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The following sections of the ANSI/NEMA 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:
   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. The decal shall include:

   1. Testing organization
   2. Project number
   3. Test date
   4. Technician name
7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect impact recorder prior to unloading.
4. Test dew point of tank gases
5. Inspect anchorage, alignment, and grounding.
6. Verify the presence of PCB content labeling.
8. Verify the bushings are clean.
9. Verify that alarm, control, and trip settings on temperature and level indicators are as specified.
10. Verify operation of alarm, control, and trip circuits from temperature and level indicators, pressure relief device, gas accumulator, and fault pressure relay, if applicable.
11. Verify that cooling fans and pumps operate correctly and have appropriate overcurrent protection.
12. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   1. Use of a low-resistance ohmmeter in accordance with Section 7.2.2.2.
   2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
   3. Perform thermographic survey in accordance with Section 9.
13. Verify correct liquid level in tanks and bushings.
14. Verify that positive pressure is maintained on gas-blanketed transformers.
15. Perform inspections and mechanical tests as recommended by the manufacturer.
16. Test load tap-changer in accordance with Section 7.12.3.
17. Verify presence of transformer surge arresters.
18. Verify de-energized tap-changer position is left as specified.

* Optional
7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (continued)

2. Electrical Tests

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

2. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground. Apply 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. Measure the resistance of each high-voltage winding in each de-energized tap-changer position. Measure the resistance of each low-voltage winding in each de-energized tap-changer position, if applicable.

8. If core ground strap is accessible, remove and measure core insulation resistance at 500 volts dc.

9. Measure the percentage of oxygen in the gas blanket.

10. Remove a sample of insulating liquid in accordance with ASTM D 923. Sample shall be tested for the following.

   1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
   2. Acid neutralization number: ANSI/ASTM D 974
   *3. Specific gravity: ANSI/ASTM D 1298
   4. Interfacial tension: ANSI/ASTM D 971 or ANSI/ASTM D 2285
   5. Color: ANSI/ASTM D 1500
   6. Visual Condition: ASTM D 1524

* Optional
7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (continued)

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

*8. Power factor or dissipation factor in accordance with ASTM D 924.

11. Remove a sample of insulating liquid in accordance with ASTM D 3613 and perform dissolved-gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D3612.

12. Test instrument transformers in accordance with Section 7.10.

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

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

15. Verify operation of cubicle or air terminal compartment space heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

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

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

3. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.2.2.1.12.1)

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

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

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

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

3.2 Test Values – Electrical

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

* Optional
7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (continued)

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

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

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

5. Investigate bushing power-factor and capacitance values that vary from nameplate values by more than ten percent. Hot-collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.

6. Typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.

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

8. Core insulation values shall be compared to the factory test value but not less than one megohm at 500 volts dc.

9. Investigate the presence of oxygen in the nitrogen gas blanket.

10. Insulating liquid values shall be in accordance with Table 100.4.


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

13. Results of surge arrester tests shall be in accordance with Section 7.19.

14. Compare grounding impedance device values to manufacturer’s published data.

15. Heaters shall be operational.

* 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.
   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)


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. INSPECTION AND TEST PROCEDURES

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)
7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers

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

2. Electrical Tests
   1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.12.3.1.
   2. Perform insulation-resistance tests in any off-neutral position in accordance with Section 7.2.2.
   3. Perform insulation power-factor or dissipation-factor tests in accordance with Section 7.2.2.
   *4. Perform winding-resistance test at each tap position.

* Optional
7. 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 D 3613 and perform dissolved gas analysis in accordance with ANSI/IEEE C57.104 or ASTM D 3612.

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

10. Verify operation of heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

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

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

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

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

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

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

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

* Optional
7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers (continued)

3.2 Test Values – Electrical

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

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

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

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

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

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

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

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

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

10. Heaters shall be operational.

* Optional
7. INSPECTION AND TEST PROCEDURES

7.13 Grounding Systems

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

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

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

* Optional
7. INSPECTION AND TEST PROCEDURES

7.13 Grounding Systems

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

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

3. Test Values

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

* Optional
7. INSPECTION AND TEST PROCEDURES

7.13 Grounding Systems (continued)

3.2 Test Values – Electrical

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

2. 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

7.19.1 Surge Arresters, Low-Voltage

1. Visual and Mechanical Inspection
   1. Compare equipment nameplate data with drawings and specifications.
   2. Inspect physical and mechanical condition.
   3. Inspect anchorage, alignment, grounding, and clearances.
   4. Verify the arresters are clean.
   5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
      1. Use of low-resistance ohmmeter in accordance with Section 7.19.1.2.
      2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
   6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.

2. Electrical Tests
   1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.19.1.1.
   2. Perform an insulation-resistance test on each arrester, phase terminal-to-ground. Apply voltage in accordance with manufacturer’s published data.
   3. Test grounding connection in accordance with Section 7.13.

3. Test Values

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

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

* Optional
7. **INSPECTION AND TEST PROCEDURES**

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

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

3. Resistance between the arrester ground terminal and the ground system shall be less than 0.5 ohm and in accordance with Section 7.13.

* Optional
7. INSPECTION AND TEST PROCEDURES

7.19.2 Surge Arresters, Medium- and High-Voltage

1. Visual and Mechanical Inspection
   1. Compare equipment nameplate data with drawings and specifications.
   2. Inspect physical and mechanical condition.
   3. Inspect anchorage, alignment, grounding, and clearances.
   4. Verify the arresters are clean.
   5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
      1. Use of low-resistance ohmmeter in accordance with Section 7.19.2.2.
      2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
   6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
   7. Verify that the stroke counter is correctly mounted and electrically connected, if present.
   8. Record the stroke counter reading.

2. Electrical Tests
   1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.19.2.1.
   2. Perform an insulation-resistance test on each arrester, phase terminal-to-ground. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.
   3. Test grounding connection in accordance with Section 7.13.
   *4. Perform a watts-loss test.

3. Test Values

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

* Optional
7. INSPECTION AND TEST PROCEDURES

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

3.2 Test Values – Electrical

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

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

3. 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
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 100.3
**Recommended Dissipation Factor/Power Factor at 20° C**
**Liquid-Filled Transformers, Regulators, and Reactors**
**Acceptance Test Values**

<table>
<thead>
<tr>
<th>Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New Power Transformers and Reactors</td>
<td>0.5%</td>
</tr>
<tr>
<td>New Distribution Transformers and Regulators</td>
<td>1.0%</td>
</tr>
<tr>
<td>Remanufactured Power Transformers and Reactors</td>
<td>1.0%</td>
</tr>
<tr>
<td>Remanufactured Distribution Transformers and Regulators</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.
# TABLE 100.4
## Insulating Fluid Limits

### Table 100.4.1
Test Limits for New Insulating Oil Received in New Equipment

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Method</th>
<th>≤ 69 kV and Below</th>
<th>&gt;69 kV - &lt; 230 kV</th>
<th>≥230 kV - &lt; 345 kV</th>
<th>≥345 kV and Above</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric breakdown, kV minimum</td>
<td>D877</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Dielectric breakdown, kV minimum @ 1mm (0.04&quot;) gap</td>
<td>D1816</td>
<td>25</td>
<td>30</td>
<td>32</td>
<td>35</td>
</tr>
<tr>
<td>Dielectric breakdown, kV minimum @ 2 mm (0.08&quot;) gap</td>
<td>D1816</td>
<td>45</td>
<td>52</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>Interfacial tension mN/m minimum</td>
<td>D971 or D2285</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Neutralization number, mg KOH/g maximum</td>
<td>D974</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>Water content, ppm maximum</td>
<td>D1533</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Power factor at 25° C, %</td>
<td>D924</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Power factor at 100° C, %</td>
<td>D924</td>
<td>0.40</td>
<td>0.40</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Color</td>
<td>D1500</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Visual condition</td>
<td>D1524</td>
<td>Bright and clear</td>
<td>Bright and clear</td>
<td>Bright and clear</td>
<td>Bright and clear</td>
</tr>
</tbody>
</table>


### Table 100.4.2
Test Limits for Silicone Insulating Liquid in New Transformers

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Method</th>
<th>Acceptable Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric breakdown, kV minimum</td>
<td>D877</td>
<td>30</td>
</tr>
<tr>
<td>Visual</td>
<td>D2129</td>
<td>clear, free of particles</td>
</tr>
<tr>
<td>Water content, ppm maximum</td>
<td>D1533</td>
<td>50</td>
</tr>
<tr>
<td>Dissipation/power factor, 60 hertz, % max. @ 25° C</td>
<td>D924</td>
<td>0.1</td>
</tr>
<tr>
<td>Viscosity, cSt @ 25° C</td>
<td>D445</td>
<td>47.5 – 52.5</td>
</tr>
<tr>
<td>Fire point, ° C, minimum</td>
<td>D92</td>
<td>340</td>
</tr>
<tr>
<td>Neutralization number, mg KOH/g max.</td>
<td>D974</td>
<td>0.01</td>
</tr>
</tbody>
</table>

### TABLE 100.4 (continued)

Insulating Fluid Limits

<table>
<thead>
<tr>
<th>ASTM Method</th>
<th>Test</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>D1816</td>
<td>Dielectric breakdown voltage for 0.08 in gap, kV</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>D1816</td>
<td>Dielectric breakdown voltage for 0.04 in gap kV</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>D974</td>
<td>Neutralization number, mg KOH/g</td>
<td>-----</td>
</tr>
<tr>
<td>D877</td>
<td>Dielectric breakdown voltage kV</td>
<td>30</td>
</tr>
<tr>
<td>D924</td>
<td>AC loss characteristic (dissipation factor), %</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>25° C</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>100° C</td>
<td>-----</td>
</tr>
<tr>
<td>D1533B</td>
<td>Water content, ppm</td>
<td>-----</td>
</tr>
<tr>
<td>D1524</td>
<td>Condition-visual</td>
<td>Clear</td>
</tr>
<tr>
<td>D92</td>
<td>Flash point (° C)</td>
<td>275</td>
</tr>
<tr>
<td>D92</td>
<td>Fire point (° C)</td>
<td>300(^a)</td>
</tr>
<tr>
<td>D971</td>
<td>Interfacial tension, mN/m, 25° C</td>
<td>38</td>
</tr>
<tr>
<td>D445</td>
<td>Kinematic viscosity, mm(^2)/s, (cSt), 40° C</td>
<td>1.0 X 10(^2) (100)</td>
</tr>
<tr>
<td>D1500</td>
<td>Color</td>
<td>-----</td>
</tr>
</tbody>
</table>


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

<table>
<thead>
<tr>
<th>Transformer Coil Rating Type in Volts</th>
<th>Minimum DC Test Voltage</th>
<th>Recommended Minimum Insulation Resistance in Megohms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Liquid Filled</td>
</tr>
<tr>
<td>0 - 600</td>
<td>1000</td>
<td>100</td>
</tr>
<tr>
<td>601 - 5000</td>
<td>2500</td>
<td>1000</td>
</tr>
<tr>
<td>Greater than 5000</td>
<td>5000</td>
<td>5000</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Nominal System Voltage (kV)</th>
<th>BIL (kV)</th>
<th>Periodic Dielectric Withstand Test Field Test Voltage (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AC</td>
</tr>
<tr>
<td>0.60</td>
<td>10</td>
<td>3.0</td>
</tr>
<tr>
<td>1.20</td>
<td>30</td>
<td>7.5</td>
</tr>
<tr>
<td>2.40</td>
<td>45</td>
<td>11.25</td>
</tr>
<tr>
<td>5.00</td>
<td>60</td>
<td>14.25</td>
</tr>
<tr>
<td>8.70</td>
<td>75</td>
<td>19.5</td>
</tr>
<tr>
<td>15.00</td>
<td>95</td>
<td>25.5</td>
</tr>
<tr>
<td>15.00</td>
<td>110</td>
<td>25.5</td>
</tr>
<tr>
<td>25.00</td>
<td>125</td>
<td>30.0</td>
</tr>
<tr>
<td>25.00</td>
<td>150</td>
<td>37.5</td>
</tr>
<tr>
<td>34.50</td>
<td>200</td>
<td>52.5</td>
</tr>
<tr>
<td>46.00</td>
<td>250</td>
<td>71.2</td>
</tr>
<tr>
<td>69.00</td>
<td>350</td>
<td>105</td>
</tr>
<tr>
<td>115.00</td>
<td>450</td>
<td>138</td>
</tr>
<tr>
<td>115.00</td>
<td>550</td>
<td>172</td>
</tr>
<tr>
<td>138.00</td>
<td>650</td>
<td>206</td>
</tr>
<tr>
<td>161.00</td>
<td>750</td>
<td>243</td>
</tr>
<tr>
<td>230.00</td>
<td>900</td>
<td>296</td>
</tr>
<tr>
<td>230.00</td>
<td>1050</td>
<td>345</td>
</tr>
<tr>
<td>345.00</td>
<td>1300</td>
<td>431</td>
</tr>
<tr>
<td>500.00</td>
<td>1675</td>
<td>562</td>
</tr>
<tr>
<td>500.00</td>
<td>1800</td>
<td>600</td>
</tr>
<tr>
<td>765.00</td>
<td>2050</td>
<td>690</td>
</tr>
</tbody>
</table>

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

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

* DC potential tests are not recommended for transformers rated higher than 200 kV BIL. DC tests may prove beneficial as a reference for future testing. In such cases the test direct voltage shall not exceed the original factory test rms alternating voltages.
### TABLE 100.12.1

**Bolt-Torque Values for Electrical Connections**

**US Standard Fasteners**\(^a\)

**Heat-Treated Steel – Cadmium or Zinc Plated**\(^b\)

<table>
<thead>
<tr>
<th>Grade</th>
<th>SAE 1&amp;2</th>
<th>SAE 5</th>
<th>SAE 7</th>
<th>SAE 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Marking</td>
<td><img src="image" alt="Marking" /></td>
<td><img src="image" alt="Marking" /></td>
<td><img src="image" alt="Marking" /></td>
<td><img src="image" alt="Marking" /></td>
</tr>
<tr>
<td>Minimum Tensile (Strength) (lbf/in(^2))</td>
<td>64K</td>
<td>105K</td>
<td>133K</td>
<td>150K</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bolt Diameter (Inches)</th>
<th>Torque (Pound-Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>4</td>
</tr>
<tr>
<td>5/16</td>
<td>7</td>
</tr>
<tr>
<td>3/8</td>
<td>12</td>
</tr>
<tr>
<td>7/16</td>
<td>19</td>
</tr>
<tr>
<td>1/2</td>
<td>30</td>
</tr>
<tr>
<td>9/16</td>
<td>42</td>
</tr>
<tr>
<td>5/8</td>
<td>59</td>
</tr>
<tr>
<td>3/4</td>
<td>96</td>
</tr>
<tr>
<td>7/8</td>
<td>150</td>
</tr>
<tr>
<td>1.0</td>
<td>225</td>
</tr>
</tbody>
</table>

\(a\). 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)

<table>
<thead>
<tr>
<th>Bolt Diameter (Inches)</th>
<th>Nonlubricated</th>
<th>Lubricated</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>3/8</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>1/2</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>5/8</td>
<td>55</td>
<td>40</td>
</tr>
<tr>
<td>3/4</td>
<td>70</td>
<td>60</td>
</tr>
</tbody>
</table>

\(^a\) 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)

<table>
<thead>
<tr>
<th>Bolt Diameter (Inches)</th>
<th>Lubricated</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>10</td>
</tr>
<tr>
<td>3/8</td>
<td>14</td>
</tr>
<tr>
<td>1/2</td>
<td>25</td>
</tr>
<tr>
<td>5/8</td>
<td>40</td>
</tr>
<tr>
<td>3/4</td>
<td>60</td>
</tr>
</tbody>
</table>

\(^a\) 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)

<table>
<thead>
<tr>
<th>Bolt Diameter (Inches)</th>
<th>Uncoated</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>15</td>
</tr>
<tr>
<td>3/8</td>
<td>20</td>
</tr>
<tr>
<td>1/2</td>
<td>40</td>
</tr>
<tr>
<td>5/8</td>
<td>55</td>
</tr>
<tr>
<td>3/4</td>
<td>70</td>
</tr>
</tbody>
</table>

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 100.18

**Thermographic Survey**

**Suggested Actions Based on Temperature Rise**

<table>
<thead>
<tr>
<th>Temperature difference (( \Delta T )) based on comparisons between similar components under similar loading.</th>
<th>Temperature difference (( \Delta T )) based upon comparisons between component and ambient air temperatures.</th>
<th>Recommended Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1°C - 3°C</td>
<td>1°C - 10°C</td>
<td>Possible deficiency; warrants investigation</td>
</tr>
<tr>
<td>4°C - 15°C</td>
<td>11°C - 20°C</td>
<td>Indicates probable deficiency; repair as time permits</td>
</tr>
<tr>
<td>- - - - -</td>
<td>21°C - 40°C</td>
<td>Monitor until corrective measures can be accomplished</td>
</tr>
<tr>
<td>&gt;15°C</td>
<td>&gt;40°C</td>
<td>Major discrepancy; repair immediately</td>
</tr>
</tbody>
</table>

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.


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.