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AMERICAN NATIONAL STANDARD

STANDARD FOR ACCEPTANCE TESTING SPECIFICATIONS for Electrical Power Equipment and Systems

Secretariat
InterNational Electrical Testing Association

Approved by
American National Standards Institute

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The following sections of the *ANSI/NETA Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems* must be incorporated by reference as part of any subsection:

3. Qualifications of Testing Organization and Personnel
   - 3.1 Testing Organization
   - 3.2 Testing Personnel
4. Division of Responsibility
   - 4.1 The Owner's Representative
   - 4.2 The Testing Organization
5. General
   - 5.1 Safety and Precautions
   - 5.2 Suitability of Test Equipment
   - 5.3 Test Instrument Calibration
   - 5.4 Test Report

The purchaser is required to include the above sections with any section(s) of 7.

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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-2010, *Standard for Certification of Electrical Testing Technicians*. Each on-site crew leader shall hold a current certification, Level III or higher, in electrical testing.

4. DIVISION OF RESPONSIBILITY

4.1 The Owner's Representative

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

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

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

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

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

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

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

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

8. Site-specific hazard notification and safety training.

4.2 The Testing Organization

The testing organization shall provide the following:

1. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform such tests and inspections.

2. Specific power requirements for test equipment.

3. Notification to the owner's representative prior to commencement of any testing.

4. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests.

5. A written record of all tests and a final report.

5. GENERAL

5.1 Safety and Precautions

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

1. Safety practices shall include, but are not limited to, the following requirements:

    1. All applicable provisions of the Occupational Safety and Health Act, particularly OSHA 29 CFR Part 1910 and 29 CFR Part 1926.

    2. ANSI/NFPA 70E, *Standard for Electrical Safety in the Workplace*.

    3. 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. Test data.
    5. Analysis and recommendations.
2. Test data records shall include the following minimum requirements:
    1. Identification of the testing organization.
    2. Equipment identification.
    3. Humidity, temperature, and other conditions that may affect the results of the tests and/or calibrations.
    4. Date of inspections, tests, maintenance, and/or calibrations.
    5. Identification of the testing technician.
    6. Indication of inspections, tests, maintenance, and/or calibrations to be performed and recorded.
    7. Indication of expected results when calibrations are to be performed.
    8. Indication of as-found and as-left results, as applicable.
    9. Identification of all test results outside of specified tolerances.
    10. 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 number

    3. Test date

    4. Technician name

7. INSPECTION AND TEST PROCEDURES

7.6.4 Circuit Breakers, SF_6

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

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

5. Verify the unit is clean.

*6. When provisions are made for sampling, remove a sample of SF_6 gas and test in accordance with Table 100.13. Do not break seal or distort "sealed-for-life" interrupters.

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

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

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

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

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

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

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

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

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

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

14. Perform time-travel analysis.

* Optional

7.6.4 Circuit Breakers, SF_6 (*continued*)

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

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.4.1.

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

3. Perform a contact/pole-resistance test.

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

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

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

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

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

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

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

11. Verify operation of heaters.

12. Test instrument transformers in accordance with Section 7.10.

3. Test Values

3.1 Test Values – Visual and Mechanical

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

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

* Optional

7.6.4 Circuit Breakers, SF_6 (*continued*)

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

4. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.6.4.1.12.1)

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

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

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

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

3.2 Test Values – Electrical

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

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

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

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

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

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

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

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

* Optional

7.6.4 Circuit Breakers, SF_6 (*continued*)

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

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

11. Heaters shall be operational.

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

* Optional

7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Verify correct connection of transformers with system requirements.
4. Verify that adequate clearances exist between primary and secondary circuit wiring.
5. Verify the unit is clean.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
    1. Use of low-resistance ohmmeter in accordance with Section 7.10.2.1 and 7.10.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
    3. Perform thermographic survey in accordance with Section 9.
7. Verify that all required grounding and shorting connections provide contact.
8. Verify correct operation of transformer withdrawal mechanism and grounding operation.
9. Verify correct primary and secondary fuse sizes for voltage transformers.
10. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

2.1 Electrical Tests - Current Transformers

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.
2. Perform insulation-resistance test of each current transformer and its secondary wiring with respect to ground at 1000 volts dc for one minute. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.
3. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
4. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1.
5. Perform an excitation test on transformers used for relaying applications in accordance with ANSI/IEEE C57.13.1.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

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

7. When applicable, perform insulation-resistance tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.5.

*8. Perform dielectric withstand tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.9.

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

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

2.2 Electrical Tests - Voltage Transformers

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

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

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

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

5. Measure voltage circuit burdens at transformer terminals.

*6. Perform a dielectric withstand test on the primary windings with the secondary windings connected to ground. The dielectric voltage shall be in accordance with Table 100.9. The test voltage shall be applied for one minute.

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

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

* Optional

7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

2.3 Electrical Tests - Coupling-Capacitor Voltage Transformers

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

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

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

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

5. Measure voltage circuit burdens at transformer terminals.

*6. Perform a dielectric withstand test on the primary windings with the secondary windings connected to ground. The dielectric voltage shall be in accordance with Table 100.9. The test voltage shall be applied for one minute.

7. Measure capacitance of capacitor sections.

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

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

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

3. Test Values

3.1 Test Values – Visual and Mechanical

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

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

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

* Optional

7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

3.2.1 Test Values – Current Transformers – Electrical

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

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

3. Polarity results shall agree with transformer markings.

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

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

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

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

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

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

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

3.2.2 Test Values –Voltage Transformers – Electrical

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

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

3. Polarity results shall agree with transformer markings.

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

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

* Optional

7.10 Instrument Transformers (*continued*)

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

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

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

3.2.3 Test Values – Coupling Capacitor Voltage Transformers

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

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

3. Polarity results shall agree with transformer markings.

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

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

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

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

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

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

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

* Optional

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.

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.

TABLE 100.12.1

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

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

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

TABLE 100.12.2

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

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

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 100.12.3

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

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

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 100.12.4

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

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

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

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

TABLE 100.13

SF_6 Gas Tests

Test	Method	Serviceability Limits [a]
Moisture	Hygrometer	Per manufacturer or ≥ 200 ppm[b]
SF_6 decomposition byproducts	ASTM D 2685	≥ 500 ppm
Air	ASTM D 2685	≥ 5000 ppm[c]
Dielectric breakdown hemispherical contacts	0.10 inch gap at atmospheric pressure	11.5 - 13.5 kV[d]

a. In the absence of consensus standards dealing with SF_6 circuit breaker gas tests, the NETA Standards Review Council suggests the above representative values.

b. According to some manufacturers.

c. Dominelli, N. and Wylie, L., *Analysis of SF_6 Gas as a Diagnostic Technique for GIS*, Electric Power Research Institute, Substation Equipment Diagnostics Conference IV, February 1996.

d. Per Even, F.E., and Mani, G. Sulfur Fluorides, Kirk, *Othmer Encyclopedia of Chemical Technology*, 4th ed., 11,428, 1994.

Reference: IEC 61634 High-Voltage Switchgear and Controlgear - *Use and Handling of Sulfur Hexafluoride (SF_6) in High-Voltage Switchgear and Controlgear*.

TABLE 100.18

Thermographic Survey
Suggested Actions Based on Temperature Rise

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

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

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

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

TABLE 100.20

Rated Control Voltages and their Ranges for Circuit Breakers

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

100.20.1
Rated Control Voltages and Their Ranges for Circuit Breakers

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

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

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 100.20 (*continued*)

Rated Control Voltages and Their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2
Rated Control Voltages and Their Ranges for Circuit Breakers
Solenoid-Operated Devices

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

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

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

TABLE 100.5

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 100.9

Instrument Transformer Dielectric Tests
Field Acceptance

Nominal System Voltage (kV)	BIL (kV)	Periodic Dielectric Withstand Test Field Test Voltage (kV)	
		AC	DC*
0.60	10	3.0	4
1.20	30	7.5	10
2.40	45	11.25	15
5.00	60	14.25	19
8.70	75	19.5	26
15.00	95	25.5	34
15.00	110	25.5	34
25.00	125	30.0	40
25.00	150	37.5	50
34.50	200	52.5	70
46.00	250	71.2	+
69.00	350	105	+
115.00	450	138	+
115.00	550	172	+
138.00	650	206	+
161.00	750	243	+
230.00	900	296	+
230.00	1050	345	+
345.00	1300	431	+
500.00	1675	562	+
500.00	1800	600	+
765.00	2050	690	+

Table 100.9 is derived from Paragraph 8.8.2 and Tables 2 of ANSI/IEEE C57.13-1993, *Standard Requirements for Instrument Transformers*.

+ Periodic dc potential tests are not recommended for transformers rated higher than 34.5 kV.

* DC potential tests are not recommended for transformers rated higher than 200 kV BIL. DC tests may prove beneficial as a reference for future testing. In such cases the test direct voltage shall not exceed the original factory test rms alternating voltages.