SCOPE OF WORK

ELECTRICAL DISTRIBUTION TESTING

VETERANS AFFAIRS MEDICAL CENTER (VAMC) SPOKANE, WA

Project 668-12-116

April 2012

Prior to commencement of the testing procedures, the testing firm shall survey and catalog all components of the facility electrical distribution system. All new systems that are under contractor warranty and have been placed into service after September 2011 do not require testing. The new systems shall be visually inspected and infrared scans performed. The listing of electrical system components within this scope does not include a number of the new components. All components shall be inspected and tested as applicable whether or not specifically listed within the scope. The above work may be conducted during normal working hours.

Provide professional services for the inspection, conducting testing of the electrical components and servicing of the facility electrical systems, equipment and all major electrical distribution apparatus. All work shall be conducted between the hours of 5:00 pm and 6:00 am, Monday thru Friday and from 7:00 am Saturday thru 6:00 am Monday. In some areas such as MRI and unique operations the hours shall be between 11:00PM to 6:00AM. Contractor shall submit a detailed work schedule from start to completion.

1. The testing firm shall provide all material, equipment, labor, and technical supervision to perform such tests and inspections.

2. It is the purpose of these specifications to assure that all tested electrical equipment and systems are operational and within industry and manufacturer's tolerances recommendation.

3. The following is a listing of specific items to be tested as specified:

    a. Perform complete testing and maintenance on the following distribution switchboards:
        - Bldg 19 Switchboard “A” Serving bldg 1.
        - Bldg 19 Switchboard “B” Serving bldg 1.
        - Bldg 2 Boiler Plant Switchboard and Motor Control Centers.
        - Bldg 2 Chiller Plant Switchboard/MCC.
        - Bldg 12 Nursing Home Care Unit (NHCU Switchboard).
        - Bldg 1 Specialty Care Addition Switchboard

    b. Complete testing of all breakers 225 amps and larger in the Distribution Panels as specified. **Note: Removal & Bench Testing not required if it is practical to test the breakers in place. The 225 A rating is based on frame size. This also applies to breakers within Motor Control Centers. There are approx. 90 breakers 225 A and larger. Approx. 45 of those have electronic trip units. Contractor to review drawings and site conditions as required to accurately determine number of breakers and conditions affecting their testing. The facility has no “fuse molded case breakers”**

c. Distribution Panel Testing and Maintenance;
   - All panels throughout the facility shall be visually inspected and an infrared scan performed.
   - All breakers less than 225 amps shall be actuated and tested as required to prove positive disconnect in the off position.
   - Vacuum all panels
   - Verify all panel schedules are current and in place.

d. **Busways**; visually inspect, check security of all connections, perform maintenance on all disconnects and breakers as specified, vacuum all enclosures.

e. Perform testing and maintenance on all Motor Control Centers (MCC's) as specified.

f. Perform testing and maintenance on all breakers in the Essential Distribution Synchronizing Switchboard (EDSS), located in Bldg. 1 as specified.

g. Perform Testing and Maintenance on all Transformers with 13.2 KV primary voltage as listed in the following table.

TRANS-FORMER NUMBER	LOCATION	BUILDING NAME&NO FED	NORMALLY CONNECTED FEEDER	VOLT	KVA	TYPE
13	North of NHCU	NHCU	A	13.2/208	300	OIL
17	South of Bldg 2	Fiscal(Bldg 4), Env(Bldg 5), Pers/Eng(Bldg 6), Substance Abuse (Bldg 7), Nursing(Bldg 8)	B	13.2/208	225	OIL
18	South of Bldg 2	Boiler Plant, Laundry (Bldg 2)	B	13.2/208	500	OIL
19	Adjacent and south of main bldg 1	Main bldg 1	A	13.2/208	1500	OIL
22	South of Bldg 14	Warehouse (Bldg 14)	B	13.2/208	75	OIL
24	Outside Chiller Plant	Chiller Plant	B	13.2/208	750	OIL
26	North of Bldg 27	Outpatient Clinic (Bldg 27)	B	13.2/208	300	OIL
29	West of Eye clinic	Eye Clinic (Bldg 30), Dental (Bldg 33)	B	13.2/208	300	OIL
36	West of Business Center	Business Center (Bldg 32)		13.2/208		
Booster	Basement RM B010	Main Bldg 1, XRAY		208/480	300	DRY
	Basement RM B010	Main Bldg 1, CAT SCAN		208/480	150	DRY
	Basement RM B010	Main Bldg 1, XRAY		208/480	150	DRY
	2nd Floor RM C202A	Main Bldg 1		208/480	150	DRY

h. Conduct **visual and infared inspection** of all high voltage feeders and associated loadbreaks at high voltage electrical manholes.

Notes:

1. VA will provide all temporary power required during the testing process.
2. All breakers with electronic trip units may be tested utilizing secondary injection.
3. Bldg name is also referenced to transformer number.

ELECTRICAL TESTING & MAINTENANCE

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1. GENERAL SCOPE

1.5 SUBMITTALS: Furnish the following:

A. Contractor qualifications, testing equipment to include calibration certification, name and qualifications of persons performing testing and/or maintenance as required under the terms of the contract.

B. Test Plan:

1. Submit test plan including proposed method of testing, sample test reports and project schedule. Note required shutdowns and coordinate with Resident Engineer/COTR.
2. Update schedule weekly and review with the Resident Engineer/COTR.
3. Test plan report shall be typed and/or computerized reporting system.

C. Certification: At completion of testing, deliver to the Resident Engineer/COTR four copies of the following:

1. Certification that all testing has been completed in accordance with the contract requirements.

D. Reports:

1. Provide four (4) copies of typed listings to the facility's Engineering Office of all devices on which testing/maintenance was performed. Contractor shall note that emphasis and clarity should be placed on identifying location, and observed code deficiencies in order that information gathered may be properly evaluated. Notification to the facility's Engineering officer shall be submitted in writing immediately, describing any critical conditions, including recommendations for corrective action.
2. Any discrepancies noted shall be identified as to code violation and NEC Chapter and Paragraph.

2. APPLICABLE REFERENCES

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

1. American National Standards Institute – ANSI

2. American Society for Testing and Materials - ASTM

ANSI/ASTM D 92-90. *Test Method for Flash and Fire Points by Cleveland Open Cup*
ANSI/ASTM D 445-94. *Test Method for Kinematic Viscosity of Transparent and Opaque Liquids*
ASTM D 664-95. *Test Method for Acid Number of Petroleum Products by Potentiometric Titration*
ASTM D 877-87 (R1995). *Test Method for Dielectric Breakdown Voltage of Insulating Liquids using Disk Electrodes*
ASTM D 923-91. *Test Method for Sampling Electrical Insulating Liquids*

ASTM D 924-92. *Test Method for A-C Loss Characteristics and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids*
ANSI/ASTM D 971-91. *Test Method for Interfacial Tension of Oil Against Water by the Ring Method*
ASTM D 974-95. *Test Method for Acid and Base Number by Color-Indicator Titration*
ANSI/ASTM D 1298-85 (R1990). *Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*
ANSI/ASTM D 1500-91. *Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)*
ASTM D 1524-94. *Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field*
ASTM D 1533-88. *Test Methods for Water in Insulating Liquids (Karl Fischer Reaction Method)*
ASTM D 1816-84a (R1990). *Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes*
ASTM D 2029-92. *Test Methods for Water Vapor Content of Electrical Insulating Cases by Measurement of Dew Point*
ASTM D 2129-90. *Test Method for Color of Chlorinated Aromatic Hydrocarbons (Askarels)*
ASTM D 2284-95. *Test Method of Acidity of Sulfur Hexafluoride*
ASTM D 2285-85 (R1990). *Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin Against Water by the Drop-Weight Method*
ASTM D 2477-84 (R1990). *Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies*
ASTM D 2685-95. *Test Method for Air and Carbon Tetrafluoride in Sulfur Hexafluoride by Gas Chromatography*
ASTM D 2759-94. *Method for Sampling Gas from a Transformer under Positive Pressure*
ASTM D 3284-90a (R1994). *Test Method for combustible Gases in Electrical apparatus in the Field*
ASTM D 3612-95. *Test Method of Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography*
ASTM D 3613-92. *Methods of Sampling Electrical Insulating Oils for Gas Analysis and Determination of Water Content*

3. Association of Edison Illuminating Companies - AEIC

4. Institute of Electrical and Electronic Engineers - IEEE

ANSI/IEEE C2-1997, *National Electrical Safety Code*
ANSI/IEEE C37-1995, *Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses*
ANSI/IEEE C57-1995, *Distribution, Power, and Regulating Transformers*
ANSI/IEEE C62-1995, *Surge Protection*
ANSI/IEEE Std. 43-1974 (R1991). *IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery*

IEEE Std. 48-1996. *Standard Test Procedures and Requirements for High-Voltage AC Cable Terminations 2.5kV through 276kV*
IEEE Std. 81-1983. *IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System (Part I)*
ANSI/IEEE Std. 81.2-1991. *IEEE Guide for Measurement of Impedance and Safety Characteristics of Large, Extended, or Interconnected Grounding Systems (Part 2)*
ANSI/IEEE Std. 95-1977 (R1991). *IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage*
IEEE Std. 100-1996. *The IEEE Standard Dictionary of Electrical and Electronics Terms*
ANSI/IEEE Std. 141-1993. *IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants (IEEE Red Book.)*
ANSI/IEEE Std. 142-1991. *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)*
ANSI/IEEE Std. 241-1990. *IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book)*
ANSI/IEEE Std. 242-1986 (R1991). *IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)*
ANSI/IEEE Std. 399-1990. *IEEE Recommended Practice for Power Systems Analysis (Brown Book)*
ANSI/IEEE Std. 400-1991. *IEEE Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field*
ANSI/IEEE Std. 421B-1979. *IEEE Standard for High-Potential-Test Requirements for Excitation Systems for Synchronous Machines*
ANSI/IEEE Std. 446-1995. *IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)*
ANSI/IEEE Std. 450-1994. *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations*
ANSI/IEEE Std. 493-1990. *IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)*
ANSI/IEEE Std. 602-1996. *IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book)*
ANSI/IEEE Std. 637-1985 (R1992). *IEEE Guide for the Reclamation of Insulating Oil and Criteria for Its Use*
ANSI/IEEE Std. 739-1995. *IEEE Recommended Practice for Energy Conservation and Cost-Effective Planning in Industrial Facilities (Bronze Book)*
ANSI/IEEE Std. 1100-1992. *IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)*
ANSI/IEEE Std. 1106-1995. *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Storage Batteries for Generating Stations and Substations*

5. Insulated Cable Engineers Association - ICEA

6. InterNational Electrical Testing Association - NETA

NETA ATS-95. *NETA Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*

7. National Electrical Manufacturer's Association - NEMA

NEMA Standard for Publication No. AB4-1991. *Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications*
NEMA Publication MG1-1993. *Motors and Generators*

8. National Fire Protection Association - NFPA
ANSI/NFPA 70-1996. *National Electrical Code*
ANSI/NFPA 70B-1994. *Recommended Practice for Electric Equipment Maintenance*
ANSI/NFPA 70E-1995. *Electrical Safety Requirements for Employee Workplaces*
ANSI/NFPA 99-1993. *Standard for Healthcare Facilities*
ANSI/NFPA 101-1994. *Life Safety Code*
ANSI/NFPA 110-1993. *Emergency and Standby Power Systems*
ANSI/NFPA 780-1995. *Installation of Lightning Protection Systems*

9. Occupational Safety and Health Administration - OSHA

10. Scaffold Industry Association - SIA
ANSI/SIA A92.2-1990. *Vehicle Mounted Elevating and Rotating Aerial Devices*

11. State and local codes and ordinances

12. Underwriters Laboratories, Inc. - UL

3. Reserved

4. DIVISION OF RESPONSIBILITY

4.1 The owner shall supply a suitable and stable source of electrical power to each test site. The testing firm shall specify the specific power requirements.

4.2 The owner shall notify the testing firm when equipment becomes available for maintenance tests. Work shall be coordinated to expedite project scheduling.

4.3 The owner shall supply a complete set of electrical plans, specifications. Contractor to verify protective device settings on all devices.

4.4 The testing firm shall notify the owner prior to commencement of any testing.

4.5 Any system, material, or workmanship which is found defective on the basis of maintenance tests shall be reported.

4.6 The testing firm shall maintain a written record of all tests and shall assemble and certify a final test report.

4.7 **Safety and Precautions**

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

    1. Current Occupational Safety and Health regulations
    2. National Safety Council, Accident Prevention Manual for Industrial Operations
    3. Applicable state and local safety operating procedures
    4. Owner's safety practices
    5. ANSI/NFPA 70E, Electrical Safety Requirements for Employee Workplaces
    6. OSHA 29 CFR 1910.147. Control of Hazardous Energy Sources (Lockout*/Tagout)*

2. All tests shall be performed with apparatus de-energized except where otherwise specifically required.

3. The testing organization shall have a designated safety representative on the project to supervise operations with respect to safety.

5. GENERAL

5.1 **Suitability of Test Equipment**

1. All test equipment shall be in good mechanical and electrical condition.

2. Split-core current transformers and clamp-on or tong-type ammeters require careful consideration of the following in regard to accuracy:

    1. Position of the conductor within the core
    2. Clean, tight fit of the core pole faces
    3. Presence of external fields
    4. Accuracy of the current transformer ratio in addition to the accuracy of the secondary meter

3. Selection of metering equipment should be based on a knowledge of the waveform of the variable being measured. Digital multi meters may be average or rms sensing and may include or exclude the dc component. When the variable contains harmonics or dc offset and, in general, any deviation from a pure sine wave, average sensing, rms scaled meters may be misleading.

4. Field test metering used to check power system meter calibration must have an accuracy higher than that of the instrument being checked.

5. Accuracy of metering in test equipment shall be appropriate for the test being performed but not in excess of two percent of the scale used.

6. Wave shape and frequency of test equipment output waveforms shall be appropriate for the test and the tested equipment.

5.2 **Test Instrument Calibration**

1. The testing firm shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy.

2. The accuracy shall be directly traceable to the National Institute of Standards and Technology (NIST).

3. Instruments shall be calibrated in accordance with the following frequency schedule:

    1. Field instruments: Analog, 6 months maximum. Digital, 12 months maximum
    2. Laboratory instruments: 12 months
    3. Leased specialty equipment: 12 months where accuracy is guaranteed by lessor

4. Dated calibration labels shall be visible on all test equipment.

5. Records, which show date and results of instruments calibrated or tested, must be kept up-to-date.

6. Up-to-date instrument calibration instructions and procedures shall be maintained for each test instrument.

7. Calibrating standard shall be of higher accuracy than that of the instrument tested.

5.3 **Test Report**

1. The test report shall include the following:

    1. Summary of project
    2. Description of equipment tested
    3. Description of test
    4. Test results
    5. Analysis and recommendations

2. Furnish three (3) copies of the complete report to the owner as required in the maintenance contract.

6. POWER SYSTEM STUDIES (not applicable)

7. INSPECTION & TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies

1. Visual and Mechanical Inspection

    1. Compare equipment nameplate data with latest one-line diagram.
    2. Inspect physical, electrical, and mechanical condition including evidence of moisture or corona.
    3. Verify appropriate anchorage, required area clearances, physical damage, and correct alignment.
    4. ~~**Physically Check and record the fuse and/or circuit breaker sizes and types for all devices correspond to drawings.**~~
    6. Inspect all bus connections for high resistance using one of the following methods:

        1. Use of low-resistance ohmmeter in accordance with Section **7.1**.2.3 (Electrical Tests).
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

    7. Confirm correct operation and sequencing of electrical and mechanical interlock systems.

        1. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
        2. Make key exchange with devices operated in off-normal positions.

    8. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.

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

    10. Verify correct barrier and shutter installation and operation.

    11. Lubrication

        1. Verify appropriate contact lubricant on moving current-carrying parts.
        2. Verify appropriate lubrication on moving and sliding surfaces.

    12. Exercise all active components.

    13. Inspect all mechanical indicating devices for correct operation.

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

15. Test operation, alignment, and penetration of instrument transformer withdrawal disconnects, current-carrying and grounding, in accordance with Section **7.10**.

16. Inspect for control power transformers.

    1. Inspect for physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
    2. Verify that primary and secondary fuse ratings or circuit breakers match drawings.
    3. Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.

2. **Electrical Tests**

    1. Perform tests on all instrument transformers in accordance with Section **7.10**.

    2. Perform ground-resistance tests in accordance with Section **7.13**.

    3. Perform resistance measurements through all bus joints with a low-resistance ohmmeter, if applicable, in accordance with Section **7.1**.1.6 (Visual and Mechanical Inspection).

    4. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground for one minute in accordance with Table 10.1.

    5. Perform system function tests in accordance with Section **8**.

    6. Control Power Transformers

        1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with Table 10.1 unless otherwise specified by manufacturer.
        2. Verify correct function of control transfer relays located in switchgear with multiple power sources.

    7. Voltage (Potential) Transformers

        1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with Table 10.1 unless otherwise specified by manufacturer.
        2. Verify secondary voltages.

    8. Verify operation of switchgear/switchboard heaters.

3. **Test Values**

   1. Compare bus connection resistances to values of similar connections.

   2. ~~Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.~~

   3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar bus by more than 25 percent of the lowest value.

   4. Insulation-resistance values for bus, control wiring, and control power transformers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 10.1. Values of insulation resistance less than this table or manufacturer's minimum should be investigated. Over potential tests should not proceed until insulation-resistance levels are raised above minimum values.

   5. The insulation shall withstand the over potential test voltage applied.

7.2 Transformers

1. Dry Type
Air-Cooled, 600 Volt and Below - Small
(167 kVA Single-Phase, 500 kVA 3-Phase, and Smaller)

1. **Visual and mechanical inspection.**

   1. Inspect physical and mechanical condition.

   2. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
   ~~Physically Check and record the fuse and/or circuit breaker sizes and types for all devices correspond to drawings.~~

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

      1. Use of low-resistance ohmmeter in accordance with Section **7.2.1.1.**2.1 (Electrical Tests).
      2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

2. **Electrical Tests**

   1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.2.1.1.**1.3 (Visual and Mechanical Inspection).

2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground with test voltage in accordance with Table 10.5. Calculate polarization index.

3. Perform turns ratio tests at the designated tap position.

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

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

4. Insulation-resistance test values at one minute should not be less than values recommended in Table 10.5. Results shall be temperature corrected in accordance with Table 10.14.

5. The polarization index should be compared to previously obtained results.

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

2. Air-Cooled, All Above 600 Volt and 600 Volt and Below - Large (Greater than 167 Single-Phase and 500 kVA 3-Phase)

1. **Visual and Mechanical Inspection**

1. Inspect physical, electrical, and mechanical condition including evidence of moisture, corona, or brittleness.

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

3. Verify that cooling fans operate.

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

1. Use of low-resistance ohmmeter in accordance with Section **7.2.1.2.**2.2 (Electrical Tests).

2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

5. Perform specific inspections and mechanical tests as recommended by manufacturer.

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

7. Verify that the core, frame, and enclosure are grounded.

8. Verify the presence of transformer surge arresters.

9. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.

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

2. **Electrical Tests**

1. Perform insulation-resistance tests winding-to-winding and each winding-to-ground, with test voltage in accordance with Table 10.5. Calculate polarization index.

2. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.2.1.2.**1.4 (Visual and Mechanical Inspection).

3. Perform turns-ratio tests at the designated tap position.

4. Perform an excitation-current test on each phase.

5. Measure the resistance of each winding at the designated position.

6. Measure core insulation-resistance at 500 volts dc if core is insulated and if the core ground strap is removable.

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

8. Perform power factor tests on all transformers and bushings.

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

4. Insulation-resistance test values at one minute should not be less than values recommended in Table 10.5. Results shall be temperature corrected in accordance with Table 10.14.

5. The polarization index should be compared to previously obtained results.

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

7. Winding-resistance test results should compare within one percent of previously obtained results after factoring in temperature correction.

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

9. Core insulation resistance values should be comparable to previously obtained results but not less than one megohm at 500 volts dc.

3. Liquid-Filled

1. **Visual and Mechanical Inspection**

   1. Inspect physical and mechanical condition.

   2. ***Verify that alarm, control, and trip settings on temperature indicators are as specified.***

   3. Verify that cooling fans and/or pumps operate correctly.

   4. Verify operation of all alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relay.

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

      1. Use of low-resistance ohmmeter in accordance with Section **7.2.2.**2.2 (Electrical Tests).
      2. ***Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.***

   6. Verify correct liquid level in all tanks and bushings.

7. Verify that positive pressure is maintained on nitrogen-blanketed transformers.

8. Perform specific inspections and mechanical tests as recommended by manufacturer.

9. Verify correct equipment grounding.

10. Test load tap-changer in accordance with Section 7.12, if applicable.

11. Verify the presence of transformer surge arresters.

2. **Electrical Tests**

1. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground, with test voltage in accordance with Table 10.5. Test duration shall be for ten minutes with resistances tabulated at 30 seconds, one minute, and ten minutes. Calculate polarization index.

2. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.2.1.5 (Visual and Mechanical Inspection).

3. Perform turns-ratio tests at the designated tap position.

4. Measure the resistance of each winding at the designated tap position.

5. If core ground strap is accessible, measure core insulation resistance at 500 volts dc.

6. Measure the percentage of oxygen in the nitrogen gas blanket, if applicable.

7. Remove a sample of insulating liquid in accordance with ASTM D923. Sample shall be tested in accordance with the referenced standard.

    1. Dielectric breakdown voltage: ASTM D877 and/or ASTM D1816
    2. Acid neutralization number: ANSI/ASTM D974
    3. Specific gravity: ANSI/ASTM D1298
    4. Interfacial tension: ANSI/ASTM D971 or ANSI/ASTM D2285
    5. Color: ANSI/ASTM D1500
    6. Visual Condition: ASTM D1524
    7. Parts per million water: ASTM D1533. Required on 25 kV or higher voltages and on all silicone-filled units.
    8. Measure dissipation factor or power factor in accordance with ASTM D924.

8. Remove a sample of insulating liquid in accordance with ASTM D3613 and perform dissolved gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D3612.

9. Perform power factor tests on all transformers and bushings.

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Micro ohm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

4. Insulation-resistance test values at one minute should not be less than values recommended in Table 10.5. Resistance values to be temperature corrected in accordance with Table 10.14.

5. The polarization index should be compared to previously obtained results.

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

7. Maximum power factor of liquid-filled transformers corrected to 20□C shall be in accordance with transformer manufacturer's published data. Representative values are indicated in Table 10.3. Compare with test equipment manufacturer's published data.

8. Investigate bushing power factors and capacitances that vary from nameplate values by more than ten percent. Investigate any bushing hot collar watts-loss results that exceed the test equipment manufacturer's published data.

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

10. Winding-resistance measurements should compare within one percent of previously obtained results after factoring in temperature correction.

11. Core insulation values should be comparable to previously obtained results but not less than one megohm at 500 volts dc.

12. Investigate presence of oxygen in nitrogen gas blanket.

13. Insulating liquid shall be in accordance with Table 10.4.

14. Evaluate results of dissolved-gas analysis in accordance with ANSI/IEEE Standard C57.104.

7.3 Cables

1. Low-Voltage, 600 Volt Maximum (This shall be limited to feeders from transformers to main switchboards and feeders from main switchboards to distribution panels)

1. **Visual and Mechanical Inspection**

    1. Inspect exposed sections of cables for physical damage and evidence of overheating.
    2. ***Inspect all bolted electrical connections for high resistance using one of the following methods:***

        1. Use of low-resistance ohmmeter in accordance with Section **7.3.1.**2.2 (Electrical Tests).
        2. ***Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.***

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

2. **Electrical Tests**

    1. Perform insulation-resistance tests on each cable phase-to-phase and phase-to-ground. Applied potential to be 1000 volts dc for one minute.
    2. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.3.1.**1.2 (Visual and Mechanical Inspection).

3. **Test Values**

    1. Compare bolted connection resistances to values of similar connections.
    2. ***Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by the manufacturer.***
    3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.
    4. Minimum insulation-resistance values should be comparable to previously obtained results but not less than two megohms.
    5. Investigate deviations between adjacent phases.

2. **Medium-Voltage, 69 kV Maximum**

1. **Visual and Mechanical Inspection**

    1. Inspect exposed sections of cables for physical damage and evidence of overheating and corona.
    2. Inspect terminations and splices for evidence of overheating and corona.
    3. Inspect all bolted electrical connections for high resistance using one of the following methods:

        1. Use of low-resistance ohmmeter in accordance with Section **7.3.2.**2.3 (Electrical Tests).
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

    4. Inspect compression-applied connectors for correct cable match and indentation.
    5. Inspect for shield grounding, cable support, and termination.
    6. Verify that visible cable bends meet or exceed ICEA and/or manufacturer's minimum allowable bending radius.
    7. Inspect fireproofing in common cable areas, if specified.
    8. If cables are terminated through window-type current transformers, make an inspection to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.

2. **Electrical Tests**

    1. Perform a shield-continuity test on each power cable by ohmmeter method.
    2. Perform an insulation-resistance test utilizing a megohmmeter with a voltage output of at least 2500 volts. Individually test each conductor with all other conductors and shields grounded. Test duration shall be one minute.
    3. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.3.2.**1.3 (Visual and Mechanical Inspection).
    4. Perform a dc high-potential test on all cables. Adhere to all precautions and limits as specified in the applicable NEMA/ICEA Standard for the specific cable. Perform tests in accordance with ANSI/IEEE Standard 400. Test procedure shall be as follows, and the results for each cable test shall be recorded as specified herein. Test voltages shall not exceed 60 percent of cable manufacturer's factory test value or the maximum test voltage in Table 10.6.

        1. Insure that the input voltage to the test set is regulated.
        2. Current-sensing circuits in test equipment shall measure only the leakage current associated with the cable under test and shall not include internal leakage of the test equipment.

3. Record wet- and dry-bulb temperatures or relative humidity and temperature.
4. Test each section of cable individually.
5. Individually test each conductor with all other conductors grounded. Ground all shields.
6. Terminations shall be adequately corona-suppressed by guard ring, field reduction sphere, or other suitable methods as necessary.
7. Insure that the maximum test voltage does not exceed the limits for terminators specified in ANSI/IEEE Standard 48 or manufacturer's specifications.
8. Apply a dc high-potential test in at least five equal increments until maximum test voltage is reached. No increment shall exceed the voltage rating of the cable. Record dc leakage current at each step after a constant stabilization time consistent with system charging current.
9. Raise the conductor to the specified maximum test voltage and hold for five minutes. Record readings of leakage current at 30 seconds and one minute and at one minute intervals thereafter.
10. Reduce the conductor test potential to zero and measure residual voltage at discrete intervals.
11. Apply grounds for a time period adequate to drain all insulation stored charge.

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.
4. Shielding must exhibit continuity. Investigate resistance values in excess of ten ohms per 1000 feet of cable.
5. Graphic plots may be made of leakage current versus step voltage at each increment and leakage current versus time at final test voltages.
6. The step voltage slope should be reasonably linear.
7. Capacitive and absorption current should decrease continually until steady state leakage is approached.
8. Compare test results to previously obtained results.

3. High-Voltage

1. **Visual and Mechanical Inspection**

1. Inspect exposed sections of cables for physical damage and evidence of overheating and corona.
2. Inspect terminations and splices for evidence of overheating and corona.

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

    1. Use of low-resistance ohmmeter in accordance with Section **7.3.3.**2.3 (Electrical Tests).
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

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

5. Inspect for shield grounding, cable support, and termination.
6. Verify that visible cable bends meet or exceed ICEA and/or manufacturer's minimum allowable bending radius.
7. Inspect fireproofing in common cable areas, if specified.
8. If cables are terminated through window-type current transformers, make an inspection to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.

2. **Electrical Tests**

1. Perform a shield-continuity test on each power cable by ohmmeter method.
2. Perform an insulation-resistance test utilizing a megohmmeter with a voltage output of at least 2500 volts. Individually test each conductor with all other conductors and shields grounded. Test duration shall be one minute.
3. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.3.3.1.3 (Visual and Mechanical Inspection).
4. Perform a dc high-potential test on all cables. Adhere to all precautions and limits as specified in the applicable NEMA/ICEA Standard for the specific cable. Perform tests in accordance with ANSI/IEEE Standard 400. Test procedure shall be as follows, and the results for each cable test shall be recorded as specified herein. Test voltages shall not exceed 60 percent of cable manufacturer's factory test value or the maximum test voltage in Table 10.6.

    1. Insure that the input voltage to the test set is regulated.
    2. Current-sensing circuits in test equipment shall measure only the leakage current associated with the cable under test and shall not include internal leakage of the test equipment.
    3. Record wet- and dry-bulb temperatures or relative humidity and temperature.
    4. Test each section of cable individually.
    5. Individually test each conductor with all other conductors grounded. Ground all shields.

6. Terminations shall be adequately corona-suppressed by guard ring, field reduction sphere, or other suitable methods as necessary.
7. Insure that the maximum test voltage does not exceed the limits for terminators specified in ANSI/IEEE Standard 48 or manufacturer's specifications.
8. Apply a dc high-potential test in at least five equal increments until maximum test voltage is reached. No increment shall exceed the voltage rating of the cable. Record dc leakage current at each step after a constant stabilization time consistent with system charging current.
9. Raise the conductor to the specified maximum test voltage and hold for five minutes. Record readings of leakage current at 30 seconds and one minute and at one minute intervals thereafter.
10. Reduce the conductor test potential to zero and measure residual voltage at discrete intervals.
11. Apply grounds for a time period adequate to drain all insulation stored charge.

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.
4. Shielding must exhibit continuity. Investigate resistance values in excess of ten ohms per 1000 feet of cable.
5. Graphic plots may be made of leakage current versus step voltage at each increment and leakage current versus time at final test voltages.
6. The step voltage slope should be reasonably linear.
7. Capacitive and absorption current should decrease continually until steady state leakage is approached.
8. Compare test results to previously obtained results.

7.4 Metal-Enclosed Busways

1. Visual and Mechanical Inspection

1. Inspect busway for physical damage and evidence of corona.
2. ***Inspect for appropriate bracing, suspension, alignment, and enclosure ground***.
3. ***Inspect all bolted electrical connections for high resistance using one of the following methods***:

    1. Use of low-resistance ohmmeter in accordance with Section **7.4.**2.3 (Electrical Tests).

2. ***Verify tightness of accessible bolted electrical*** connections and bus joints by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

4. Confirm physical orientation in accordance with manufacturer's labels to insure adequate cooling.
5. Examine outdoor busway for removal of "weep-hole" plugs, if applicable, and the correct installation of joint shield.
6. Inspect and clean all ventilating openings.

2. **Electrical Tests**

   1. Measure insulation resistance of each busway, phase-to-phase and phase-to-ground for one minute, in accordance with Table 10.1.
   2. Perform an over potential test on each busway, phase-to-ground with phases not under test grounded, in accordance with Table 10.17. Where no dc test value is shown in Table 10.17, ac value shall be used. The test voltage shall be applied for one minute.
   3. ***Perform infared inspection of all all bolted connections and bus joints to determine the existence of any high resistance connections.***
   4. Verify operation of busway heaters.

3. **Test Values**

   1. Compare bolted connection resistances to values of similar connections.
   2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
   3. Micro ohm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar bus joints and connections by more than 25 percent of the lowest value.
   4. Insulation-resistance test voltages and resistance values shall be in accordance with manufacturer's specifications or Table 10.1. Minimum resistance values are for a nominal 1000-foot busway run or megohms for 1000 feet. For busway runs over 1000 feet, derate accordingly by the formula:

$$R_{1000ft} = \text{Measured Re sis tan ce x } \frac{\text{Length of Run}}{1000}$$

   Values of insulation resistance less than this table or manufacturer's minimum should be investigated. Overpotential tests should not proceed until insulation-resistance levels are raised above minimum values.

   5. The insulation shall withstand the overpotential test voltage applied.

7.5 Switches

1. **Air Switches**
1. **Low-Voltage**

1. **Visual and Mechanical Inspection**

    1. Inspect physical and mechanical condition.
    2. Verify appropriate anchorage and required area clearances.
    3. Verify appropriate equipment grounding.
    4. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
    5. Verify that fuse sizes and types are in accordance with drawings and short-circuit and coordination studies.
    6. Verify that each fuse holder has adequate mechanical support.
    7. Inspect all bolted electrical connections for high resistance using one of the following methods:

        1. Use of low-resistance ohmmeter in accordance with Section **7.5.1.1.**2.4 (Electrical Tests).
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

    8. Test all interlocking systems for correct operation and sequencing.
    9. Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
    10. Exercise all active components.
    11. Verify all indicating and control devices.
    12. Verify operation of heaters, if applicable.
    13. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
    14. Lubrication

        1. Verify appropriate contact lubricant on moving current-carrying parts.
        2. Verify appropriate lubrication on moving and sliding surfaces.

2. **Electrical Tests**

    1. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute. Test voltage shall be in accordance with manufacturer's published data or Table 10.1.
    2. Measure contact-resistance across each switchblade and fuse holder.
    3. Measure fuse resistance.
    4. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.5.1.1.**1.7 (Visual and Mechanical Inspection).
    5. Perform ground-fault test in accordance with Section **7.14**, if applicable.

3. **Test Values**

   1. Compare bolted connection resistances to values of similar connections.
   2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
   3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar switches by more than 25 percent of the lowest value.
   4. Minimum insulation resistance shall be in accordance with manufacturer's published data or Table 10.1.
   5. Investigate fuse-resistance values that deviate from each other by more than 15 percent.

2. Medium-Voltage, Metal-Enclosed

1. **Visual and Mechanical Inspection**

   1. Inspect physical and mechanical condition.
   2. Verify appropriate anchorage and required area clearances.
   3. Verify appropriate equipment grounding.
   4. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
   5. Verify that fuse sizes and types are in accordance with drawings and short-circuit and coordination studies.
   6. Verify that expulsion-limiting devices are in place on all holders having expulsion-type elements.
   7. Verify that each fuse holder has adequate mechanical support.
   8. Inspect all bolted electrical connections for high resistance using one of the following methods:

      1. Use of low-resistance ohmmeter in accordance with Section **7.5.1.2.**2.3 (Electrical Tests).
      2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

   9. Test all interlocking systems for correct operation and sequencing.
   10. Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
   11. Exercise all active components.
   12. Compare switchblade clearances with industry standards.
   13. Verify all indicating and control devices for correct operation.
   14. Verify operation of heaters, if applicable.
   15. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.

16. Lubrication

    1. Verify appropriate contact lubricant on moving current-carrying parts.
    2. Verify appropriate lubrication on moving and sliding surfaces.

2. **Electrical Tests**

    1. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute. Test voltage shall be in accordance with manufacturer's published data or Table 10.1.
    2. Perform an overpotential test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 10.2.
    3. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.5.1.2.**1.8 (Visual and Mechanical Inspection).
    4. Measure contact resistance across each switchblade and fuse holder.
    5. Measure fuse resistance.

3. **Test Values**

    1. Compare bolted connection resistances to values of similar connections.
    2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
    3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar switches by more than 25 percent of the lowest value.
    4. The insulation shall withstand the overpotential test voltage applied.
    5. Insulation resistance shall be in accordance with Table 10.1.
    6. Investigate fuse resistance values that deviate from each other by more than 15 percent.

3. High- and Medium-Voltage, Open

1. **Visual and Mechanical Inspection**

    1. Inspect physical and mechanical condition.
    2. Verify appropriate equipment grounding.
    3. Inspect all bolted electrical connections for high resistance using one of the following methods:

        1. Use of low-resistance ohmmeter in accordance with Section **7.5.1.3.**2.1 (Electrical Tests).

2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

4. Perform mechanical operator tests in accordance with manufacturer's published data, if applicable.
5. Verify correct operation and adjustment of motor operator limit-switches and mechanical interlocks, if applicable.
6. Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation.

7. Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
8. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
9. Lubrication

   1. Verify appropriate contact lubricant on moving current-carrying parts.
   2. Verify appropriate lubrication on moving and sliding surfaces.

2. **Electrical Tests**

   1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.5.1.3.**1.3 (Visual and Mechanical Inspection).
   2. Perform insulation-resistance tests on each pole phase-to-ground with switch closed for one minute. Test voltage should be in accordance with manufacturer's published data or Table 10.1.
   3. Perform an overpotential test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 10.19.
   4. Perform contact-resistance test across each switchblade and fuse holder.

3. **Test Values**

   1. Compare bolted connection resistances to values of similar connections.
   2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
   3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar switches by more than 25 percent of the lowest value.
   4. Insulation resistance values shall be in accordance with manufacturer's data or Table 10.1.
   5. The insulation shall withstand the overpotential test voltage applied.

2. Oil Switches: Medium-Voltage

1. **Visual and Mechanical Inspection**

    1. Inspect physical and mechanical condition.
    2. Inspect anchorage, alignment, and grounding.
    3. Perform mechanical operator tests in accordance with manufacturer's published data, if applicable.
    4. Verify correct operation and adjustment of motor operator limit-switches and mechanical interlocks, if applicable.
    5. Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation.
    6. Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
    7. Check each fuse holder for adequate support and contact.
    8. Verify that fuse sizes and types correspond to drawings.
    9. Test all electrical and mechanical interlock systems for correct operation and sequencing.
    10. Inspect all bolted electrical connections for high resistance using one of the following methods:

        1. Use of low-resistance ohmmeter in accordance with Section **7.5.2.**2.2 (Electrical Tests).
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

    11. Verify that insulating oil level is correct.
    12. Inspect and/or replace gaskets as recommended by the manufacturer as required.
    13. Lubrication

        1. Verify appropriate contact lubricant on moving current-carrying parts.
        2. Verify appropriate lubrication on moving and sliding surfaces.

    14. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
    15. Record as-found and as-left operation counter readings, if applicable.

2. **Electrical Tests**

    1. Perform a contact-resistance test.
    2. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.2.1.10 (Visual and Mechanical Inspection).
    3. Remove a sample of insulating liquid in accordance with ASTM D923. Sample shall be tested in accordance with the referenced standard.

1. Dielectric breakdown voltage: ASTM D877
2. Color: ANSI/ASTM D1500
3. Visual condition: ASTM D1524

4. Perform insulation-resistance tests pole-to-pole, pole-to-ground, and across open poles at 2500 volts minimum.
5. Perform insulation resistance test on all control wiring at 1000 volts dc. For units with solid-state components, follow manufacturer's recommendations.
6. Perform an overpotential test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 10.19.

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar switches by more than 25 percent of the lowest value.

4. Insulating liquid shall be in accordance with Table 10.4.
5. Control wiring insulation resistance shall be a minimum of two megohms.
6. The insulation shall withstand the overpotential test voltage applied.

3. Vacuum Switches: Medium-Voltage

1. **Visual and Mechanical Inspection**

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Perform mechanical operator tests in accordance with manufacturer's published data, if applicable.
4. Verify correct operation and adjustment of motor operator limit-switches and mechanical interlocks, if applicable.
5. Measure critical distances such as contact gap as recommended by manufacturer.
6. Inspect all bolted electrical connections for high resistance using one of the following methods:

    1. Use of low-resistance ohmmeter. See Section **7.5.3.**2.1 Electrical Tests).
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

7. Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
8. Check each fuse holder for adequate support and contact.
9. Verify that fuse sizes and types correspond to drawings.
10. Test all electrical and mechanical interlock systems for correct operation and sequencing.
11. Verify oil level, if applicable.
12. Lubrication

    1. Verify appropriate contact lubricant on moving current-carrying parts.
    2. Verify appropriate lubrication on moving and sliding surfaces.

13. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
14. Record as-found and as-left operation counter readings, if applicable.

2. **Electrical Tests**

    1. Perform resistance measurements through all bus joints with a low-resistance ohmmeter, if applicable. See Section 7.5.3.1.7 (Visual and Mechanical Inspection).
    2. Perform a contact-resistance test.
    3. Verify open and close operation from control devices, if applicable.
    4. Perform insulation-resistance tests pole-to-pole, pole-to-ground, and across open poles at 2500 volts minimum.
    5. Perform vacuum bottle integrity (overpotential) test across each vacuum bottle with the switch in the open position in strict accordance with manufacturer's published data. **Do not exceed maximum voltage stipulated for this test.** Provide adequate barriers and protection against x-radiation during this test. Do not perform this test unless the contact displacement of each interrupter is within manufacturer's tolerance. (Be aware that some dc high-potential test sets are half-wave rectified and may produce peak voltages in excess of the switch manufacturer's recommended maximum.)
    6. (Deleted)
    7. Perform insulation-resistance test on all control wiring at 1000 volts dc. For units with solid-state components, follow manufacturer's recommendations.
    8. Perform an overpotential test in accordance with manufacturer's published data.

3. **Test Values**

    1. Compare bolted connection resistances to values of similar connections.
    2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar switches by more than 25 percent of the lowest value.
4. Contact displacement shall be in accordance with factory recorded data marked on the nameplate of each vacuum switch or bottle.
5. The vacuum bottles shall withstand the overpotential voltage applied.
6. Control wiring insulation resistance shall be a minimum of two megohms.
7. The insulation shall withstand the overpotential test voltage applied.
8. Insulating liquid shall be in accordance with Table 10.4.

7.6 Circuit Breakers

1. Low-Voltage

1. Insulated Case/Molded Case

1. **Visual and Mechanical Inspection**

   1. Inspect circuit breaker for correct mounting.
   2. Operate circuit breaker to insure smooth operation.
   3. Inspect case for cracks or other defects.
   4. Inspect all bolted electrical connections for high resistance using one of the following methods:

      1. Use of low-resistance ohmmeter in accordance with Section **7.6.1.1.**2.3 (Electrical Tests).
      2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

   5. Inspect mechanism contacts and arc chutes in unsealed units.

2. **Electrical Tests**

   1. Perform a contact-resistance test.
   2. Perform an insulation-resistance test at 1000 volts dc from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase.
   3. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.6.1.1.**1.4 (Visual and Mechanical Inspection).
   4. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and antipump function.
   5. Verify the calibration of all functions of the trip unit by means of secondary injection for breakers having electronic trip units, otherwise utilize primary injection.

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
3. Micro ohm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar breakers by more than 25 percent of the lowest value.
4. Circuit breaker insulation resistance shall be in accordance with Table 10.1.
5. Control wiring insulation resistance shall be a minimum of two megohms.
6. Trip characteristic of breakers shall fall within manufacturer's published time-current characteristic tolerance band, including adjustment factors.
7. For molded-case circuit breakers all trip times shall fall within Table 10.7. Circuit breakers exceeding specified trip time at 300 percent of pickup shall be tagged defective.
8. For molded-case circuit breakers instantaneous pickup values shall be within values shown in Table 10.8.

2. Power

1. **Visual and Mechanical Inspection**

    1. Inspect physical and mechanical condition.
    2. Inspect anchorage, alignment, and grounding. Inspect arc chutes. Inspect moving and stationary contacts for condition, wear, and alignment.
    3. Verify that all maintenance devices are available for servicing and operating the breaker.
    4. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
    5. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism.
    6. Inspect all bolted electrical connections for high resistance using one of the following methods:

        1. Use of low-resistance ohmmeter in accordance with Section **7.6.1.2.**2.3 (Electrical Tests).
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

    7. Verify cell fit and element alignment.
    8. Verify racking mechanism.
    9. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
    10. Lubrication

1. Verify appropriate contact lubricant on moving current-carrying parts.
2. Verify appropriate lubrication on moving and sliding surfaces.

2. **Electrical Tests**

1. Perform a contact-resistance test.
2. Perform an insulation-resistance test at 1000 volts dc from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase.
3. Inspect all bolted electrical connections for high resistance using one of the following methods:

    1. Use of low-resistance ohmmeter in accordance with Section **7.6.1.2.**1.6 (Visual and Mechanical Inspection).
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

4. Make adjustments for the final settings in accordance with the coordination study supplied by owner.
5. Determine minimum pickup current by primary current injection.
6. Determine long-time delay by primary current injection.
7. Determine short-time pickup and delay by primary current injection.
8. Determine ground-fault pickup and delay by primary current injection.
9. Determine instantaneous pickup value by primary current injection.
10. Verify the calibration of all functions of the trip unit by means of secondary injection.
11. Activate auxiliary protective devices, such as ground-fault or undervoltage relays, to insure operation of shunt trip devices. Check the operation of electrically-operated breakers in their cubicles.

12. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and antipump function.
13. Verify operation of charging mechanism.

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
3. Micro ohm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar breakers by more than 25 percent of the lowest value.
4. Circuit breaker insulation resistance shall be in accordance with Table 10.1.

5. Control wiring insulation resistance shall be a minimum of two megohms.
6. Trip characteristics of breakers shall fall within manufacturer's published time-current tolerance bands.

4. Medium-Voltage
1. Air

1. **Visual and Mechanical Inspection**

    1. Inspect physical and mechanical condition.
    2. Inspect anchorage, alignment, and grounding. Inspect arc chutes. Inspect moving and stationary contacts for condition, wear, and alignment.
    3. Verify that all maintenance devices are available for servicing and operating the breaker.
    4. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
    5. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism.

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

        1. Use of low-resistance ohmmeter in accordance with Section **7.6.2.1.**2.3 (Electrical Tests).
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

    7. Verify cell fit and element alignment.
    8. Verify racking mechanism.
    9. Inspect puffer operation.
    10. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
    11. Lubrication:

        1. Verify appropriate contact lubricant on moving current-carrying parts.
        2. Verify appropriate lubrication on moving and sliding surfaces.

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

2. **Electrical Tests**

    1. Perform a contact-resistance test.
    2. Measure insulation resistance pole-to-pole, pole-to-ground, and across open poles. Use a minimum test voltage of 2500 volts.
    3. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable. See Section **7.6.2.1.**1.6 (Visual and Mechanical Inspection).

4. With breaker in the test position, make the following tests:

    1. Trip and close breaker with the control switch.
    2. Trip breaker by operating each of its protective relays.
    3. Verify trip-free and antipump function.
    4. Perform minimum pickup voltage tests on trip and close coils.

5. Measure blow-out coil circuit resistance.

3. **Test Values**

    1. Compare bolted connection resistances to values of similar connections.
    2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
    3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar breakers by more than 25 percent of the lowest value.
    4. Circuit breaker insulation resistance shall be in accordance with Table 10.1.
    5. Control wiring insulation resistance shall be a minimum of two megohms.
    6. Dissipation-factor/power-factor test results shall be compared with previous tests of similar breakers or manufacturer's published data.
    7. The insulation shall withstand the overpotential test voltage applied.
    8. Minimum pickup for trip and close coils shall conform to manufacturer's published data.

2. Oil (Not Applicable)

3. Vacuum (Not Applicable)

4. SF_6 (Not Applicable)

7.7 Circuit Switchers

1. Visual and Mechanical Inspection

    1. Inspect physical and mechanical condition.
    2. Lubrication

        1. Verify appropriate contact lubricant on moving current-carrying parts.
        2. Verify appropriate lubrication on moving and sliding surfaces.

    3. Inspect anchorage, alignment, and grounding.
    4. Perform all mechanical operational tests on both the circuit switcher and its operating mechanism.
    5. Inspect all bolted electrical connections for high resistance using one of the following methods:

1. Use of low-resistance ohmmeter. See Section 7.7.2.1 (Electrical Tests).
2. Verify tightness of accessible bolted electrical connections by calibrated torque- wrench method in accordance with manufacturer's published data or Table 10.12.

6. Verify correct operation of SF_6 interrupters.
7. Verify correct SF_6 pressure.
8. Verify correct operation of isolating switch.
9. Record as-found and as-left operation counter readings.

2. **Electrical Tests**

1. Perform resistance measurements through all connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.7.**1.5 (Visual and Mechanical Inspection).
2. Perform contact-resistance test of interrupters and isolating switches.
3. Perform minimum pickup voltage tests on trip and close coils.
4. Trip circuit switcher by operation of each protective device.
5. Verify correct operation of electrical shunt trip of interrupters.
6. Perform insulation-resistance tests pole-to-pole, pole-to-ground, and across open poles at 15,000 volts minimum.
7. Perform an overpotential test in accordance with manufacturer's published data.

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
3. Micro ohm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar switchers by more than 25 percent of the lowest value.
4. Minimum pickup for trip and close coils shall conform to manufacturer's published data.
5. Circuit switcher insulation resistance shall be in accordance with Table 10.1.
6. Control wiring insulation resistance shall be a minimum of two megohms.
7. The insulation shall withstand the over potential test voltage applied.

7.8 Network Protectors, 600 Volt Class

1. **Visual and Mechanical Inspection**

1. Open the protector and rack it out of the enclosure. Note that the network bus and transformer generally will be energized. Exercise extreme caution. Observe clearances and check for smoothness of operation when racking.

2. Inspect physical and mechanical condition.
3. Inspect the enclosure door gasket and sight glass for damage.
4. Inspect the interior of the enclosure for debris or damaged components. Inspect insulating components, current carrying parts, and secondary disconnecting devices. Exercise extreme caution when working around the network bus conductors.
5. Check for missing parts on the protector. Check tightness of electrical and mechanical connections. Tighten as necessary according to manufacturer's published data.
6. Inspect insulating barriers for damage and correct mounting.
7. Inspect network protector fuse covers, fuses, and blown fuse indicators for damage.
8. Inspect closing motor brushes and commutator surface for wear or damage. Replace brushes or disassemble motor for cleaning as necessary. Inspect and clean motor brake mechanism, as applicable.
9. Remove and inspect arc chutes for damage.
10. Inspect main and arcing contacts. Clean surfaces and align contacts as necessary.
11. Verify sequence of main and arcing contacts by slow-closing the protector. Adjust as necessary according to manufacturer's published data.
12. Manually open and close the protector and verify that the mechanism latches correctly in each position. Verify correct operation of the position indicator.
13. Verify electrical connections to network and auxiliary relays. Clean relay contacts if necessary. Inspect electromechanical relays for freedom of movement of internal parts.
14. Verify electrical connections to auxiliary switches, secondary disconnects, current transformers, voltage transformers, control power transformers, closing motors, contactors, trip coils, loading resistors, and any other auxiliary devices.
15. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
16. Lubrication
    1. Verify appropriate contact lubricant on moving current-carrying parts.
    2. Verify appropriate lubrication on moving and sliding surfaces.
17. Record the as-found and as-left operations counter readings.
18. Perform a leak test on submersible enclosure in accordance with manufacturer's published data.

2. **Electrical Tests**

    1. Perform insulation-resistance tests at 1000 volts dc for one minute across the contacts of each pole with the protector open and from pole-to-pole and each pole-to-ground with the protector closed.
    2. Verify current transformer ratios in accordance with Section 7.10.

3. Perform a contact-resistance test.
4. Measure the resistance of each protector power fuse.
5. Measure minimum pickup voltage of motor control relay.

6. Verify that the motor can charge the closing mechanism at the minimum voltage specified by the manufacturer.
7. Measure minimum pickup voltage of the trip actuator. Verify that the actuator resets correctly.
8. Calibrate the network protector relays in accordance with Section **7.9**.
9. Perform operational tests.

    1. Verify correct operation of all mechanical and electrical interlocks.
    2. Verify trip-free operation.
    3. Verify correct operation of the auto-open-close control handle.
    4. Verify the protector will close with voltage on the transformer side only.
    5. Verify the protector will open when the source feeder breaker is opened.

3. **Test Values**

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.
3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar protectors by more than 25 percent of the lowest value.
4. Insulation resistance of the protector components shall be in accordance with Table 10.1.
5. Control wiring insulation resistance shall be a minimum of two megohms.
6. Resistance of power fuses shall be evaluated on a comparative basis.
7. Minimum voltage to operate the trip actuator shall not exceed 7.5 percent of rated control circuit voltage.
8. Minimum acceptable motor closing voltage shall not exceed 73 percent of rated control circuit voltage.
9. Network protector should automatically close upon closing the feeder breaker with normal load demand and automatically trip when source feeder breaker is opened.

7.9 Protective Relays

1. **Visual and Mechanical Inspection**

1. Inspect relays and cases for physical damage.

2. Tighten case connections. Inspect cover for correct gasket seal. Clean cover glass. Inspect shorting hardware, connection paddles, and/or knife switches. Remove any foreign material from the case. Verify target reset.
3. Inspect relay for foreign material, particularly in disc slots of the damping and electromagnets. Verify disk clearance. Verify contact clearance and spring bias. Inspect spiral spring convolutions. Inspect disk and contacts for freedom of movement and correct travel. Verify tightness of mounting hardware and connections. Burnish contacts. Inspect bearings and/or pivots.
4. Verify that all settings are in accordance with coordination study or setting sheet supplied by owner.

2. **Electrical Tests**

    1. Perform insulation-resistance test on each circuit-to-frame. Determine from the manufacturer's published data the allowable procedures for this test for solid-state and microprocessor-based relays.
    2. Inspect targets and indicators.
        1. Determine pickup and dropout of electromechanical targets.
        2. Verify operation of all light-emitting diode indicators.
        3. Set contrast for liquid-crystal display readouts.

3. **Functional Operation**

    1. 2/62 Timing Relay

        1. Determine time delay.
        2. Verify operation of instantaneous contacts.

    2. 21 Distance Relay

        1. Determine maximum reach.
        2. Determine maximum torque angle.
        3. Determine offset.
        4. Plot impedance circle.

    3. 24 Volts/Hertz Relay

        1. Determine pickup frequency at rated voltage.
        2. Determine pickup frequency at a second voltage level.
        3. Determine time delay.

    4. 25 Sync Check Relay

        1. Determine closing zone at rated voltage.
        2. Determine maximum voltage differential that permits closing at zero degrees.
        3. Determine live line, live bus, dead line, and dead bus set points.
        4. Determine time delay.

5. Verify dead bus/live line, dead line/live bus and dead bus/dead line control functions.

5. 27 Undervoltage Relay

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

6. 32 Directional Power Relay

1. Determine minimum pickup at maximum torque angle.
2. Determine closing zone.
3. Determine maximum torque angle.
4. Determine time delay.
5. Verify the time delay at a second point on the timing curve for inverse time relays.

*6. Plot the operating characteristic.

7. 40 Loss of Field (Impedance) Relay

1. Determine maximum reach.
2. Determine maximum torque angle.
3. Determine offset.

4. Plot impedance circle.

8. 46 Current Balance Relay

1. Determine pickup of each unit.

2. Determine percent slope.

3. Determine time delay.

9. 46N Negative Sequence Current Relay

1. Determine negative sequence alarm level and trip.

2. Determine negative sequence minimum trip level.

3. Determine maximum time delay.

4. Verify two points on the $(I_2)^2t$ curve.

10. 47 Phase Sequence or Phase Balance Voltage Relay

1. Determine positive sequence voltage to close the normally open contact.

2. Determine positive sequence voltage to open the normally closed contact (undervoltage trip).

3. Verify negative sequence trip.

4. Determine time delay to close the normally open contact with sudden application of 120 percent of pickup.

5. Determine time delay to close the normally closed contact upon removal of voltage when previously set to rated system voltage.

11. 49R Thermal Replica Relay

1. Determine time delay at 300 percent of setting.

2. Determine a second point on the operating curve.

3. Determine pickup.

12. 49T Temperature (RTD) Relay

1. Determine trip resistance.

2. Determine reset resistance.

13. 50 Instantaneous Overcurrent Relay

1. Determine pickup.

2. Determine dropout.

3. Determine time delay.

14. 51 Time Overcurrent

1. Determine minimum pickup.

2. Determine time delays at two points on the time current curve.

15. 55 Power Factor Relay

1. Determine tripping angle.

2. Determine time delay.

16. 59 Overvoltage Relay

1. Determine overvoltage pickup.

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

17. 60 Voltage Balance Relay

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

 2. Plot the operating curve for the relay.

18. 63 Transformer Sudden Pressure Relay

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

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

 3. Verify trip circuit to remote breaker.

19. 64 Ground Detector Relay

 1. Determine maximum impedance to ground causing relay pickup.

20. 67 Directional Overcurrent Relay

 1. Determine directional unit minimum pickup at maximum torque angle.

 2. Determine closing zone.

 3. Determine maximum torque angle.

 4. Plot operating characteristics.

 5. Determine overcurrent unit pickup.

 6. Determine overcurrent unit time delay at two points on the time current curve.

21. 79 Reclosing Relay

 1. Determine time delay for each programmed reclosing interval.

 2. Verify lockout for unsuccessful reclosing.

 3. Determine reset time.

 4. Determine close pulse duration.

 5. Verify instantaneous overcurrent lockout.

22. 81 Frequency Relay

    1. Verify frequency set points.
    2. Determine time delay.
    3. Determine undervoltage cutoff.

23. 85 Pilot Wire Monitor

    1. Determine overcurrent pickup.
    2. Determine undercurrent pickup.
    3. Determine pilot wire ground pickup level.

24. 87 Differential

    1. Determine operating unit pickup.
    2. Determine the operation of each restraint unit.
    3. Determine slope.
    4. Determine harmonic restraint.
    5. Determine instantaneous pickup.
    6. Plot operating characteristics for each restraint.

4. Control Verification

    1. Verify that each of the relay contacts performs its intended function in the control scheme including breaker trip tests, close inhibit tests, 86 lockout tests, and alarm functions.

5. Test Values

    1. When not otherwise specified, use manufacturer's recommended tolerances.
    2. When critical test points are specified, the relay should be calibrated to those points even though other test points may be out of tolerance.

7.10 Instrument Transformers

1. Visual and Mechanical Inspection

    1. Inspect physical and mechanical condition.

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

   1. Use of low-resistance ohmmeter in accordance with Section **7.10.**2.1 and **7.10.**3.1 (Electrical Tests).

   2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

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

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

5. Verify correct primary and secondary fuse sizes for voltage (potential) transformers.

6. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.

2. Electrical Tests - Current Transformers

   1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.2 (Visual and Mechanical Inspection).

   2. Perform a polarity test of each current transformer.

   3. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1.

   4. Perform an excitation test on transformers used for relaying applications in accordance with ANSI/IEEE C57.13.1.

   5. Measure current circuit burdens at transformer terminals and determine the total burden.

   6. When applicable, perform insulation-resistance and dielectric withstand tests on the primary winding with secondary grounded. Test voltages shall be in accordance with Tables 10.1 and 10.9 respectively.

3. Electrical Tests - Voltage Transformers

   1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.2 (Visual and Mechanical Inspection).

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 10.1. Do not perform this test with solid-state devices connected.

3. Perform a polarity test on each transformer to verify the polarity marks or H1-X1 relationship as applicable.

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

5. Measure potential circuit burdens at transformer terminals and determine the total burden.

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 10.9. The test voltage shall be applied for one minute.

4. Test Values

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

4. Insulation-resistance measurement on any instrument transformer shall be not less than that shown in Table 10.1.

5. Polarity results shall agree with transformer markings.

6. Compare measured burdens to calculated burdens supplied by owner.

7. Ratio accuracies shall be within 0.5 percent of nameplate or manufacturer's published data.

8. The insulation shall withstand the overpotential test voltage applied.

7.11 Metering

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.

2. Verify tightness of electrical connections.

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

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

5. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.

2. Electrical Tests

   1. Check calibration of meters at all cardinal points.

   2. Calibrate meters in accordance to manufacturer's published data.

   3. Verify all instrument multipliers.

7.12 Regulating Apparatus (Not Applicable)

7.13 Grounding Systems

1. Visual and Mechanical Inspection

   1. Verify ground system.

2. Electrical Tests

   1. Perform fall-of-potential test or alternative in accordance with IEEE Standard 81 on the main grounding electrode or system.

   2. Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and/or derived neutral points.

3. Test Values

   1. The resistance between the main grounding electrode and ground should be no greater than five ohms for 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)

   2. Investigate point-to-point resistance values which exceed 0.5 ohm.

7.14 Ground-Fault Protection Systems

1. Visual and Mechanical Inspection

1. Visually inspect the components for damage and errors in polarity or conductor routing.

    1. Verify that ground connection is made ahead of neutral disconnect link and on the line side of any ground fault sensor.

    2. Verify that neutral sensors are connected with correct polarity on both primary and secondary.

    3. Verify that all phase conductors and the neutral pass through the sensor in the same direction for zero sequence systems.

    4. Verify that grounding conductors do not pass through zero sequence sensors.

    5. Verify that the grounded conductor is solidly grounded.

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

    1. Use of low-resistance ohmmeter in accordance with Section 7.14.2.2 (Electrical Tests).

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

3. Verify correct operation of all functions of the self-test panel.

4. Verify pickup and time-delay settings.

2. Electrical Tests

    1. Measure the system neutral-to-ground insulation resistance with the neutral disconnect link temporarily removed. Replace neutral disconnect link after testing.

    2. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.14.**1.2 (Visual and Mechanical Inspection).

    3. Perform the following pickup tests using primary injection:

        1. Verify that the relay does not operate at 90 percent of the pickup setting.

        2. Verify pickup is less than 125 percent of setting or 1200 amperes, whichever is smaller.

4. For summation type systems utilizing phase and neutral current transformers, verify correct polarities by applying current to each phase-neutral current transformer pair. This test also applies to molded-case breakers utilizing an external neutral current transformer.

    1. Relay should operate when current direction is the same relative to polarity marks in the two current transformers.

    2. Relay should not operate when current direction is opposite relative to polarity marks in the two current transformers.

5. Measure time delay of the relay at 150 percent or greater of pickup.

6. Verify reduced control voltage tripping capability is 55 percent for ac systems and 80 percent for dc systems.

7. Verify blocking capability of zone interlock systems.

3. Test Values

    1. Compare bolted connection resistances to values of similar connections.

    2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

    3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

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

    5. Insulation resistance values shall be in accordance with Table 10.1.

    6. Relay timing shall be in accordance with manufacturer's specifications but must be no longer than one second at 3000 amperes.

7.15 Rotating Machinery (Not Applicable)

7.16 Motor Control

1. Motor Starters

1. Low-Voltage

1. Visual and Mechanical Inspection

    1. Inspect physical and mechanical condition.

2. Inspect contactors.

   1. Verify mechanical operation.

   2. Inspect and adjust contact gap, wipe, alignment, and pressure in accordance with manufacturer's published data.

   3. Motor-Running Protection

      1. Compare overload element rating with motor full-load current rating to verify correct sizing.

      2. If power-factor correction capacitors are connected on the load side of the overload protection, include the effect of the capacitive reactance in determining appropriate overload element size.

      3. If motor-running protection is provided by fuses, verify correct fuse rating considering motor characteristics and power-factor correction capacitors.

   4. ***Inspect all bolted electrical connections for high resistance using one of the following methods:***

      1. Use of low-resistance ohmmeter in accordance with Section 7.16.1.1.2.1 (Electrical Tests).

      2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

   5. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.

   6. Lubrication

      1. Verify appropriate contact lubricant on moving current-carrying parts.

      2. Verify appropriate lubrication on moving and sliding surfaces.

2. Electrical Tests

   1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.16.1.1.**1.4 (Visual and Mechanical Inspection).

2. Measure insulation resistance of each combination starter, phase-to-phase and phase-to-ground, with the starter contacts closed and the protective device open. Test voltage shall be in accordance with Table 10.1. Refer to manufacturer's published data for devices with solid-state components.

3. Test the motor overload relay elements by injecting primary current through the overload circuit and monitoring trip time of the overload element.

   NOTE: Test times for thermal trip units will, in general, be longer than manufacturer's curve if single-pole testing is performed. Optionally test with all poles in series for time test and each pole separately for comparison. (Refer to ANSI/NEMA ICS 2, Part 4.)

4. Test circuit breakers in accordance with Section **7.6.1.1**.

5. Perform operational tests by initiating control devices.

3. Test Values

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

4. Insulation-resistance values shall be in accordance with Table 10.1.

5. Control wiring insulation test resistance shall be a minimum of two megohms.

6. Overload trip times shall be in accordance with manufacturer's published data.

2. Motor Control Centers

1. Low-Voltage

1. Refer to Section **7.1**, Switchgear and Switchboard Assemblies, for appropriate inspections and tests of the motor control center bus.

2. Refer to Section **7.5.1.1**, Low-Voltage Switches, for appropriate inspections and tests of the motor control center switches.

3. Refer to Section **7.6.1**, Low-Voltage Circuit Breakers, for appropriate inspections and tests of the motor control center circuit breakers.

4. Refer to Section **7.16.1**, Low-Voltage Motor Starters, for appropriate inspections and tests of the motor control center starters.

7.17 Variable Frequency Drives - Reserved

7.18 Direct-Current Systems (Not Applicable)

7.19 Surge Arresters

1. Low-Voltage Surge Protection Devices

1. Visual and Mechanical Inspection

    1. Inspect physical and mechanical condition.

    2. Inspect for correct mounting and adequate clearances.

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

        1. Use of low-resistance ohmmeter in accordance with Section **7.19.1.**2.1 (Electrical Tests).

        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

    4. 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 all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.19.1.**1.3 (Visual and Mechanical Inspection).

    2. Perform insulation-resistance tests. Use manufacturer's recommended values or Table 10.1.

    3. Test grounding connection in accordance with Section **7.13**.

3. Test Values

    1. Compare bolted connection resistances to values of similar connections.

    2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

4. Insulation-resistance values shall be in accordance with Table 10.1.

5. Resistance between the arrester ground terminal and the ground system shall be less than 0.5 ohm.

7.20 Capacitors and Reactors

1. Capacitors

1. Visual and Mechanical Inspection

   1. Inspect physical and mechanical condition.

   2. Inspect capacitors for correct mounting and required clearances.

   3. Verify that capacitors are electrically connected in their specified configuration.

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

      1. Use of low-resistance ohmmeter in accordance with Section **7.20.2.**2 (Electrical Tests).

      2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

2. Electrical Tests

   1. Perform insulation-resistance tests from terminal(s) to case for one minute on capacitors with more than one bushing. Test voltage and minimum resistance shall be in accordance with manufacturer's published data or Table 10.1.

   2. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable. See Section **7.20.1.**1.4 (Visual and Mechanical Inspection).

   3. Measure the capacitance of all terminal combinations.

   4. Measure resistance of internal discharge resistors.

3. Test Values

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Micro ohm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

4. Insulation-resistance values less than Table 10.1 shall be investigated.

5. Investigate capacitance values differing from manufacturer's published data.

6. Investigate discharge resistor values differing from manufacturer's published data. In accordance with NEC Article 460, residual voltage of a capacitor shall be reduced to 50 volts in the following time intervals after being disconnected from the source of supply:

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

7.21 Outdoor Bus Structures

1. Visual and Mechanical Inspection

    1. Inspect physical and mechanical condition.

    2. ***Inspect all bolted electrical connections for high resistance using one of the following methods:***

        1. Use of low-resistance ohmmeter in accordance with Section **7.21.**2.1 (Electrical Tests).

        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

    3. Clean insulators.

2. Electrical Tests

    1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.21.**1.2 (Visual and Mechanical Inspection).

2. Measure insulation resistance of each bus, phase-to-ground with other phases grounded.

3. Perform overpotential test on each bus phase, phase-to-ground with other phases grounded. Potential application shall be for one minute.

4. Measure resistance of bus section joints with low-resistance ohmmeter.

3. Test Values

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels shall be in accordance with manufacturer's published data or Table 10.12.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 25 percent of the lowest value.

4. Insulation-resistance tests shall be in accordance with Table 10.1.

5. Overpotential test voltage shall be in accordance with manufacturer's published data or Table 10.19. The insulation shall withstand the overpotential test voltage applied.

6. Compare measured bus connector joint resistance to an equal length of bus and to similar connections.

7.22 Emergency Systems

1. Engine Generator (Not Applicable)

2. Automatic Transfer Switches (Perform this testing on 150KW Generator)

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.

2. Lubrication

1. Verify appropriate contact lubricant on moving current-carrying parts.

2. Verify appropriate lubrication on moving and sliding surfaces.

3. Verify that manual transfer warnings are attached and visible.

4. Verify tightness of all control connections.

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

    1. Use of low-resistance ohmmeter in accordance with Section **7.22.3.**2.2 (Electrical Tests).

    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.

6. Perform manual transfer operation.

7. Verify positive mechanical interlocking between normal and alternate sources.

2. Electrical Tests

    1. Perform a contact-resistance test.

    2. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.22.3.**1.5 (Visual and Mechanical Inspection).

    3. Perform insulation-resistance tests, phase-to-phase and phase-to-ground, with switch in both source positions.

    4. Verify settings and operation of control devices.

    5. Calibrate and set all relays and timers in accordance with Section **7.9**.

3. Test Values

    1. Compare bolted connection resistances to values of similar connections.

    2. Bolt-torque levels shall be in accordance with Table 10.12 unless otherwise specified by manufacturer.

    3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar switches by more than 25 percent of the lowest value.

    4. Insulation-resistance test voltages and minimum values shall be in accordance with Table 10.1.

7.23 Automatic Circuit Reclosers and Line Sectionalizers (Not Applicable)

7.24 Electrical Safety Equipment

1. Test and certify existing VA hot sticks and blankets.

8. SYSTEM FUNCTION TESTS

8.1 General

1. Perform system function tests upon completion of equipment tests as defined in Section **7**. It is the purpose of system function tests to prove the correct interaction of all sensing, processing, and action devices.

2. Implementation

    1. Develop test parameters for the purpose of evaluating performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

       Perform these tests.

    2. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.

    3. Verify the correct operation of all sensing devices, alarms, and indicating devices.

TABLE 10.1
Insulation Resistance Tests
on
Electrical Apparatus and Systems

Maximum Rating of Equipment in Volts	Minimum Test Voltage, dc in Volts	Recommended Minimum Insulation Resistance in Megohms
250	500	25
600	1,000	100
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
35,000	15,000	100,000
46,000	15,000	100,000
69,000	15,000	100,000

In the absence of consensus standards dealing with insulation-resistance tests, the NETA Technical Committee suggests the above representative values.

See Table 10.14 for temperature correction factors.

Actual test results are dependent on the length of the conductor being tested, the temperature of the insulating material, and the humidity of the surrounding environment at the time of the test. In addition, insulation resistance tests are performed to establish a trending pattern and a deviation from the baseline information obtained during maintenance testing enabling the evaluation of the insulation for confined use.

TABLE 10.2
Switchgear Low-Frequency Withstand Test Voltages

Type of Switchgear	Rated Maximum Voltage (kV) (rms)	Maximum Test Voltage kV	
		ac	dc
LV (Low-Voltage Power Circuit Breaker Switchgear)	.254/.508/.635	1.6	2.3
MC (Metal-Clad Switchgear)	4.76	14.0	20.0
	8.25	27.0	37.0
	15.0	27.0	37.0
	38.0	60.0	+
SC (Station-Type Cubicle Switchgear)	15.5	37.0	+
	38.0	60.0	+
	72.5	120.0	+
MEI (Metal-Enclosed Interrupter Switchgear)	4.76	14.0	20.0
	8.25	19.0	27.0
	15.0	27.0	37.0
	15.5	37.0	52.0
	25.8	45.0	+
	38.0	60.0	+

Derived from ANSI/IEEE C37.20.1-1993, Paragraph 5.5, *Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear*, C37.20.2-1993, Paragraph 5.5, *Standard for Metal-Clad and Station-Type Cubicle Switchgear* and C37.20.3-1993, Paragraph 5.5, *Standard for Metal-Enclosed Interrupter Switchgear*, and includes 0.75 multiplier with fraction rounded down.

The column headed "DC" is given as a reference only for those using dc tests to verify the integrity of connected cable installations without disconnecting the cables from the switchgear. It represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for voltage rating of switchgear. The presence of this column in no way implies any requirement for a dc withstand test on ac equipment or that a dc withstand test represents an acceptable alternative to the low-frequency withstand tests specified in this specification, either for design tests, production tests, conformance tests, or field tests. When making dc tests, the voltage should be raised to the test value in discrete steps and held for a period of one minute.

Because of the variable voltage distribution encountered when making dc withstand tests, the manufacturer should be contacted for recommendations before applying dc withstand tests to the switchgear. Voltage transformers above 34.5kV should be disconnected when testing with dc. Refer to ANSI/IEEE C57-13-1978 (R1987) *IEEE Standard Requirements for Instrument Transformers* [10], Section 8 and, in particular 8.8.2, (the last paragraph) which reads "Periodic kenotron tests should not be applied to transformers of higher than 34.5 kV voltage rating."

+ Consult Manufacturer

TABLE 10.3
Recommended Dissipation Factor/Power Factor
of Liquid-Filled Transformers

	Oil Maximum	Silicone Maximum	Tetrachloro-ethylene Maximum	High Fire Point Hydrocarbon Maximum
Power Transformers	2.0%	0.5%	3.0%	2.0%
Distribution Transformers	3.0%	0.5%	3.0%	3.0%

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

TABLE 10.4
Suggested Limits for Service-Aged Insulating Fluids

Mineral Oil*				
Test	**ASTM Method**	**69 kV and Below**	**Above 69 kV through 288 kV**	**345 kV and Above**
Dielectric breakdown, kV minimum	D877	26	26	26
Dielectric breakdown, kV minimum @ 0.04 gap	D1816	23	26	26
Dielectric breakdown, kV minimum @ 0.08 gap	D1816	34	45	45
Interfacial tension, mN/m minimum	D971	24	26	30
Neutralization number, mg KOH/g maximum	D974	0.2	0.2	0.1
Water content, ppm maximum	D1533	35	25	20
Power factor at 25°C, %	D924	1.0****	1.0****	1.0****
Power factor at 100 °C, %	D924	1.0****	1.0****	1.0****

Test	**ASTM Method**	**Silicone****	**Less Flammable Hydrocarbon*****
Dielectric Breakdown, kV minimum	D877	25	24
Visual	D2129	Colorless, clear, free of particles	N/A
Water Content, ppm maximum	D1533	100	45
Dissipation factor, % max. @ 25°C	D924	0.2	1.0
Viscosity, cSt @ 25°C	D445	47.5 - 52.5	N/A
Fire Point, °C, minimum	D92	340	300
Neutralization number, mg KOH/g max.	D974	0.2	N/A
Neutralization number, mg KOH/g max.	D664	N/A	0.25
Interfacial Tension, mN/m minimum @ 25°C	D971	N/A	22

* IEEE C57.106-1991 *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 5.

** IEEE C57.111-1989 *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 3.

*** IEEE C57.121-1988 *Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers*, Table 3.

**** IEEE Standard. 637-1985 *IEEE Guide for the Reclamation of Insulating Oil and Criteria for Its Use*.

TABLE 10.5
Transformer Insulation-Resistance

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
5001 - 15000	5000	5000	25000

In the absence of consensus standards, the NETA Technical Committee suggests the above representative values.

NOTE: Since insulation resistance depends on insulation rating (kV) and winding capacity (kVA), values obtained should be compared to manufacturer's published data.

TABLE 10.6
Medium-Voltage Cables
Maximum Maintenance Test Voltages (kV, dc)

Insulation Type	Rated Cable Voltage	Insulation Level	Test Voltage kV, dc
Elastomeric: Butyl and Oil Base	5 kV	100%	19
	5 kV	133%	19
	15 kV	100%	41
	15 kV	133%	49
	25 kV	100%	60
Elastomeric: EPR	5 kV	100%	19
	5 kV	133%	19
	8 kV	100%	26
	8 kV	133%	26
	15 kV	100%	41
	15 kV	133%	49
	25 kV	100%	60
	25 kV	133%	75
	28 kV	100%	64
	35 kV	100%	75
Polyethylene (see Note 4)	5 kV	100%	19
	5 kV	133%	19
	8 kV	100%	26
	8 kV	133%	26
	15 kV	100%	41
	15 kV	133%	49
	25 kV	100%	60
	25 kV	133%	75
	35 kV	100%	75

Derived from ANSI/IEEE Standard 141-1993 Table 12-9 and by factoring the applicable ICEA/NEMA Standards by 75% as recommended in Section 18-9.2.4 of NFPA 70B, 1994 Edition *Electrical Equipment Maintenance*.

Refer to notes on the following page.

TABLE 10.6 - NOTES

NOTE 1: Selection of test voltage for in-service cables depends on many factors. The owner should be consulted and/or informed of the intended test voltage prior to performing the test. Caution should be used in selecting the maximum test voltage and performing the test since cable failure during the test will require repair or replacement prior to re-energizing.

NOTE 2: AEIC C55 and C56 list test voltages approximately 20 percent higher than the ICEA values for the first five years of service. These values are based on 65 percent of the factory test voltages. A reduction to 40 percent is recommended for a cable in service longer than five years.

NOTE 3: ANSI/IEEE 400-1991 specifies much higher voltages than either the ICEA or the AEIC. These voltages overstress cables and are intended to find marginal cable during shutdown to avoid in-service failures. These test voltages should not be used without the concurrence of the owner. If the cable is still in warranty, the cable manufacturer should be consulted for their concurrence. (See the Standard for a discussion of the pros and cons of high direct-voltage tests.)

NOTE 4: See Electric Power Research Institute Report, EPRI TR-101245, "Effect of DC Testing on Extruded Cross-Linked Polyethylene Insulated Cables." DC high potential testing of aged XLPE-insulated cable in wet locations may reduce remaining life.

TABLE 10.7
Molded-Case Circuit Breakers
Values for Inverse Time Trip Test
(At 300% of Rated Continuous Current of Circuit Breaker)

Range of Rated Continuous Current Amperes	Maximum Trip Time in Seconds For Each Maximum Frame Rating[1]	
	□250V	251 - 600V
0-30	50	70
31-50	80	100
51-100	140	160
101-150	200	250
151-225	230	275
226-400	300	350
401-600	------------	450
601-800	------------	500
801-1000	------------	600
1001-1200	------------	700
1201-1600	------------	775
1601-2000	------------	800
2001-2500	------------	850
2501-5000	------------	900

Reproduction of Table 5-3 from NEMA Standard AB4-1991.

[1] For integrally-fused circuit breakers, trip times may be substantially longer if tested with the fuses replaced by solid links (shorting bars).

TABLE 10.8
Instantaneous Trip Setting Tolerances
for Field Testing
of Marked Adjustable Trip Circuit Breakers

	Tolerances of High and Low Settings	
Ampere Rating	**High**	**Low**
□250	+40% -25%	+40% -30%
>250	±25%	±30%

Reproduction of Table 5-4 from NEMA publication AB4-1991.

For circuit breakers with nonadjustable instantaneous trips, tolerances apply to the manufacturer's published trip range, i.e., +40 percent on high side, -30 percent on low side.

TABLE 10.9
Instrument Transformer Dielectric Tests
Field Maintenance

Nominal System (kV)	BIL (kV)	Periodic Dielectric Withstand Test Field Test Voltage (kV)	
		ac	dc
0.6	10	2.6	4
1.1	30	6.5	10
2.4	45	9.7	15
4.8	60	12.3	19
8.32	75	16.9	26
13.8	95	22.1	34
13.8	110	22.1	34
25	125	26.0	40
25	150	32.5	50
34.5	150	32.5	50
34.5	200	45.5	70
46	250	61.7	+
69	350	91.0	+
115	450	120.0	+
115	550	149.0	+
138	550	149.0	+
138	650	178.0	+
161	650	178.0	+
161	750	211.0	+
230	900	256.0	+
230	1050	299.0	+

Table 10.9 is derived from Paragraph 8.8.2 and Tables 2 and 7 of ANSI/IEEE C57.13, "Standard Requirements for Instrument Transformers."

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

* Under some conditions transformers may be subjected to periodic insulation test using direct voltage from kenotron sets. In such cases the test direct voltage should not exceed the original factory test rms alternating voltage. Periodic kenotron tests should not be applied to (instrument) transformers of higher than 34.5 kV voltage rating.

TABLE 10.10
Maximum Allowable Vibration Amplitude

Speed - RPM	Amplitude - Inches Peak to Peak
3000 and above	0.001
1500 - 2999	0.002
1000 - 1499	0.0025
999 and below	0.003

Derived from NEMA publication MG 1-1993, Sections 20.53, 21.54, 22.54, 23.52, and 24.50.

TABLE 10.11
Periodic Electrical Test Values for Insulating Aerial Devices
Insulating Aerial Devices with a Lower Test Electrode System
(Category A and Category B)

Unit Rating	**60 Hertz (rms) Test**			**Direct Current Test**		
	Voltage kV (rms)	**Maximum Allowable Current Microamperes**	**Time**	**Voltage kV**	**Maximum Allowable Current Microamperes**	**Time**
46 kV & below	40	40	1 minute	56	28	3 minutes
69 kV	60	60	1 minute	84	42	3 minutes
138 kV	120	120	1 minute	168	84	3 minutes
230 kV	200	200	1 minute	240	120	3 minutes
345 kV	300	300	1 minute	360	180	3 minutes
500 kV	430	430	1 minute	602	301	3 minutes
765 kV	660	660	1 minute	924	462	3 minutes

Insulating Aerial Devices without Lower Test Electrode System
(Category C)

Error! Reference source not found.Unit Rating	**60 Hertz (rms) Test**			**Direct Current Test**		
	Voltage kV (rms)	Maximum Allowable Current Microamperes	Time	Voltage kV	Maximum Allowable Current Microamperes	Time
46 kV & below	40	400	1 minute	56	56	3 minutes

Insulating Aerial Ladders and Insulating Vertical Aerial Towers

Unit Rating	**60 Hertz (rms) Test**			**Direct Current Test**		
	Voltage kV (rms)	Maximum Allowable Current Microamperes	Time	Voltage kV	Maximum Allowable Current Microamperes	Time
46 kV & below	40	400	1 minute	56	56	3 minutes
20 kV & below	20	200	1 minute	28	28	3 minutes

TABLE 10.11 (cont.)
Chassis Insulating Systems
Lower Insulated Booms

60 Hertz (rms) Test			Direct Current Test		
Voltage kV (rms)	Maximum Allowable Current Milliamperes	Time	Voltage kV	Maximum Allowable Current Microamperes	Time
35	3.0	3 minutes	50	50	3 minutes

NOTE:
1. Derived from ANSI/SIA A92-2-1990.
2. A method of calculating test voltages for units rated other than those tabulated here is as follows:
    1. The 60 Hz test values are equal to line to ground at the unit rating value time 1.5.
    2. Multiply the 60 Hz test values times 1.4 to arrive at the direct current values.

TABLE 10.12
US Standard
Bolt Torques for Bus Connections
Heat-Treated Steel - Cadmium or Zinc Plated

Grade	SAE 1 & 2	SAE 5	SAE 7	SAE 8
Minimum Tensile (P.S.I.)	64K	105K	133K	150K
Bolt Diameter In Inches	Torque (Foot Pounds)			
¼	4.0	5.6	8.0	8.4
5/16	7.2	11.2	15.2	17.6
3/8	12.0	20.0	27.2	29.6
7/16	19.2	32.0	44.0	48.0
½	29.6	48.0	68.0	73.6
9/16	42.4	70.4	96.0	105.6
5/8	59.2	96.0	133.6	144.0
¾	96.0	160.0	224.0	236.8
7/8	152.0	241.6	352.0	378.4
1.0	225.6	372.8	528.0	571.2

Bolt Torques for Bus Connections
Silicon Bronze Fasteners[1]
Torque (Foot-Pounds)

Bolt Diameter in Inches	Nonlubricated	Lubricated
5/16	15	10
3/8	20	14
1/2	40	25
5/8	55	40
3/4	70	60

[1] Bronze alloy bolts shall have a minimum tensile strength of 70,000 pounds per square inch.

TABLE 10.12 (cont.)
Aluminum Alloy Fasteners[2]
Torque (Foot Pounds)

Bolt Diameter in Inches	Lubricated
5/16	8.0
3/8	11.2
1/2	20.0
5/8	32.0
3/4	48.0

[2] Aluminum alloy bolts shall have a minimum tensile strength of 55,000 pounds per square inch.

Bolt Torques for Bus Connections
Stainless Steel Fasteners[3]
Torque (Foot Pounds)

Bolt Diameter in Inches	Uncoated
5/16	14
3/8	25
1/2	45
5/8	60
3/4	90

[3] Bolts, cap screws, nuts, flat washers, locknuts: 18-8 alloy. Belleville washers: 302 alloy.

Table 10.13
SF_6 Gas Tests

Test	Test Limits
Moisture by hygrometer method	Per manufacturer or investigate greater than 200 ppm [(1)]
SF_6 decomposition byproducts by ASTM D2685	Greater than 500 ppm [(2)]
Air by ASTM D-2685	Greater than 5000 ppm [(3)]
Dielectric Breakdown using hemispherical contacts at 0.10 inch gap at atmospheric pressure	11.5 - 13.5 kV [(4)]

(1) According to some manufacturers.
(2) In the absence of consensus standards dealing with SF_6 circuit breaker gas tests, the NETA Technical Committee suggests the above representative values.
(3) 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.
(4) Per Even, F.E., and Mani, G. "Sulfur Fluorides", Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., 11,428, 1994.

TABLE 10.14
Insulation Resistance
Conversion Factors

For Conversion of Test
Temperature to 20°C

Temperature		Multiplier	
°C	°F	Apparatus Containing Immersed Oil Insulations	Apparatus Containing Solid Insulations
0	32	0.25	0.40
5	41	0.36	0.45
10	50	0.50	0.50
15	59	0.75	0.75
20	68	1.00	1.00
25	77	1.40	1.30
30	86	1.98	1.60
35	95	2.80	2.05
40	104	3.95	2.50
45	113	5.60	3.25
50	122	7.85	4.00
55	131	11.20	5.20
60	140	15.85	6.40
65	149	22.40	8.70
70	158	31.75	10.00
75	167	44.70	13.00
80	176	63.50	16.00

TABLE 10.15
High-Potential Test Voltage
for Automatic Circuit Reclosers

Nominal Voltage Class, kV	Maximum Voltage, kV	Rated Impulse Withstand Voltage, kV	Maximum Field Test Voltage, kVac
14.4 (1φ and 3φ)	15.0	95	26.2
14.4 (1φ and 3φ)	15.5	110	37.5
24.9 (1φ and 3φ)	27.0	150	45.0
34.5 (1φ and 3φ)	38.0	150	52.5
46.0 (3φ)	48.3	250	78.7
69.0 (3φ)	72.5	350	120.0

Derived from ANSI/IEEE C37.61-1973(R1993) (*Standard Guide for the Application, Operation, and Maintenance of Automatic Circuit Reclosers*), C37.60-1981(R1993) (*Standard Requirements for Overhead, Pad-Mounted, Dry-Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for AC Systems*).

TABLE 10.16
High-Potential Test Voltage
for Periodic Test of Line Sectionalizers

Nominal Voltage Class kV	Maximum Voltage kV	Rated Impulse Withstand Voltage kV	Maximum Field Test Voltage kVAC	DC 15 Minute Withstand (kV)
14.4 (1□)	15.0	95	26.2	39
14.4 (1□)	15.0	125	31.5	39
14.4 (3□)	15.5	110	37.5	39
24.9 (1□)	27.0	125	45.0	58
34.5 (3□)	38.0	150	52.5	77

Derived from ANSI/IEEE C37.63-1984(R1990) Table 2 (*Standard Requirements for Overhead, Pad-Mounted, Dry-Vault, and Submersible Automatic Line Sectionalizers of AC Systems*).

The table includes a 0.75 multiplier with fractions rounded down.

In the absence of consensus standards, the NETA Technical Committee suggests the above representative values.

NOTE: Values of ac voltage given are dry test one minute factory test values.

Table 10.17
Metal-Enclosed Bus Dielectric Withstand Test Voltages

Type of Bus	Rated kV	Maximum Test Voltage, kV	
		ac	dc
Isolated Phase for Generator Leads	24.5	37.0	52.0
	29.5	45.0	--
	34.5	60.0	--
Isolated Phase for Other than Generator Leads	15.5	37.0	52.0
	25.8	45.0	--
	38.0	60.0	--
Nonsegregated Phase	0.635	1.6	2.3
	4.76	14.2	20.0
	15.0	27.0	37.0
	25.8	45.0	63.0
	38.0	60.0	--
Segregated Phase	15.5	37.0	52.0
	25.8	45.0	63.0
	38.0	60.0	--
DC Bus Duct	0.3	1.6	2.3
	0.8	2.7	3.9
	1.2	3.4	4.8
	1.6	4.0	5.7
	3.2	6.6	9.3

Derived from ANSI-IEEE C37.23-1987, Tables 3A, 3B, 3C, 3D and paragraph 6.4.2. The table includes a 0.75 multiplier with fractions rounded down.

Note:

The presence of the column headed "dc" does not imply any requirement for a dc withstand test on ac equipment. This column is given as a reference only for those using dc tests and represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for each class of bus.

Direct current withstand tests are recommended for flexible bus to avoid the loss of insulation life that may result from the dielectric heating that occurs with rated frequency withstand testing.

Because of the variable voltage distribution encountered when making dc withstand tests and variances in leakage currents associated with various insulation systems, the manufacturer should be consulted for recommendations before applying dc withstand tests to this equipment.

TABLE 10.18
Thermographic Survey
Suggested Actions Based on Temperature Rise

Temperature difference (DT) based on comparisons between similar components under similar loading.	Temperature difference (DT) based upon comparisons between component and ambient air temperatures.	Recommended Action
1□C - 3□C	0□C - 10□C	**Possible deficiency; warrants investigation**
4□C - 15□C	11□C - 20□C	**Indicates probable deficiency; repair as time permits**
-- -- --	22□C - 40□C	**Monitor continuously until corrective measures can be accomplished**
> 16□C	> 40□C	**Major discrepancy; repair immediately**

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

TABLE 10.19
Over potential Test Voltages for Electrical Apparatus
Other than Inductive Equipment

Nominal System (Line) Voltage[1] (kV)	Insulation Class	AC Factory Test (kV)	Maximum Field Applied AC Test (kV)	Maximum Field Applied DC Test (kV)
1.2	1.2	10	6.0	8.5
2.4	2.5	15	9.0	12.7
4.8	5.0	19	11.4	16.1
8.3	8.7	26	15.6	22.1
14.4	15.0	34	20.4	28.8
18.0	18.0	40	24.0	33.9
25.0	25.0	50	30.0	42.4
34.5	35.0	70	42.0	59.4
46.0	46.0	95	57.0	80.6
69.0	69.0	140	84.0	118.8

In the absence of consensus standards, the NETA Technical Committee suggests the above representative values.

[1] Intermediate voltage ratings are placed in the next higher insulation class.