. Record as-found and as-left operation counter readings.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.3.A.8.1.
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 static contact/pole-resistance test.
- \*5. Perform dynamic contact/pole resistance test.
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, and 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 the breaker open and each phase with the breaker 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.
- \*11. Perform magnetron atmospheric condition (MAC) test on each vacuum interrupter.
12. 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.
13. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
14. Verify operation of heaters.
15. Test instrument transformers in accordance with Section 7.10.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### C. 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.A.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.A.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.A.8.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.6.3.A.8.3)
5. Contact timing values shall be in accordance with manufacturer's published data. (7.6.3.A.12)
6. Trip/close coil current values shall be in accordance with manufacturer's published data. (7.6.3.A.13)
7. Travel and velocity values shall be in accordance with manufacturer's published data. (7.6.3.A.14)
8. Operation counter shall advance one digit per close-open cycle. (7.6.3.A.15)

#### D. 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. Dynamic contact resistance values shall be in accordance with manufacturer's published data.
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. INSPECTION AND TEST PROCEDURES

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

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 shall be compared to manufacturer's published data. In the absence of manufacturer's published data the comparison shall be made to similar breakers.
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 milliamperere/milliwatt loss basis, and the results should be compared to values of similar bushings.
- \*11. Evaluate each vacuum interrupter in accordance with test equipment manufacturer's instructions.
12. 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.
13. 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.
14. Heaters shall be operational.
15. 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<sub>6</sub>

#### A. 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<sub>6</sub> 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<sub>6</sub> gas-insulated system in accordance with manufacturer’s published data.
8. Test for SF<sub>6</sub> gas leaks in accordance with manufacturer’s published data.
9. Verify correct operation of alarms and pressure-limit switches for pneumatic, hydraulic, and SF<sub>6</sub> 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
  3. Perform a thermographic survey in accordance with Section 9.
13. Verify the appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
14. Perform contact-timing test.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.6.4 Circuit Breakers, SF<sub>6</sub> (continued)

- \*15. Perform trip/close coil signature analysis.
- 16. Perform mechanism motion analysis.
- 17. Record as-found and as-left operation counter readings.

#### B. Electrical Tests

- 1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.4.A.12.1.
- 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 cannot 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.6.4 Circuit Breakers, SF<sub>6</sub> (continued)

#### C. Test Values – Visual and Mechanical

1. SF<sub>6</sub> gas shall have values in accordance with Table 100.13. (7.6.4.A.6)
2. Results of the SF<sub>6</sub> gas leak test shall confirm that no SF<sub>6</sub> gas leak exists. (7.6.4.A.8)
3. Settings for alarm, pressure, and limit switches shall be in accordance with manufacturer's published data. (7.6.4.A.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.A.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.A.12.2)
6. Results of the thermographic survey shall be in accordance with Section 9. (7.6.4.A.12.3)
7. Contact timing values shall be in accordance with manufacturer's published data. (7.6.4.A.14)
8. Trip/close coil current values shall be in accordance with manufacturer's published data (7.6.4.A.15)
9. Travel and velocity values shall be in accordance with manufacturer's published data. (7.6.4.A.16)
10. Operations counter shall advance one digit per close-open cycle. (7.6.4.A.17)

#### D. 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.6.4 Circuit Breakers, SF<sub>6</sub> (*continued*)

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.
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 milliamperere/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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
7. Verify operation of SF<sub>6</sub> interrupters is in accordance with manufacturer's published data.
8. Verify SF<sub>6</sub> 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.

#### B. Electrical Tests

1. Perform resistance measurements through all connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.7.A.6.
2. Perform contact-resistance test of interrupters and isolating switches.
3. Perform insulation-resistance tests on each pole phase-to-ground.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.7 Circuit Switchers (*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. 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.

### C. 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.A.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.A.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.7.A.6.3)
4. SF<sub>6</sub> interrupters shall operate in accordance with manufacturer's published data. (7.7.A.7)
5. SF<sub>6</sub> pressure shall be in accordance with manufacturer's published data. (7.7.A.8)
6. Isolating switch shall operate in accordance with system and manufacturer's design. (7.7.A.9)
7. Interlocking systems shall operate in accordance with system and manufacturer's design. (7.7.A.10)
8. Operation counter shall advance one digit per close-open cycle. (7.7.A.12)

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.7 Circuit Switchers (*continued*)

#### D. 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. INSPECTION AND TEST PROCEDURES**

### **7.8 Network Protectors, 600-Volt Class**

#### **A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.8.A.10.1.
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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### C. 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.A.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. (7.8.A.10.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.8.A.10.3)
4. Operations counter shall advance one digit per close-open cycle. (7.8.A.14)

#### D. 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 75 percent of rated control circuit voltage.
10. Results of network protector relay calibrations shall be in accordance with Section 7.9.

\* Optional

## **7. INSPECTION AND TEST PROCEDURES**

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

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



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## 7. INSPECTION AND TEST PROCEDURES

### 7.9.1 Protective Relays, Electromechanical and Solid-State

#### A. 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. Inspect the unit.
  1. Relay Case
    1. Tighten case connections.
    2. Inspect cover for correct gasket seal.
    3. Inspect shorting hardware, connection paddles, and knife switches.
    4. Remove any foreign material from the case.
    5. Verify target reset.
    6. Clean cover glass.
  2. 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.
    4. Inspect disk and contacts for freedom of movement and correct travel.
    5. Verify tightness of mounting hardware and connections.
    6. Burnish contacts.
    7. Inspect bearings and pivots.
5. Verify that all settings are in accordance with coordination study or setting sheet supplied by owner.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### B. 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. Test targets and indicators.
  1. Determine pickup and dropout of electromechanical targets.
  2. Verify operation of all light-emitting diode indicators.
  3. Set contrast for liquid-crystal display readouts.
3. Protection Elements
  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 and directional characteristic.
    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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

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. Determine advanced closing angle.
  6. 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
  1. Determine minimum pickup at maximum torque angle.
  2. Determine tripping 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

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).
  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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

13. 50 Instantaneous Overcurrent Relay
  1. Determine pickup.
  2. Determine dropout.
  3. Determine time delay.
14. 50BF Breaker Failure
  1. Determine current supervision pickup.
  2. Determine time delays.
  3. Test all inputs and outputs.
15. 51 Time Overcurrent
  1. Determine minimum pickup.
  2. Determine time delay at two points on the time current curve.
16. 55 Power Factor Relay
  1. Determine tripping angle.
  2. Determine time delay.
17. 59 Overvoltage Relay
  1. Determine overvoltage pickup.
  2. Determine time delay to close the contact with sudden application of 120 percent of pickup.
18. 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

19. 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.
20. 64 Ground Detector Relay
  1. Determine maximum impedance to ground causing relay pickup.
21. 67 Directional Overcurrent Relay
  1. Determine directional unit minimum pickup at maximum torque angle.
  2. Determine tripping 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.
22. 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.
23. 81 Frequency Relay
  1. Verify frequency set points.
  2. Determine time delay.
  3. Determine undervoltage cutoff.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

- 24. 85 Pilot Wire Monitor
  - 1. Determine overcurrent pickup.
  - 2. Determine undercurrent pickup.
  - 3. Determine pilot wire ground pickup level.

- 25. 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/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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### C. Test Values – Visual and Mechanical

1. Relay Case
  1. Case connections shall be torqued in accordance with manufacturer's published data. (7.9.1.A.4.1.1)
  2. Cover gasket shall be intact and able to prevent foreign matter from entering the case. (7.9.1.A.4.1.2)
  3. Cover glass, connection paddles, and/or knife switches shall be clean. (7.9.1.A.4.1.3)
  4. Case shall be free of foreign material. (7.9.1.A.4.1.4)
  5. The target reset shall be operational. (7.9.1.A.4.1.5)
2. Relay
  1. Relay shall be free of foreign material. (7.9.1.A.4.2.1)
  2. Relay disc clearance, contact clearance, and spring bias shall operate in accordance with manufacturer's published data. (7.9.1.A.4.2.2)
  3. Relay spiral spring shall be concentric. (7.9.1.A.4.2.3)
  4. Relay discs and contacts shall have freedom of movement and correct travel distance in accordance with manufacturer's published data. (7.9.1.A.4.2.4)
  5. Mounting hardware and connections shall be tightened to the manufacturer's recommended torque values. (7.9.1.A.4.2.5)
  6. Contacts shall be clean and make good contact with each other. (7.9.1.A.4.2.6)
  7. Bearings and pivots shall have clean and fluid movement. (7.9.1.A.4.2.7)
3. Relay settings shall match the coordination study or setting sheet supplied by owner. (7.9.1.A.5)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### D. Test Values – Electrical

1. Insulation-resistance values shall be in accordance with manufacturer's published data. Values of insulation resistance less than the manufacturer's recommendations shall be investigated.
2. Targets and Indicators
  1. Pickup and dropout of electromechanical targets shall be in accordance with manufacturer's published data.
  2. Light-emitting diodes shall illuminate.
3. Operation of protection elements for devices listed in Section 7.9.1.B, one through 25, shall be calibrated using manufacturer's recommended tolerances unless critical test points are specified by the setting engineer.
4. Control Verification
  1. Control verification outputs and protection schemes, as listed in Section 7.9.1.B.4, shall operate as per the design. Results shall be within the manufacturer's published tolerances.
  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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.9.2 Protective Relays, Microprocessor-Based

#### A. 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 engineered setting file and coordination study.
8. Download settings and logic from the relay and compare the settings to those specified in the coordination study or setting sheet supplied by owner.
9. Connect backup battery.
10. Set clock if not controlled externally and verify relay displays the correct date and time.
11. Check with setting engineer for applicable firmware updates and product recalls.
12. Inspect, clean, and verify operation of shorting devices.

#### B. 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. Verify SCADA metering values at remote terminals.
4. Protection Elements

Check functional operation of each element used in the protection scheme as described for electromechanical and solid-state relays in 7.9.1.B.3. When not otherwise specified, use manufacturer's recommended tolerances.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### 5. Control Verification

1. Check operation of all active digital inputs.
2. Check all output contacts or SCRs, preferably by operating the controlled device such as circuit breaker, auxiliary relay, or alarm.
3. Check all internal logic functions used in the protection scheme.
4. For pilot schemes, perform a loop-back test to check the receive and transmit communication circuits.
5. Upon completion of testing, reset all min/max records and fault counters. Delete sequence-of-events records and all event records.
6. Verify trip and close coil monitoring functions.
7. Verify setting change alarm to SCADA.
8. Verify relay SCADA communication and indications such as protection operate, protection fail, communication fail, fault recorder trigger.
9. Verify all communication links are operational.

#### C. Test Values – Visual and Mechanical

1. Light-emitting diodes, displays, and targets should illuminate. (7.9.2.A.2)
2. Relay should be clean and operational. (7.9.2.A.4)
3. Settings and logic should agree with the most recent engineered setting files. (7.9.2.A.8)
4. Verify relay displays the correct date and time. (7.9.2.A.10)

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### D. Test Values – Electrical

1. Insulation-resistance values should be in accordance with manufacturer's published data. Values of insulation resistance less than manufacturer's recommendations should be investigated.
2. Voltage and current analog readings should be in accordance with manufacturer's published tolerances.
3. SCADA readings should be within the manufacturer's published tolerances.
4. Operation of protection elements for devices as listed in 7.9.1.B, items 1 through 25, should be operational and within manufacturer's recommended tolerances.
5. Control verification inputs, outputs, and protection schemes, as listed in 7.9.2.B.5, items 1 through 9, should operate as per the design. Results should be within the manufacturer's published tolerances.

\* Optional



## **7. INSPECTION AND TEST PROCEDURES**

### **7.10.1 Instrument Transformers, Current Transformers**

#### **A. 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 7.10.1.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
7. Verify that all required grounding and shorting connections provide contact.
8. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

#### **B. 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.A.6.1.
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.
6. Measure current circuit burdens at transformer terminals in accordance with ANSI/IEEE C57.13.1.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.10.1 Instrument Transformers, Current Transformers (*continued*)

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. 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 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.

#### C. 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.A.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.A.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.10.1.A.6.3)

#### D. 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 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 IEEE C57.13.
5. Excitation results shall match the curve supplied by the manufacturer or be in accordance with IEEE 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.10.1 Instrument Transformers, Current Transformers (*continued*)

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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.10.2 Instrument Transformers, Voltage Transformers

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
7. Verify that all required grounding and connections provide contact.
8. Verify correct primary and secondary fuse sizes for voltage transformers.
9. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
10. Perform as-left tests.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.2.A.6.1.
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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.10.2 Instrument Transformers, Voltage Transformers (*continued*)

- \*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 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.

#### C. 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. (7.10.2.A.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. (7.10.2.A.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.10.2.A.6.3)

#### D. 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 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 IEEE 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 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.

\* Optional





## 7. INSPECTION AND TEST PROCEDURES

### 7.10.3 Instrument Transformers, Coupling-Capacitor Voltage Transformers

#### A. 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 7.10.3.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
7. Verify that all required grounding and connections provide contact.
8. Verify correct primary and secondary fuse sizes for voltage transformers.
9. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
10. Perform as-left tests.

#### B. Electrical Tests

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 ratio test on all tap positions.
5. Measure voltage circuit burdens at transformer terminals.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.10.3 Instrument Transformers, Coupling-Capacitor Voltage Transformers (*continued*)

- \*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.

#### C. 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. (7.10.3.A.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. (7.10.3.A.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.10.3.A.6.3)

#### D. 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.10.3 Instrument Transformers, Coupling-Capacitor Voltage Transformers (*continued*)

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.

\* Optional



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## 7. INSPECTION AND TEST PROCEDURES

### 7.10.4 Instrument Transformers, High-Accuracy Instrument Transformers

— RESERVED —

\* Optional

## **7. INSPECTION AND TEST PROCEDURES**

### **7.11.1 Metering Devices, Electromechanical and Solid-State**

#### **A. Visual and Mechanical Inspection**

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Verify tightness of electrical connections.
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).

#### **B. Electrical Tests**

1. Verify accuracy of meters at all cardinal points.
2. Calibrate meters in accordance with manufacturer's published data.
3. Verify all instrument multipliers.
4. Verify that current transformer and voltage transformer secondary circuits are intact.

#### **C. Test Values – Visual and Mechanical**

1. Tightness of electrical connections shall assure a low-resistance connection. (7.11.1.A.3)

#### **D. Test Values - Electrical**

1. Meter accuracy shall be in accordance with manufacturer's published data.
2. Calibration results shall be within manufacturer's published tolerances.
3. Instrument multipliers shall be in accordance with system design specifications.
4. Test results shall confirm the integrity of the secondary circuits of current and voltage transformers.

\* Optional

## **7. INSPECTION AND TEST PROCEDURES**

### **7.11.2 Metering Devices, Microprocessor-Based**

#### **A. 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.
4. Verify 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.

#### **B. 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. INSPECTION AND TEST PROCEDURES

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

#### C. Test Values – Visual and Mechanical

1. Nameplate data shall be per drawings and specifications. (7.11.2.A.1)
2. Tightness of electrical connections shall assure a low resistance connection. (7.11.2.A.4)
3. Display and indicating devices shall operate per manufacturer's published data. (7.11.2.A.6)

#### D. 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.12.1.1.A.8.1.
2. Perform insulation-resistance tests on each winding-to-ground in any off-neutral position. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.
3. Perform insulation power-factor or dissipation-factor tests on windings in accordance with test equipment manufacturer's published data.

\* Optional





## 7. INSPECTION AND TEST PROCEDURES

### 7.12.1.1 Regulating Apparatus, Voltage, Step Voltage 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. 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. Sample insulating liquid in the main tank and tap-changer tank or common tank in accordance with ASTM D923 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
  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 in insulating liquids: ASTM D 1533

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

13. If the regulator has a separate tap-changer compartment, 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. Verify operation of heaters.

#### C. Test Values – Visual and Mechanical

1. Auxiliary devices should operate in accordance with system design. (7.12.1.1.A.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.A.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.A.8.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.12.1.1.A.8.3)
5. Motor, drive train, and automatic cutoff should operate in accordance with manufacturer's design. (7.12.1.1.A.9)
6. Liquid level in tanks and bushings should be within indicated tolerances. (7.12.1.1.A.10)
7. The operation counter shall move incrementally for each operation performed. (7.12.1.1.A.13)

#### D. Test Values – Electrical

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

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.12.1.1 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 the manufacturer if winding-resistance test values vary by more than two percent from factory test values or between adjacent phases.
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 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. Heaters shall be operational.

\* Optional

## **7. INSPECTION AND TEST PROCEDURES**

### **7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators**

**— WITHDRAWN —**

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.12.2 Regulating Apparatus, Current

— RESERVED —

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.12.3 Regulating Apparatus, Load Tap-Changers

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.12.3.A.7.1.
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. INSPECTION AND TEST PROCEDURES

### 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 D923 and perform dissolved gas analysis in accordance with ANSI/IEEE C57.104 or ASTM D 3612.
- \*9. Perform magnetron atmospheric condition (MAC) test on each vacuum interrupter.
- \*10. 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.
11. Verify operation of heaters.

### C. 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.A.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.A.7.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.12.3.A.7.3)
4. Auxiliary device operation shall be in accordance with design intent. (7.12.3.A.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.A.9)
6. Liquid level in tanks shall be within indicated tolerances. (7.12.3.A.10)
7. Operation counter shall have had an incremental change in accordance with tap-changer operation. (7.12.3.A.13)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### D. 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.
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. Evaluate each vacuum interrupter in accordance with test equipment manufacturer's instructions.
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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.13 Grounding Systems

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
4. Inspect anchorage.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with section 7.13.A.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.

#### C. Test Values – Visual and Mechanical

1. Grounding system electrical and mechanical connections shall be free of corrosion. (7.13.A.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.A.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.A.3.2)

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.13 Grounding Systems (*continued*)

#### D. 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. The resistance between the main grounding electrode and ground shall be no greater than five ohms for large commercial or industrial systems and one 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
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.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.14.A.4.1.
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. INSPECTION AND TEST PROCEDURES

### 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.

#### C. 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.A.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.A.4.2)

#### D. 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.
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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

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



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## 7. INSPECTION AND TEST PROCEDURES

### 7.15.1 Rotating Machinery, AC Induction Motors and Generators

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
- \*6. Perform special tests such as air-gap spacing and machine alignment.
- \*7. Manually rotate the rotor and check for problems with the bearings or shaft.
- \*8. Rotate the shaft and measure and record the shaft extension runout.
9. Verify the application of appropriate lubrication and lubrication systems.
10. Verify that resistance temperature detector (RTD) circuits conform to drawings.

#### B. Electrical Tests – AC Induction

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, in accordance with Section 7.15.1.A.5.1.
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 for 60/30 second periods.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

3. On machines rated at 2300 volts and greater, perform dielectric withstand voltage tests in accordance with:
  1. ANSI/IEEE Standard 95 for dc dielectric withstand voltage tests.
  2. NEMA MG1 for ac dielectric withstand voltage tests.
4. Perform phase-to-phase stator resistance test on machines 2300 volts and greater.
- \*5. Perform insulation power-factor or dissipation-factor tests.
- \*6. Perform power-factor or dissipation-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 while machine is running under load.

### C. Test Values – Visual and Mechanical

1. Inspection (7.15.A.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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

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.A.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.A.5.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.15.1.A.5.3)
5. Air-gap spacing and machine alignment shall be in accordance with manufacturer's published data. (7.15.1.A.6)

#### D. 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 recommended minimum insulation resistance ( $IR_{1 \text{ min}}$ ) test results in megohms shall be in accordance with Table 100.11.
  1. The polarization index value shall not be less than 2.0.
  2. The dielectric absorption ratio shall not be less than 1.4.
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. INSPECTION AND TEST PROCEDURES

### 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 be in accordance with manufacturer's published data. In the absence of manufacturer's published data, vibration amplitudes 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
6. Perform special tests such as air-gap spacing and machine alignment.
7. Manually rotate the rotor and check for problems with the bearings or shaft.
8. Rotate the shaft and measure and record the shaft extension runout.
9. Verify the application of appropriate lubrication and lubrication systems.
10. Verify that resistance temperature detector (RTD) circuits conform to drawings.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.15.2.A.5.1.
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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

3. On machines rated at 2300 volts and greater perform dielectric withstand voltage tests in accordance with:
  1. ANSI/IEEE Standard 95 for dc dielectric withstand voltage tests.
  2. NEMA MG1 for ac dielectric withstand voltage tests.
4. Perform phase-to-phase stator resistance test on machines 2300 volts and greater.
- \*5. Perform insulation power-factor or dissipation-factor tests.
- \*6. Perform power-factor or dissipation-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 while machine is running under load.
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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

- \*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.
  - 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.

#### C. Test Values – Visual and Mechanical

- 1. Inspection (7.15.2.A.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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

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.A.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.A.5.2)
4. Results of thermographic survey shall be in accordance with Section 9. (7.15.2.A.5.3)
5. Air-gap spacing and machine alignment shall be in accordance with manufacturer's published data. (7.15.2.A.6)

#### D. 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 recommended minimum insulation resistance ( $IR_{1 \text{ min}}$ ) test results in megohms shall be in accordance with Table 100.11.
  1. The polarization index value shall not be less than 2.0.
  2. The dielectric absorption ratio shall not be less than 1.4.
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 or dissipation 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. INSPECTION AND TEST PROCEDURES

### 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 be in accordance with manufacturer's published data. In the absence of manufacturer's published data, vibration amplitudes 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 ( $IR_{1 \text{ min}}$ ) test results in megohms shall be in accordance with Table 100.11.
15. The individual pole-pole ac voltage drop shall not exceed 10 percent variance from the average value (average value = test voltage divided by number of coils) applicable to all of the 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.
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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
6. Inspect commutator and tachometer generator.
- \*7. Perform special tests such as air-gap spacing, bar tightness of commutator, and machine alignment, if applicable.
- \*8. If the rotor can be manually rotated, check for any obvious problems with the bearings or shaft.
- \*9. If the motor shaft can be rotated, measure and record the shaft extension runout.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.15.3.A.5.1.
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 for 60/30 second periods.
3. Perform ac or dc high-potential test in accordance with NEMA MG 1, Section 3.1, or IEEE 95, respectively, on the field windings, armature, interpoles and compensating windings (if applicable), and commutator.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

- \*4. Perform an ac or dc voltage-drop test on all field poles.
- \*5. Perform a surge (impulse) comparison test on the field and armature winding.
6. Perform armature commutator bar-to-bar resistance test.
7. If the motor has both shunt and series field windings, their relative polarity is to be checked and the leads are to be marked appropriately.
8. Measure armature running current and field current or voltage. Compare to nameplate.
- \*9. Perform vibration tests while machine is running under load.
10. Verify that all protective devices are in accordance with Section 7.16.

### C. Test Values – Visual and Mechanical

1. Inspection (7.15.3.A.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. Commutator runout 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.A.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.A.5.2)
4. Results of thermographic survey shall be in accordance with Section 9. (7.15.3.A.5.3)
5. Commutator and tachometer generator shall be in accordance with manufacturer's published data and system design. (7.15.3.A.6)
6. Air-gap spacing and machine alignment shall be in accordance with manufacturer's published data. (7.15.3.A.7)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### D. 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 recommended minimum insulation resistance (IR 1 min) test results in megohms shall be in accordance with Table 100.11.
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 individual pole-to-pole ac voltage drop shall not exceed ten percent variance from the average value (average value = test voltage divided by number of coils) applicable to all of the 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.
8. Investigate bar-to-bar resistance values of armature that deviate by more than five percent.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.16.1.1 Motor Control, Motor Starters, Low-Voltage

#### A. 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/motor protection settings are correct for 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
8. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.16.1.1.A.7.1.
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. INSPECTION AND TEST PROCEDURES

### 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.

#### C. 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.A.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.A.7.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.16.1.1.A.7.3)

#### D. 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. 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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. INSPECTION AND TEST PROCEDURES

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

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.16.1.2.A.5.1.
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 magnetron atmospheric condition (MAC) test on each vacuum interrupter.
- \*5. 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.
6. 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.
7. Perform contact resistance tests.
8. Measure blowout coil circuit resistance.
9. Measure resistance of power fuses.
10. Energize contactor using an auxiliary source. Adjust armature to minimize operating vibration where applicable.
11. Test control power transformers in accordance with Section 7.1.
12. Test starting transformers, if applicable, in accordance with Section 7.2.1.
13. Test starting reactors, if applicable, in accordance with 7.20.3.
14. Test motor protection devices in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Section 7.9.
- \*15. Perform system function test in accordance with ANSI/NETA ECS.
16. Verify operation of cubicle space heater.
17. Test instrument transformers in accordance with Section 7.10.
18. Test metering devices in accordance with Section 7.11.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### C. 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.A.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.A.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.16.1.2.A.5.3)
4. Electrical and mechanical interlocks shall operate in accordance with system design. (7.16.1.2.A.6)
5. Barrier and shutter installation and operation shall be in accordance with manufacturer's design. (7.16.1.2.A.7)
6. Indicating devices shall operate in accordance with system design. (7.16.1.2.A.8)

#### D. 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. Insulation-resistance values of control wiring shall not be less than two megohms.
4. Evaluate each vacuum interrupter in accordance with test equipment manufacturer's instructions.
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. 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.
7. 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

8. Resistance values of blowout coils shall be in accordance with manufacturer's published data.
9. Resistance values shall not deviate by more than 15 percent between identical fuses.
10. Contactor coil shall operate with minimal vibration and noise.
11. Control power transformer test results shall be in accordance with Section 7.1.2.8.
12. Starting transformer test results shall be in accordance with Section 7.2.1.
13. Starting reactor test results shall be in accordance with Section 7.20.3.
14. Motor protection parameters shall be in accordance with manufacturer's published data.
15. System function test results shall be in accordance with manufacturer's published data and system design.
16. Heaters shall be operational.
17. Instrument transformer test results shall be in accordance with Section 7.10.
18. Metering device test results shall be in accordance with Section 7.11.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.16.2.1 Motor Control, Motor Control Centers, Low-Voltage

1. Refer to Section 7.1 for appropriate inspections and tests of the motor control center bus.
2. Refer to Section 7.5.1.1 for appropriate inspections and tests of the motor control center switches.
3. Refer to Section 7.6.1.1 and 7.6.1.2 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

### 7.16.2.2 Motor Control, Motor Control Centers, Medium-Voltage

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

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.17 Adjustable Speed Drive Systems

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
9. Verify correct fuse sizing in accordance with manufacturer's published data.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.17.A.8.1.
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. INSPECTION AND TEST PROCEDURES

### 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 7.9.1.3.10)
  2. Input overvoltage protection (Section 7.9.1.3.16)
  3. Output phase rotation (Section 7.9.1.3.10)
  4. Overtemperature protection (Section 7.9.1.3.11)
  5. DC overvoltage protection (Section 7.9.1.3.16)
  6. Overfrequency protection (Section 7.9.1.3.22)
  7. Drive overload protection (Section 7.9.1.3.14 or 7.6.1.1)
  8. Fault alarm outputs (Section 7.9.1.4)
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.
9. Measure fuse resistance.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.17 Adjustable Speed Drive Systems *(continued)*

#### C. 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.A.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.A.8.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.17.A.8.3)

#### D. 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.
9. Investigate fuse resistance values that deviate from each other by more than 15 percent.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.

#### B. 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.A.12.1.
2. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended settings.
3. Verify all charger functions and alarms.
4. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

5. Measure intercell connection resistances.
6. Perform internal ohmic measurement tests.
7. Perform a load test in accordance with manufacturer's published data or ANSI/IEEE 450.
8. Measure the battery system voltage from positive-to-ground and negative-to-ground.

#### C. Test Values – Visual and Mechanical

1. Electrolyte level and specific gravity shall be within normal limits. (7.18.1.1.A.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.A.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.A.12.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.1.A.12.3)

#### D. 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. INSPECTION AND TEST PROCEDURES

### 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.

\* Optional



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## 7. INSPECTION AND TEST PROCEDURES

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

#### A. 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, battery spill containment system, 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.

#### B. 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.A.10.1.
2. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended settings.
3. Verify all charger functions and alarms.
4. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.
5. Measure intercell connection resistances.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

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

#### C. Test Values – Visual and Mechanical

1. Electrolyte level shall be within normal limits. (7.18.1.2.A.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.A.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.A.10.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.2.A.10.3)

#### D. 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.
8. Voltage measured from positive to ground shall be equal in magnitude to the voltage measured from negative to ground.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.

#### B. 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.A.9.1.
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. INSPECTION AND TEST PROCEDURES

### 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.
9. Measure the battery system voltage from positive to ground and negative to ground.

#### C. 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.A.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.A.9.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.3.A.9.3)

#### D. 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.
9. Voltage measured from positive to ground shall be similar in magnitude to the voltage measured from negative to ground.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.18.2 Direct-Current Systems, Chargers

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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.

#### B. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.18.2.A.5.1.
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. INSPECTION AND TEST PROCEDURES

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

#### C. 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.A.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.A.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.18.2.A.5.3)

#### D. 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.19.1.A.5.1
2. Perform an insulation-resistance test on each arrester, phase terminal-to-ground. Apply voltage in accordance with manufacturer's published data.
3. Test grounding connection in accordance with Section 7.13.

#### C. 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.A.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.A.5.2)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.19.1 Surge Arresters, Low-Voltage (*continued*)

#### D. 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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.19.2 Surge Arresters, Medium- and High-Voltage

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
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 present.
8. Record the stroke counter reading.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.19.2.A.5.1.
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.

#### C. 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.A.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.A.5.2)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.19.2 Surge Arresters, Medium- and High-Voltage (*continued*)

#### D. 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. See Section 7.20.1.A.6.1.
2. Perform insulation-resistance tests from phase terminal(s) to case for one minute. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.1.
3. Measure the capacitance of all terminal combinations.
4. Measure resistance of the internal discharge resistors.

#### C. 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.A.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.A.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.20.1.A.6.3)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.20.1 Capacitors and Reactors, Capacitors (*continued*)

#### D. 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, Article 460, residual voltage of a capacitor shall be reduced to 50 volts in the following time intervals after being disconnected from the source of supply:

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

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.20.2 Capacitors and Reactors, Capacitor Control Devices

— RESERVED —

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
6. Verify that tap connections are as specified, if applicable.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.20.3.1.A.5.1.
2. Perform winding-to-ground insulation-resistance tests. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.1.
3. Measure winding resistance.
- \*4. Perform dielectric withstand voltage tests on each winding-to-ground.

#### C. 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.A.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.A.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.20.3.1.A.5.3)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

#### D. 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform 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. INSPECTION AND TEST PROCEDURES

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

*(continued)*

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.20.3.2.A.10.1.
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.
  5. Color: ASTM D-1500.
  6. Visual Condition: ASTM D-1524.
  7. Water in insulating liquids: ASTM D-1533.
  - \*8. Measure power factor or dissipation factor in accordance with ASTM D-924.
8. Remove a sample of insulating liquid in accordance with ASTM D923 and perform dissolved-gas analysis in accordance with ANSI/IEEE C57.104 or ASTM D-3612.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

*(continued)*

#### C. Test Values – Visual and Mechanical

1. Operation of temperature devices shall be in accordance with system requirements. (7.20.3.2.A.7)
2. Operation of pumps and fans shall be in accordance with manufacturer's recommendations and system design. (7.20.3.2.A.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.A.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.A.10.2)
5. Results of the thermographic survey shall be in accordance with Section 9. (7.20.3.2.A.10.3)
6. Liquid levels shall be in accordance with manufacturer's published tolerances. (7.20.3.2.A.11)
7. Positive pressure shall be indicated on the pressure gauge for gas-blanketed reactors. (7.20.3.2.A.12)

#### D. 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 milliamperere/ milliwatt-loss basis, and the results shall be compared to values of similar bushings.
5. Consult the manufacturer if winding-resistance test values vary by more than two percent from factory test values or between adjacent phases.

\* Optional

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## 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.21.A.5.1.
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.

#### C. 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.A.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.A.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.21.A.5.3)

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.21 Outdoor Bus Structures (*continued*)

#### D. 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 voltage test, the test specimen is considered to have passed the test.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.22.1 Emergency Systems, Engine Generator

NOTE: Other than protective shutdowns, the prime mover is not addressed in these specifications.

#### A. 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.

#### B. 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.

#### C. 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.A.3)

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.22.1 Emergency Systems, Engine Generator (*continued*)

#### D. Test Values – Electrical

1. The recommended minimum insulation resistance ( $IR_{1 \text{ min}}$ ) test results in megohms shall be in accordance with Table 100.11.
  - 1.1 The polarization index value shall not be less than 2.0.
  - 1.2 The dielectric absorption ratio shall be greater than 1.0.
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.

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
8. Verify operation of forced ventilation.
9. Verify that filters are in place and vents are clear.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.22.2.A.7.1.
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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

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.

#### C. Test Values – Visual and Mechanical

1. Electrical and mechanical interlock systems shall operate in accordance with system design requirements. (7.22.2.A.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.A.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.A.7.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.22.2.A.7.3)

#### D. 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.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
9. Perform manual transfer operation.
10. Verify positive mechanical interlocking between normal and alternate sources.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.22.3.A.8.1.
- \*2. Perform insulation resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch in both source positions 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 or for control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

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

4. Perform a contact/pole-resistance test.
5. Verify settings and operation of control devices.
6. Calibrate and set all relays and timers in accordance with Section 7.9
7. Verify phase rotation, phasing, and synchronized operation as required by the application.
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.

#### C. 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.A.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.A.8.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.22.3.A.8.3)

#### D. 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 transfer switches 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.

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

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

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. 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.
5. Control devices shall operate in accordance with manufacturer's published data.
6. Relay test results shall be in accordance with Section 7.9.
7. Phase rotation, phasing, and synchronization shall be in accordance with system design specifications.
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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
7. Verify appropriate insulating liquid level.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.24.1.A.6.1
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 magnetron atmospheric condition (MAC) test on each vacuum interrupter.
10. 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.
11. Perform dielectric withstand voltage tests on each pole-to-ground and pole-to-pole with recloser in closed position.
12. Verify operation of heaters, if applicable.
13. Test all protective functions in accordance with Section 7.9.
14. Test all metering and instrumentation in accordance with Section 7.11.
15. Test instrument transformers in accordance with Section 7.10.

#### C. Test Values – Visual and Mechanical

1. Mechanical operation and contact alignment shall be in accordance with manufacturer's published data. (7.24.1.A.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.A.6.1)

\* Optional



## 7. INSPECTION AND TEST PROCEDURES

### 7.24.1 Automatic Circuit Reclosers and Line Sectionalizers, Automatic Circuit Reclosers, Oil/Vacuum (*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. (7.24.1.A.6.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.24.1.A.6.3)
5. Insulating liquid level shall be in accordance with manufacturer's recommended tolerances. (7.24.1.A.7)

#### D. 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 or data from test equipment manufacturers.
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 milliamperes/milliwatt loss basis, and the results shall be compared to values of similar bushings.
9. Evaluate each vacuum interrupter in accordance with test equipment manufacturer's instructions.
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

\* Optional

## 7. INSPECTION AND TEST PROCEDURES

### 7.24.1 Automatic Circuit Reclosers and Line Sectionalizers, Automatic Circuit Reclosers, Oil/Vacuum (*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 voltage test, the test specimen is considered to have passed the test.
12. Heaters shall be operational.
13. Protective device function test results shall be in accordance with Section 7.9.
14. Metering and instrumentation test results shall be in accordance with Section 7.11.
15. 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

#### A. 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.B.1.
  2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
  3. Perform thermographic survey in accordance with Section 9.
7. Verify appropriate insulating liquid level.

#### B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.24.2.A.6.1.
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. INSPECTION AND TEST PROCEDURES

### 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.

#### C. Test Values – Visual and Mechanical

1. Mechanical operation and contact alignment shall be in accordance with manufacturer's published data. (7.24.2.A.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.A.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.A.6.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.24.2.A.6.3)
5. Insulating liquid level shall be in accordance with manufacturer's recommended tolerances. (7.24.2.A.7)

#### D. 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. INSPECTION AND TEST PROCEDURES

### 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 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**

#### **A. 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.

#### **B. 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.

#### **C. 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.A.2)

#### **D. 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. 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 AND COMMISSIONING**

It is the purpose of system function tests to prove the correct interaction of all sensing, processing, and action devices. Perform system function tests in accordance with ANSI/NETA ECS *Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems*.

## **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, 2010 Edition, Section 11.17.

### **4. Test Results**

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

\* Optional





## 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

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.

## 10. ELECTROMAGNETIC FIELD TESTING (*continued*)

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 —



**TABLES**

**NETA<sup>®</sup>**

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

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**TABLE 100.1**  
**Insulation Resistance Test Values**  
**Electrical Apparatus and Systems Other Than Rotating Machinery**

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	1,500
8,000	2,500	2,500
15,000	2,500	5,000
25,000	5,000	10,000
34,500	5,000	100,000
46,000 and above	5,000	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.

For rotating machinery insulation-resistance test values see Table 100.11.

For medium-voltage cables, the values shown are typical. Conductor and insulation geometry, temperature, and overall cable length need to be taken into account per manufacturers published data for definitive minimum insulation resistance criteria.

**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
	.730/1.058	2.2	3.1
Metal-Clad Switchgear	4.76	14	20
	8.25	27	37.5
	15.0	27	37.5
	27.0	45	†
	38.0	60	†
Station-Type Cubicle Switchgear	15.5	37	†
	38.0	60	†
	72.5	120	†
Metal Enclosed Interrupter Switchgear	With stress cone type terminations (With IEEE 386 type terminations)	With stress cone type terminations (With IEEE 386 type terminations)	
	4.76 (4.76)	14	20
	8.25 (8.25)	19	27
	15.0 (14.1)	27	37
	27.0 (26.3)	37	52
	38.0 (36.6)	45	†

Derived from ANSI/IEEE C37.20.1-2015, Paragraph 6.5, *Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear*, C37.20.2-2015, Paragraph 6.5, *Standard for Metal-Clad Switchgear*, C37.20.2-1993 *Standard for Metal-Clad and Station-Type Cubicle Switchgear*, Paragraph 5.5, and C37.20.3-2013, Paragraph 5.2, *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**

	<b>Mineral Oil Maximum</b>	<b>Natural Ester Fluid</b>
<b>Power Transformers, Regulators, and Reactors</b>	0.5%	1.0%

In the absence of consensus standards dealing with transformer dissipation/power factor values, the NETA Standards Review Council suggests the above representative values.

Distribution transformer power factor results shall compare to previously obtained results.

**TABLE 100.4**  
**Insulating Fluid Limits**

<b>Table 100.4.1</b>					
<b>Test Limits for New Insulating Oil Received in New Equipment</b>					
<b>Mineral Oil</b>					
<b>Test</b>	<b>ASTM Method</b>	<b>≤ 69 kV and Below</b>	<b>&gt;69 kV - &lt; 230 kV</b>	<b>≥230 kV - &lt; 345 kV</b>	<b>≥345 kV and Above</b>
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	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 C57.106-2006, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

<b>Table 100.4.2</b>		
<b>Test Limits for Silicone Insulating Liquid in New Transformers</b>		
<b>Test</b>	<b>ASTM Method</b>	<b>Acceptable Values</b>
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 (R2009), *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		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 <sup>a</sup>		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm <sup>2</sup> /s, (cSt), 40° C	1.0 X 10 <sup>2</sup> (100)		1.3 X 10 <sup>2</sup> (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					
Rated Voltage Phase-to-Phase kV	Conductor Size AWG or kcmil (mm)	Nominal Insulation Thickness mils (mm)		Maximum DC Field Test Voltages, kV During/After Installation	
		100% Insulation Level	133% Insulation Level	100% Insulation Level	133% Insulation Level
5	8-1000 (8.4-507)	90 (2.29)	115 (2.92)	28	36
	Above 1000 (507)	140 (3.56)	140 (3.56)	28	36
8	6-1000 (13.3-507)	115 (2.92)	140 (3.56)	36	44
	Above 1000 (507)	175 (4.45)	175 (4.45)	36	44
15	2-1000 (33.6-507)	175 (4.45)	220 (5.59)	56	64
	Above 1000 (507)	220 (5.59)	220 (5.59)	56	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					
Rated Voltage Phase-to-Phase kV	Conductor Size AWG or kcmil	Nominal Insulation Thickness Mils (mm)		AC Test Voltage, kV	
		100% Insulation Level	133% Insulation Level	100% Insulation Level	133% Insulation Level
5 kV	8-1000	90 (2.29)	115 (2.92)	18	23
	1001-3000	140 (3.56)	140 (3.56)	28	28
8 kV	6-1000	115 (2.92)	140 (3.56)	23	28
	1001-3000	175 (4.45)	175 (4.45)	35	35
15 kV	2-1000	175 (4.45)	220 (5.59)	35	44
	1001-3000	220 (5.59)	220 (5.59)	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 Shielded Power Cable		
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

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.

IEEE 48 Terminations, IEEE 404 Joints, IEEE 386 Separable Connectors

ICEA S-97-682 Metallic Shield MV Cable, ICEA S-94-649 Concentric Wire MV Cable, ICEA S-108-720 HV/EHV Cable

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	20
25	31
35	44

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

**TABLE 100.7**  
**Inverse Time Trip Test**  
**at 300% of Rated Continuous Current of Circuit Breakers**  
**Molded-Case Circuit Breakers**

Range of Rated Continuous Current (Amperes)	Maximum Trip Time in Seconds For Each Maximum Frame Rating <sup>a</sup>	
	≤ 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 4-2009, *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**

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

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

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

**TABLE 100.9**  
**Instrument Transformer Dielectric Tests**  
**Field 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 8.5.2 and Table 2 of ANSI/IEEE C57.13-2016, *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**

<b>RPM @ 60 Hz</b>	<b>Velocity in/s peak</b>	<b>Velocity mm/s</b>	<b>RPM @ 50 Hz</b>	<b>Velocity in/s peak</b>	<b>Velocity mm/s</b>
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 1–2011, 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**  
**Insulation Resistance Test Values**  
**Rotating Machinery for One Minute at 40° C**

Winding Rated Voltage <sup>a</sup> (V)	Test Voltage, DC	Recommended Minimum Insulation Resistance (Megohms): Windings Before 1970, Field Windings, Others Not Listed in Table 100.11 <sup>b</sup>	Recommended Minimum Insulation Resistance (Megohms): DC Armature, AC Windings, (form-wound coils)	Recommended Minimum Insulation Resistance (Megohms): Random-Wound Stator Coils, Form-Wound Coils below 1 kV
< 1,000	500	kV + 1	100	5
1,000 – 2, 500	500 – 1,000	kV + 1	100	-
2,501 – 5,000	1,000 – 2, 500	kV + 1	100	-
5,001 – 12,000	2,500 – 5,000	kV + 1	100	-
> 12,000	5,000 – 10,000	kV + 1	100	-

Refer to table 100.14 for temperature correction factors.

- a. Rated line-to-line voltage for three-phase ac machines, line-to-ground voltage for single-phase machines, and rated direct voltage for dc machines or field windings
- b. kV is the rated machine terminal-to-terminal voltage.

**TABLE 100.12.1**  
**Bolt-Torque Values for Electrical Connections**

**US Standard Fasteners <sup>a</sup>**  
**Heat-Treated Steel – Cadmium or Zinc Plated <sup>b</sup>**

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in <sup>2</sup> )	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<sup>a</sup>**  
**Silicon Bronze Fasteners<sup>b c</sup>**  
**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<sup>a</sup>**  
**Aluminum Alloy Fasteners<sup>b c</sup>**  
**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<sup>a</sup>**  
**Stainless Steel Fasteners<sup>b c</sup>**  
**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<sub>6</sub> Gas Tests**

Test	Method	Limits
Water Content	ASTM D2029	-62°C or 8.3 ppmv max
Hydrolyzable Flourides	ASTM D2284	0.3 max, mL/kg (0.3 ppmw)
Air	ASTM D2685	0.05% max, weight (500 ppmw)
Carbon Tetraflouride	ASTM D2685	0.05% max, weight (500 ppmw)
Assay	--	99.8% min, weight

Based on ASTM D2472 *Standard Specification for Sulphur Hexafluoride* (2015 edition), Table 1

**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 Other Than Rotating Machinery
-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° F

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

$$K = 3.95$$

$$R_c = R_a \times K$$

$$R_c = 2.0 \times 3.95$$

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



**TABLE 100.14 (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, Other Than Rotating Machinery
-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*.

Notes: The insulation resistance coefficient is based on the halving of the insulation resistance to the change in temperature.

Apparatus Containing Immersed Oil Insulation Table uses 10° C change with temperature halving.

Apparatus Containing Solid Insulation Table uses 15° C change with temperature halving.

Formula:

$$R_c = R_a \times K$$

Where:  $R_c$  is resistance corrected to 40° C

$R_a$  is measured resistance at test temperature

K is applicable multiplier

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

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

$$K = 0.40$$

$$R_c = R_a \times K$$

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





**TABLE 100.15**  
**High-Potential Test Voltage**  
**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 C37.60-2012, *High-voltage switchgear and controlgear – Part 111: Automatic circuit reclosers and fault interrupters for alternating current systems up to 38 kV*.

**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 $\phi$ )	15.0	95	35	53
24.9 (1 $\phi$ )	27.0	125	40	78
34.5 (3 $\phi$ )	38.0	150	50	103

Derived from ANSI/IEEE C37.63- 2013 Table 2 (*Standard Requirements for Overhead, Pad-Mounted, Dry-Vault, and Submersible Automatic Line Sectionalizers for Alternating Current Systems Up to 38 kV*).

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	--
	27.0	45.0	--
	38.0	60.0	--
Nonsegregated Phase	1.058	2.25	--
	4.76	14.2	--
	8.25	27.0	--
	15.0	27.0	--
	15.5	37.5	--
	27.0	45.0	--
Segregated Phase	15.5	37.0	--
	27.0	45.0	--
	38.0	60.0	--
DC Bus Duct	0.3/.325	1.6	2.3
	0.8	2.7	3.9
	1.2	36.0	5.4
	1.6	4.0	5.7
	3.2	6.6	9.3

Derived from ANSI/IEEE C37.23-2015, Tables 1, 2, 3, 4 and paragraph 6.4.3. 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 ( $\Delta T$ ) based on comparisons between similar components under similar loading.	Temperature difference ( $\Delta T$ ) based upon comparisons between component and ambient air temperatures.	Recommended Action
1°C - 3°C	1°C - 10°C	Possible deficiency; warrants investigation
4°C - 15°C	11°C - 20°C	Indicates probable deficiency; repair as time permits
- - - - -	21°C - 40°C	Monitor until corrective measures can be accomplished
>15°C	>40°C	Major discrepancy; repair immediately

Temperature specifications vary depending on the exact type of equipment. Even in the same class of equipment (i.e., cables) there are various temperature ratings. Heating is generally related to the square of the current; therefore, the load current will have a major impact on  $\Delta T$ . In the absence of consensus standards for  $\Delta T$ , 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 8.9.2.2, Conducting an IR Thermographic Inspection, *Electrical Power Systems Maintenance and Testing*, by Paul Gill, PE, 2008 edition.

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

Derived from Table 8, ANSI C37.06-2009, *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.

<b>100.20.2</b>	
<b>Rated Control Voltages and Their Ranges for Circuit Breakers Solenoid-Operated Devices</b>	
<b>Rated Voltage</b>	<b>Closing Voltage Ranges for Power Supply</b>
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, Minutes	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 remanance).

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 .. °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 rms value of sinusoidal voltage of rated frequency, with, if applied to the secondary winding of a CT, would result in an exciting current corresponding to the maximum permissible error current appropriate to CT class

$E_{alc}$  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 and Multiple Conductor Cables with Interlocked Armor, Smooth or  
Corrugated Aluminum Sheath or Lead Sheath**

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

**Notes**

Specific references from Appendix I:

1. Interlocked-Armor and Metallic-Sheathed Cables

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

2. Flat-Tape Armored or Wire-Armored Cables

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

3. Tape-Shielded Cables

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

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

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

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

4. Wire-Shielded Cables

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

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

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

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## APPENDIX A

### Definitions

NETA recognizes the archived IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, as its official source for electrical definitions. As a secondary resource, NETA recognizes *Webster's Unabridged Dictionary*. The definitions in the list provided by NETA are either not included in the either of these references 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.

#### *Commissioning, electrical*

The systematic process of documenting and placing into service newly installed or retrofitted electrical power equipment and systems.

#### *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.

## APPENDIX A

### Definitions (*continued*)

*Inspection*

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

*Interim amendment*

An interim amendment is made by NETA's Standards Review Council when there is a potential hazard prior to review by the Section Panel or the public

*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.

*Time-travel analysis*

The measurement of the opening and closing strokes of circuit contacts from the time of an initiating signal to the complete at rest position of the contact. The analysis shall provide the information required to determine distance traveled, velocity of travel, contact insertion, contact bounce, and contact parting time.

*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.

## APPENDIX A

### Definitions (*continued*)

#### *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-2017)

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 judgment on the continued serviceability, deterioration, or non-serviceability of the specific equipment. NETA, a nationally-recognized certification agency, provides recognition of four levels of competency within the electrical testing industry in accordance with *ANSI/NETA ETT 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 Certified 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 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-2017)

#### SPECIFICATIONS AND PUBLICATIONS

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

ANSI/NETA ECS-2015	<i>Standard for Electrical Commissioning of Electrical Power Equipment and Systems</i>
ANSI/NETA ETT-2015	<i>Standard for Certification of Electrical Testing Technicians</i>
ANSI/NETA MTS-2015	<i>Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems</i>
ANSI/NETA ATS-2017	<i>Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems</i>

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

#### EDUCATIONAL PROGRAMS

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



## APPENDIX D

### Form for Comments

(This appendix is not part of American National Standard ANSI/NETA ATS-2017)

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

Date \_\_\_\_\_

Name (please print) \_\_\_\_\_

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City/State/Zip \_\_\_\_\_

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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](http://www.netaworld.org) under Standards Activities.

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**APPENDIX E**  
**Form for Proposals**

(This appendix is not part of American National Standard ANSI/NETA ATS-2017)

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

When drafting a proposed section:

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

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

Include references.

When applicable, use the standard base format:

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

Date \_\_\_\_\_

Name \_\_\_\_\_ Tel No. \_\_\_\_\_

Company \_\_\_\_\_ Fax No. \_\_\_\_\_

Address \_\_\_\_\_ E-Mail \_\_\_\_\_

Please indicate organization represented (if any) \_\_\_\_\_

NETA document title \_\_\_\_\_ Year \_\_\_\_\_

Section/Number \_\_\_\_\_

Note 1: Type or print legibly in black ink.

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

I hereby grant NETA the nonexclusive, royalty-free rights, including nonexclusive, royalty-free rights in copyright, in this proposal. I understand that I acquire no rights in any publication of NETA in which this proposal in this or another similar analogous form is used.

Signature (required) \_\_\_\_\_

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