STATEMENT OF WORK

INTRODUCTION: This Statement of Work (SOW) describes the requirements for the maintenance, inspection, testing, and/or calibration and study(s) of the Electrical Power Distribution System and all of its components. These work items are referenced as "Maintenance and Testing" and/or "Electrical Study" in this document, hereafter.

Project includes the contractor provide Electrical Studies of the Electrical Power Distribution System described here in other specific tasks as further defined by this request for proposal (RFP). Deliverables include, but are not limited to a Ground Resistance Analysis, Short Circuit Study, Hazard Risk Tables, Arc Flash Labeling, Coordination Curves, Voltage Drop Calculations, Emergency Power System Analysis, Analysis and Recommendations, Protective Device Settings, and Cost Estimates.

The SOW describes the requirements for the Qualified Electrical Contract Professionals - known as "Contractors" in this document, hereafter. Contractors who are contracted by VHA Medical Center to perform maintenance and testing of the Electrical Power Distribution System shall meet all following requirements:

1. Contractors shall be certified by the International Electrical Testing Association (NETA) as NETA Certified Technician, and completed the Occupational Safety & Health Administration (OSHA) approved 10-hour construction safety training.
2. Contractors shall have technical trainings, and track records of working experience in maintenance, inspection, and testing of the Electrical Power Distribution System and its components in healthcare, industrial, educational, and commercial facilities for a minimum of (5) continuous years.
3. Contractors shall have safety trainings - either on-the-job or class-room type in electrical safety outlined in the OSHA Standard 29 Code of Federal Regulations (CFR) 1910 Subpart S - Electrical, and the NFPA 70E - Standard for Electrical Safety in the workplace. Training certifications shall be submitted to the VA Contracting Officer prior to work. If no training certifications are available, the contractor employer shall certify that he/she has met this requirement in writing, and submit it to the Contracting Officer prior to work.
4. Contractors shall have ready access to the latest versions of the following references:
    - NFPA 70, National Electrical Code
    - NFPA70B, Recommended Practice for Electrical Equipment Maintenance
    - NFPA 70E, Standard for Electrical Safety in the Workplace
    - NFPA 110, Standard for Emergency and Standby Power System
    - OSHA Standard 29 CFR 1910, Subparts I & S
    - Inter-National Electrical Testing Association, Inc. (NETA) - Maintenance and Testing Specifications, Latest Edition
    - Operation and Maintenance manuals, and specifications of the electrical equipment maintained and tested. These documents may be obtained from the VHA Medical Center, or the equipment manufactures

5. Contractors shall be equipped with all necessary tools, equipment, and Personal Protective Equipment (PPE) to perform the work safely, effectively, and timely. Tools, equipment, and PPE shall comply with the requirements of OSHA Standard 29 CFR 1910, Subpart I, and NFPA 70E.
6. Occupational Safety and Health Requirements (OSHA) – Part 1910 Subpart J – The control of hazardous energy (lockout/tagout) (1910.147), Occupational Safety and Health Requirements Part 1910 Subpart S – Electrical (1910.301 – 1910.399), and Safety and Health Regulations for Construction Part 1926 Subpart K – Electrical (1926.400 – 1926.499) shall apply.
7. List of Buildings included in this SOW by Gross Square Feet (GSF)

Building #	GSF	Building #	GSF
1	126,203	57	2,380
1AC	58,060	58	3,803
2	74,473	61	425
3	13,469	62	625
4	3,616	63	392
5	3,912	64	520
6	3,912	65	4,019
7	6,041	71	16,738
9	319	72	1,120
10	3,983	81	24,120
11	13,376	82	5,000
13	15,391	T6	1,029
14	1,545	T7	1,029
15	1,194	T8	1,029
16	16,574		
17	9,887		

Maintenance, Inspection, Testing, and/or Calibration of the Electrical Power Distribution System (EDS):

GENERAL: Contractor to provide all technical supervision, equipment, labor and materials necessary to perform the scope of work as described for a complete Three-Year Periodic Test, Inspection, and Maintenance of the Electrical Distribution System at VA Roseburg Healthcare System, Oregon. Testing shall be in accordance with the latest editions of the National Fire Protection Association (NFPA); National Electrical Code (NFPA 70), Recommended Practice for Electrical Equipment Maintenance (NFPA 70B), Standard for Electrical Safety Requirements for Employee Workplaces (NFPA 70E), Standard for Health Care Facilities (NFPA 99), Life Safety Code (NFPA 101), Recommended Practice for protection and Coordination of Industrial and Commercial Power Systems (IEEE 242-2001).

Prior to commencement of the testing procedures, the testing firm shall survey and catalog all components of the facility electrical distribution system. 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 recommendations.
3. Work items, definitions, and references shall comply with the latest edition of the NETA - Maintenance Testing Specifications.
   a. Below is a list of electrical equipment that shall be maintained and tested:
      - Switchgear and Switchboard Assemblies
      - Transformers, Dry Type, Air-Cooled, Low Voltage, Small
      - Transformers, Dry Type, Air-Cooled, Low Voltage, Large
      - Transformers, Liquid-Filled
      - Primary High-Voltage Sectionalizing Cabinets
      - Metal-Enclosed Busways
      - Switches, Air, Low-Voltage
      - Switches, Air, Medium-Voltage, Metal-Enclosed
      - Switches, Oil, Medium-Voltage
      - Switches, Vacuum, Medium-Voltage
      - Switches, SF_6, Medium-Voltage
      - Circuit Breakers, Air, Insulated-Case/Molded-Case

- Circuit Breakers, Air, Low-Voltage Power
- Circuit Breakers, Air, Medium-Voltage Power
- Circuit Breakers, Oil, Medium and High-Voltage
- Circuit Breakers, Vacuum, Medium-Voltage
- Circuit Breakers, SF_6
- Protective Relays, Mechanical, and Solid State
- Protective Relays, Microprocessor Based
- Grounding Systems
- Ground-fault Protection Systems
- Motor Control, Motor Starter, Low-Voltage
- Motor Control, Motor Starter, Medium-Voltage
- Emergency Systems, Engine Generators
- Emergency Systems, Automatic Transfer Switches
- Infra-Red Scanning: This work item must be done while the Electrical Distribution System is energized. Appropriate safety precautions must be taken and hot work permits requires by the station shall be approved by the COTR before, during and after scanning the system. Contractor shall use an infra-red scanning camera to detect and document hot spots in the Electrical Power Distribution System. Objective of this work is to inspect, test, detect, maintain, and/or repair any loose, broken, or corroded connections in the system. Problem connections shall be replaced with new connectors, and/or tightened with torque wrench to meet the equipment manufactures' specifications. Repairs shall be re-scanned at no additional cost to the government. Results, findings, and/or recommendations to correct deficiencies shall be documented in the final report.

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. 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. Where scan indicates lose and/or hot connections the contractor shall tighten connections and re-scan. See list of buildings to be tested.
- 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. Replace missing, hand written and/or pen and ink modified schedules. Provide new/updated panel schedules as required. Schedules shall be typed.

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.

g. Perform Testing and Maintenance on all Transformers with 20.8 KV primary voltage.

   1. Transformers of 500 kiloVolt Amps (kVA) or larger shall be cleaned exteriorly, inspected for sign of overheating with an infra-red thermal detecting equipment, and inspected for any damages to the housing, connection points, or insulation.

   2. Liquid cooled transformers must have the cooling liquid tested and replaced, when tests indicate that the liquid no longer meets manufacturer's specification. The liquid must be re-filled to meet the manufacturer's specification.

   3. Dry type transformers must be thoroughly cleaned exteriorly, and inspected for overheating with an infra-red thermal detecting equipment.

   4. Primary Oil-Filled **Transformers** - T2, T3, T4, T5, T6, T7, T8, T9, T11, T12, T13, T14, T15, T16, and T17.

h. Conduct **visual and infrared inspection** of all high voltage feeders and associated load-breaks at high voltage electrical manholes.

   1. VA will provide all emergency power required during the testing process.

   2. All breakers with electronic trip units may be tested utilizing secondary injection.

   3. Contractor to identify potential problems in manholes including but not limited to water infiltration, debris, cables under water, cable restraints (racks), and manhole integrity. Identify manholes that have sump pumps and record all locations. Visually inspect all feeders for proper labeling (see cable section for further work).

4. Contractor shall use lint-free rags to clean conductors, contact points between the circuit breakers and main buss bars, buss bars and interior of the electrical equipment. Use a vacuum cleaner to remove large debris; compressed air is not to be used for this purpose. Visually inspect for sign(s) of overheating, misaligned contacts, damaged insulation, or lose lugs.

5. Lubricate all moving parts with manufacturer's approved lubricants.

6. Test and exercise circuit breakers located in switchgears, switchboard, and distribution panels to ensure operation under overload, and short circuit conditions.

7. Test ground fault protection devices for proper function if they are installed in the Electrical Power Distribution System.

8. Inspect, clean, repair, replace, and/or tighten ground connections. Test ground resistance for the entire facility grounding system.

9. Identify the hot spots in the electrical equipment by using infra-red thermal detecting equipment. Tighten problem connections to meet equipment manufacturers' specification using a torque wrench or other approved devices.

10. Calibrate and maintain adjustable protective relays.

11. Test all control systems equipment for proper operation after maintenance is performed and before placing them back in normal service.

12. Only qualified senior staff at the facility and/or qualified electrical contract professionals is authorized to execute any operation, testing, and maintenance of the Electrical Power Distribution System in accordance with TJC and NFPA requirements, and that all work on these systems is compliant with OSHA standards.

13. All electrical work is executed with all proximate energized circuits de-energized. It is the intent of this directive to make planned electrical system shutdowns for maintenance/repair the standard operating procedure, not the exception.

14. Written procedures are established to prepare the medical center for a planned electrical outage. The procedures must take into account the worst case of risk to patients, staff, visitors, and VHA property. When a planned electrical outage cannot be accomplished, the following requirements are mandatory for working on energized circuit:

    a. Full and proper protective equipment (PPE) is available and worn by the qualified electricians (i.e., certified and tested insulating material to cover exposed energized electrical components, certified and tested insulated tools). ***NOTE:*** *Refer to the NFPA 70E, and General Safety Guidebook for guidance on the appropriate PPE.*

    b. Qualified electricians are provided with flame-retardant clothing for work at the proximity of energized electrical equipment.

    c. Before initiating work, a specific work plan is developed and a peer review of the plan documented.

        1. The work plan must include: procedures to be used on and near the energized electrical equipment, barriers to be installed, safety equipment to be provided, and exit paths to be accessed.

        2. An Energized Circuit Work Permit must be obtained from the Safety Office.

        3. Any energized electrical work plan must have the prior knowledge, and approval of the Medical Center Director. ***NOTE:*** *However, the Chief of Engineering Service may approve energized electrical work plan for Branch Circuits, from the final overcurrent protecting devices to the*

outlets, that do *not* *serve the critical patient care areas, such as Surgery Rooms, Critical Care, Intensive Care, Data Processing Room, IT closets, MRI, Isolation Rooms, Emergency Rooms, or Supply, Processing, and Distribution (SPD) rooms.*

ELECTRICAL TESTING & MAINTENANCE

Table of Contents

TABLES

1. GENERAL SCOPE

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

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

3. The work specified in these specifications may involve hazardous voltages, materials, operations, and equipment. These specifications do not purport to address all of the safety problems associated with their use. It is the responsibility of the user to review all applicable regulatory limitations prior to the use of these specifications

1.1 SUBMITTALS: Furnish the following:

1. 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.
2. Test, Inspection, and Maintenance Assessment/Action; Flash Hazards Analysis Study Plan(s):
    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.
3. 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.
4. 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. QUALIFICATIONS OF TESTING ORGANIZATION & PERSONNEL

3.1 Testing Organization

1. The testing organization shall be an independent, third party entity which can function as an unbiased testing authority, professionally independent of the manufacturers, suppliers, and installers of equipment or systems being evaluated.
2. The testing organization shall be regularly engaged in the testing of electrical equipment devices, installations, and systems.
3. The testing organization shall use technicians who are regularly employed for testing services.
4. An organization having a “Full Membership” classification issued by the Inter-National Electrical Testing Association meets the above criteria.
5. The testing organization shall submit appropriate documentation to demonstrate that it satisfactorily complies with these requirements.

3.2. Testing Personnel

1. Technicians performing these electrical tests and inspections shall be trained and experienced concerning the apparatus and systems being evaluated. These individuals shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must evaluate the test data and make a judgment on the serviceability of the specific equipment.
2. Technicians shall be certified in accordance with ANSI/NETA ETT-2000, Standard for Certification of Electrical Testing Personnel. Each on-site crew leader shall hold a current certification, Level III or higher, in electrical testing.

4. DIVISION OF RESPONSIBILITY

4.1 Owners Representative shall supply the following to the testing organization:

1. The owner shall make a determination of who will supply a suitable and stable source of electrical power to each test site. The testing firm shall specify the specific power requirements.
2. A determination of who shall perform certain preliminary low-voltage insulation-resistance, continuity, and/or low-voltage motor rotation tests prior to and in addition to tests specified herein.

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

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

5. Site-specific hazard and safety training

4.2 The Testing Organization shall provide the following:

1. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform such tests and inspections.
2. The testing firm shall notify the owner prior to commencement of any testing.
3 A timely notification of any system, material, or workmanship which is found defective on the basis of maintenance/acceptance tests.
4 The testing firm shall maintain a written record of all tests and shall assemble and certify a final test report.

5. GENERAL

5.1 Safety and Precautions

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

1. Safety practices shall include, but are not limited to, the following requirements:
    1. All current applicable provisions of the Occupational Safety and Health Act, particularly OSHA 29CFR 1910.
    2. Accident Prevention Manual for Industrial Operations, National Safety Council
    3. Applicable state and local safety operating procedures
    4. Owner's safety practices and permitting.
    5. ANSI/NFPA 70E, *Standard for Electrical Safety Requirements for Employee Workplaces.*
    6. OSHA 29 CFR 1910.147. *Control of Hazardous Energy Sources (Lockout/Tagout).*
    7. A safety lead person shall be identified prior to commencement of work.
    8. A safety briefing shall be conducted prior to the commencement of work.
2. All tests shall be performed with apparatus de-energized, and grounded 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. This may be the same individual as described in 5.1.2.

5.2 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.

5.3 Test Instrument Calibration

1. The testing firm shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy for each test instrument calibrated.
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 maximum
    3. Leased specialty equipment: 12 months maximum
    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.

5.4 Test Report

1. The test report shall include the following:
    1. Summary of project
    2. Company's name, address, telephone & FAX numbers.
    3. Name and signature of contractors who perform the maintenance and testing.
    4. VA Work Contract Number, name and number of VA Contracting Officer.
    5. Date of inspections, tests, maintenance, and/or calibrations.
    6. Copies of contractor's valid licenses, professional and training certificates.
    7. Descriptions and model number of specialized tools and equipment used, such as torque wrench or infra-red scanning camera.
    8. Humidity, temperature, and other conditions that may affect the results of the tests and/or calibrations.
    9. Indication of inspections, tests, maintenance, and/or calibrations to be performed and recorded.
    10. Indication of expected results when calibrations are to be performed.
    11. Indication of “as-found” and “as-left” results, as applicable.
    12. Sufficient spaces to allow all results and comments to be indicated.
    13. Description of equipment tested
    14. Description of test
    15. Location, Type, Name, and nameplate information of electrical equipment to be maintained and tested.
    16. Descriptions of work items.
    17. Test results
    18. Reference materials such as equipment manufacture's specifications, coordination study, etc.
    19. Provide analysis and remarks on conditions of electrical equipment. List all deficiencies, if any.
    20. Recommended corrective actions, if any.
2. Furnish four (4) hard copies of the complete written report to VA Contracting Officer within seven (7) calendar days of visit.
3. Submit four (4) hard copies of the complete written reports, and one (1) CD-Rom of the electronic version of the report in Microsoft Word format to the Chief of Engineering Service within seven (7) calendar days of visit. All reference materials shall be included in the electronic version of the report, either through scanning or other means of electronic text import methods.

4. Contractors shall report deficiencies that are deemed critical or catastrophic immediately to the Contracting Officer, and Chief of Engineering Service for immediate actions.

6. POWER SYSTEM STUDIES

I. General

a. The Contractor shall perform electrical studies for the Department of Veterans Affairs Roseburg Healthcare System located in Roseburg, Oregon. All work shall be accomplished in strict compliance with the latest edition of NFPA Code 70E, Electrical Safety Requirements For Employee Workplaces; and IEEE 242-2001 Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems. All survey work will be accomplished on energized equipment unless an outage is absolutely necessary on specific equipment. All requests for outages must be submitted in writing to and approved by the Facility Manager/Chief Engineer. Appropriate protective devices (PPE) and/or equipment shall be used in those exceptional cases where it is necessary to remove covers/open equipment thereby exposing live buses or other energized components.

b. The Contractor shall conduct an entrance briefing with the Facility Manager/Chief Engineer upon arrival to the Roseburg campus. The Contractor shall use the meeting to introduce him/herself and to discuss the procedures for obtaining the necessary drawings and field information. The Contractor shall have the Chief Engineer/Facility Manger complete or review a survey of compliance with VHA Directive 2006-056, Electrical Power Distribution System. At the completion of the site survey, the Contractor shall conduct a short briefing with the Medical Center Director or Designee to discuss any major problems or life threatening issues if any are discovered during the survey. All information obtained during the site visit or any conditions discovered during subsequent calculations shall be kept in strict confidence.

c. The electrical system study(s) will include site visits to the site by a team from the Contractor. The Contractor's team members will consist of experienced, professional staff having extensive knowledge in the field of electrical power and shall include at least one registered professional electrical engineer. The Contactor will be responsible for obtaining all necessary data for these reports from as-built drawings, field investigations and from available VAMC staff (utilizing the staff's knowledge and familiarity of the facility electrical systems) information for site electrical utilities will also be gained from as-built drawings and Contractor's personal inspection of these utilities.

II. Furnished Documentation

a. **As-Built Drawings.** As-built drawings may not be 100% accurate and will need verification by the Contractor. Substantial deviations from actual as-built condition which affects the SOW shall be brought to the attention of the COR.

b. **A list of buildings to be assessed.** Electrical equipment, such as switchboards, panelboards, industrial control panels, meter socket enclosures, transformers, sectional switched, transfer switches and motor control centers, that are in other than dwelling units, and are likely to require examination, adjustment, servicing, or maintenance while energized.
   1. Panels in Buildings - 1, 1AC, 2, 3, 4, 5, 6, 7, 9, 10, 11, 13, 14, 15, 16, 17, 57, 58, 60, 61, 62, 63, 64, 65, 71, 81, 82, T-6, T-7, T-8, and the Incoming Switch Gear Cabinet.
   2. **Transformers** - T2, T3, T4, T5, T6, T7, T8, T9, T11, T12, T13, T14, T15, T16, and T17.

c. **Plans and One-line Diagrams**. Site plan, incoming electrical service and primary distribution system one-line diagram and basic one-line diagram if requested.

d. **VHA Directive 2006-056 (or latest version) and accompanying Survey**. The Directive and Survey shall be completed (or reviewed, if existing) with the Chief Engineer/Facility Manager during the entrance briefing. See Attachment 1 for the VHA Electrical Directive and Compliance Survey Form.

e. **VAMC personnel** knowledgeable of the existing electrical systems that shall accompany the Contractor's team members during the site investigation. The contractor shall coordinate and verify schedule and personnel, with the COR, in advance of site visit. The COR shall ensure that medical center personnel are available to accompany the survey team. Field survey data collection efforts shall require no more than two members of VAMC staff.

f. **Any significant electrical maintenance and testing** reports performed at the VAMC.

g. Facility Ground Resistance Test Reports. VAMCs are required to "test ground resistance for the entire facility" every 36 months in accordance with VHA Directive 2006-056. VAMC is to provide the A-E the most recent of these ground resistance test report.

III DELIVERABLES

For 60% and 90% submission, provide four hard copies and electronic copies (compact disc) of the electrical system study (including data files).

1. Drawings (Full-size for site, primary one-line diagram and secondary one-line diagrams) Use AutoCAD10th the local VAMCs version) and provide the viewer on each CD. For the Final Study Submittal, the VAMC shall receive "live" CADD drawing files which can be manipulated and updated.
2. Reports shall be loose leaf, three-hole punched, in an appropriately sized binder to include all data and drawings.
3. Submit, with the bid proposal, a proposed schedule for completion of each of the studies in the order as listed above.
4. The content requirements for each submission:

a. 60% submission SHALL include:

1. Letter from local electric utility provider indicating the available fault current at the point of service.

2. Executive Summary.
3. Analysis and calculations for the Primary Distribution System and partial Secondary Distribution System for each building including switchgear, switchboard and distribution panel etc. Analysis shall include Short Circuit Study and Protective Device Coordination Curves (black only). The analysis shall be based on the actual device data (including but not limit to fuses, breakers and relays).

b. 90% submission SHALL include:

1. All Content from 60% submittal (except as updated below)
2. Deficiencies report and cost estimates.
3. All comments from 60% submission with annotations and responses;
4. All items identified in Para. 5, Specific Scope, as a separate Tab or Section to include:

   A. One-Line Diagram
   B. Grounding Analysis
   C. Short Circuit Study
   D. Hazard-Risk Table
   E. Coordination Curves (In black)
   F. Voltage Drop Calculations
   G. Emergency Power Analysis
   H. Recommendations
   I. Protective Device Settings
   J. Cost Estimates

5. Completed analysis and calculations for the entire Primary and Secondary distribution.
6. Completed one-line diagrams. Each building on the building list in the Scope of Work shall be identified on the diagrams.

c. For Final Submission, provide three hard copies and one electronic copy (compact disc) of the electrical system study (including data files).

One original document of Final Submission shall be sent to the COR at Sheridan VAMC and shall include:

1. **A completed Report**, including all corrected data from the 60% and 90% submittals and the coordination curves shall be printed in color.
2. Responses to the 60% and 90% submission comments from VAMC, including annotations and response.
3. Electronic copy (CD) of the entire report including all SKM data, AutoCad, Word, Excel files and PDF.
4. Color photos that show devices listed on the deficiency report.
5. Arc Flash Boundary Signage/Labels reflecting the Hazard-Risk Table.
6. Provide final report with stamp and signature by a Licensed Professional Electrical Engineer.

IV. SPECIFIC SCOPE

The Contractor shall prepare a complete short circuit and coordination study including voltage drop calculations on the entire electrical system (both normal and emergency). It shall begin at the incoming utility electrical service (for the normal system) and at the emergency generators (for the emergency system) and continue through to each branch circuit panelboard, motor control center or motor control panel in each building. The study shall include a system one-line diagram; short circuit and ground resistance analysis, hazard risk table, arc flash labeling, protective coordination plots, voltage drop calculations and the following for each building:

a. **One Line Diagrams:**

1. The one-line diagrams shall show the schematic wiring of the electrical distribution system for each building. Include all electrical equipment and wiring protected by the over current devices.
2. Also show on the one line diagrams the following specific information:
   a. Calculated short circuit values at each bus.
   b. Breaker and fuse ratings.
   c. Transformer kVA, voltage ratings and wiring connections.
   d. Voltage at each bus.
   e. Identification of each bus.
   f. Conduit material, feeder sizes and lengths.
   g. Generator kW and voltage ratings

b. **Ground Resistance Analysis:** A concise qualitative description (not to exceed one (1) page of narrative) describing the overall condition of the facility ground resistance shall be provided. Any violations of NEC or other abnormalities (high ground resistance, damaged conductors or electrodes, harmonics, etc) warranting further detailed study shall be highlighted. Analysis of the facility ground resistance shall be based upon:

1. Facility Ground Resistance Test reported (provided by VAMC);
2. Visual inspection of visible ground system components (made during site investigation). Include photographs in Appendices.
3. Interviews with VAMC engineering staff; and
4. Other data on ground system made available by the VAMC.

c. **Short Circuit Study:**

1. Scope of Study. Determine the short-circuit current available at each component of the electrical system and the ability of the component to withstand and/or interrupt the current. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.
2. Procedure. The short-circuit study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399 and the step-by-step procedures outlined in the short-circuit calculation chapters of IEEE 141 and ANSI/IEEE 242.
3. Systematically calculate the fault impedance to determine the available short circuit and ground fault currents at each bus. Incorporate the motor

contribution in determining the momentary and interrupting ratings of the protective devices. Motors less than 25 HP may be grouped together.

4. The study shall be calculated by using SKM software. Pertinent data and the rationale employed in developing the calculations shall be incorporated in the introductory remarks of the study.
5. Present the data determined by the short circuit study in a table format. Include the following:
   a. Basis, description, purpose, and scope of the study.
   b. Tabulations of the data used to model the system components and a corresponding one-line diagram.
   c. Descriptions of the scenarios evaluated and identification of the scenario used to evaluate equipment short-circuit ratings.
   d. Tabulations of equipment short-circuit ratings versus available fault duties. The tabulation shall identify percentage of rated short-circuit and clearly note equipment with insufficient ratings.
   e. Conclusions and recommendations.
   f. Transformer kVA and voltage ratings, percent impedance, X/R ratios and wiring connections.
   g. Generator kW and voltage ratings.
   h. Conduit material, feeder sizes, length and X/R ratios.
   i. Device identification (Manufacturer, Catalog No. and Device Curve No. and ID)
   j. Operating voltage.
   k. Protective device.
   l. Device rating.
   m. Calculated short circuit current.
   n. Hazard-Risk category at each piece of equipment for the worst-case fault condition.

d. Hazard-Risk Table: For each piece of electrical equipment identified in the Short Circuit Study above, provide in table format the following information using NFPA 70E, 2012 edition and calculations as appropriate:

1. From NFPA 70E, Table 130.4 (C) “Approach Boundaries to Live Parts for Shock Protection.”
   a. Limited Approach Boundary.
   b. Restricted Approach Boundary.
   c. Prohibited Approach Boundary.
2. From NFPA 70E, Article 130.5 “Flash Hazard Analysis." A flash hazard analysis shall be done in order to protect personnel from possibility of being injured by an arc flash. The analysis shall determine the **Flash Protection Boundary** and the **Hazard/Risk Category**. From NFPA 70, Annex D.8, **"Basic Equations for calculating Incident Energy and Flash Protection Boundary."** The contractor shall use IEEE Standard 1584 equations to estimate incident energy and **Flash Protection Boundary**.

3. From NFPA 70E, Table 130.7 (C) (15) (a) **"Hazard Risk Category Classifications"**, include in the table the worst-case Hazard Risk Category (0 through 4) associated each piece of equipment. (i.e. work on any energized parts of Metal Clad Switchgear, 1kV and above, has a Hazard Risk Category of 4) List required protective FR clothing for each category.
4. Confirm the required personal protective equipment with arc rating to provide adequate protection for personnel working on or near-energized conductors or components.

e. Arc Flash Labeling:

1. Contractor shall produce and deliver to the VAMC up to five hundred (500) arc flash warning labels in accordance with NFPA 70 (NEC) and NFPA 70E. Labels shall be 4" x 6" (nominal) printed on industrial quality, adhesive backed vinyl. "Danger" labels shall have pre-printed headers in red; "Warning" labels shall have pre-printed headers in orange. Electrical equipment shall be labeled IAW NFPA 70, Article 110.16. The arc flash hazard analysis to be determine the Arc Flash Protection Boundary for each label shall be calculated IAW NFPA 70E Paragraph 130.5. For each device for which a hazardous analysis is conducted, the equipment shall be field marked with a label containing the available incident energy or required level of PPE. Electrical equipment meeting the requirements of Exception #1 of Para. 130.5 may use generic labels.
2. In addition to the requirements of NFPA 70 and 70E, each customized label containing specific available incident energy or required level of PPE shall identify the corresponding piece of electrical equipment, by Panelboard or device identifier and Building number. The identification shall be in a manner understood by VAMC personnel who will be applying the labels to the respective devices. Generic labels do not require equipment and building identifiers.

f. Coordination Study:

1. Scope of Study. Determine protective device characteristics, settings, or sizes that provide a balance between equipment protection and selective device operation that is optimum for the electrical system. Provide an analysis of all possible operating scenarios.
2. Procedure. The coordination study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399 and ANSI/IEEE 242. Protective device selection and settings shall comply with requirements of the NFPA 70 National Electrical Code.
3. Study Report. Results of the coordination study shall be summarized in a final report containing the following items:
   a. Basis, description, purpose, and scope of the study and a corresponding one-line diagram.
   b. Time-current curves demonstrating the coordination of time-over-current protective devices.

c. Tabulations of protective devices identifying circuit location, manufacturer, type, range of adjustment, IEEE device number, current transformer ratios, recommended settings or device size, and referenced time-current curve.
d. Conclusions and recommendations.

4. Prepare the coordination curves to determine the required settings of protective devices to assure selective coordination. Graphically illustrate (using log paper) that adequate time separation exists between series devices, including the utility company upstream device. Plot the specific Time Current Characteristics (TCC) of each device in the electrical system as follows:
   a. Provide TCC curve down to the last branch-circuit panelboard (regardless the protective device is an adjustable or fixed device) in the three-branches of the Essential Electrical System (EES).
   b. Provide TCC curve down to the last adjustable device (stop after the first fixed device) in the Normal System but at the the minimum two-level curves from each of the building Service Entrance switchgear/switchboard shall be provided.
5. The following specific information shall also be shown on the coordination curves at each level of power distribution system:
   a. Device identification (including Manufacturer, Catalog Number, and Device Curve Number and ID)
   b. Voltage and current ratio for curves.
   c. 3-phase and 1-phase ANSI damage points for each transformer.
   d. No-damaged, melting, and clearing curves for fuses.
   e. Cable damage curves.
   f. Transformer inrush points.
   g. Maximum short circuit cutoff point.
   h. Excerpts from one-line diagram reflecting the protective devices modeled on each curve. This excerpt may be inserted onto a corner (typically top right-hand) of the curve print out or may be on the preceding facing page for ease of reference.
   i. Provide explanation, analysis, and recommendation to achieve better coordination.
   j. The analysis for recommended curve of a particular device shall be put right after the existing curve in the report for comparison.
6. Develop a table to summarize the settings selected for the protective devices. Include all medium voltage devices in the table, as well as all low voltage devices which require modification, showing the following data:
   a. Device identification.
   b. Relay CT ratios, tap, time dial, and instantaneous pickup.
   c. Circuit breaker sensor rating, long-time, short-time, and instantaneous settings, and time bands.
   d. Fuse rating and type.
   e. Ground fault pickup and time delay.

g. Voltage Drop Calculations:

1. Provide voltage drop calculations for all three-phase branch and feeder circuits. Show calculated voltages at each bus and voltage drops on each feeder.
2. Calculations shall be based of the maximum values of kVA, kW, kvar, power factor and amperes for each power circuit.
    a. For branch circuit level, use 80% of nameplate rating.
    b. For incoming service and distribution level, use 50% of the nameplate rating or actual maximum peak demand load collected in the field if it is available.
3. Provide tabular information showing the sizes of all cables, transformers and other circuit data.
4. Provide a system one-line diagram which clearly identifies individual equipment busses, bus numbers, cable and bus connections and other circuit information.
5. Provide a separate section or tables which provide an evaluation of the calculated voltage drops with recommendations for improvements where voltage drops exceed the allowable NEC limits.

h. Emergency Power System Analysis:

First, a narrative describing the existing emergency power system(s) at the medical center shall be provided, to include a description of each emergency generator, physical location, size (kW and ampacity), voltage, configuration (phase, wire), circuit number, age, and overall condition. A summary of the average loading on each generator (based on data provided by the VAMC) shall be provided and then compared to projected future loads (A-E shall develop load projections from discussing forecast projects and growth with VAMC engineering staff). Finally, A-E shall provide a qualitative narrative on the suitability of the existing generators to meet projected future loads. If existing Emergency Power System, including generators, is not adequate to meet either current or future demands, recommendations shall be provided in the study.

i. Analysis and Recommendations

1. For all electrical equipment, determine if adequate code clearances exist. Note cases by site, building and specific equipment that do not include adequate code clearances and provide a cost estimate to resolve the problems. Provide information in table format.
2. Determine if ground fault protection exists where required by NFPA 70 Articles 215 and 517. Note all cases where ground fault protection does not exist and provide cost estimates to correct. Provide information in table format.
3. For all automatic transfer switches, determine if the correct 3-pole or 4-pole switches are used. Where ground fault protection is used on the normal feed to the switch, determine if the switch is correctly wired. Note all cases where

this condition exists and provide cost estimates to correct. Provide information in table format.

4. Note any use of cable limiters and provide recommendations to avoid any single phasing conditions. Note all cases where this condition exists and provide cost estimates to correct. Provide information in table format.
5. On the medium voltage switchgear, where under-voltage relays (27) are used, determine whether all 3 phases are monitored or only 2 phases are monitored. For those locations where only 2 phases are monitored, provide a cost estimate for providing adequate protection for all 3 phases.
6. Analyze the short circuit calculations, and highlight any equipment that is determined to be underrated. Provide recommendations to effectively protect the underrated equipment.
7. After developing the coordination curves, highlight areas lacking coordination. Present a technical evaluation with a discussion of the logical compromises for best coordination.
8. Report any NEC code violation found and provide a cost estimate to resolve the problem.
9. Assess the equipment condition using grading method in term of A, B, C, D and F.

   Grade A - Like New Condition. Majority of useful life span remains. "Excellent".
   Grade B - Good Condition. Over half of useful life span remains. "Good"
   Grade C - Average Condition. Less than half of useful life span remains. "Average",or "Fair", or C+ "Above Average"
   Grade C- - Workable Condition. May be past assigned useful life, but still working. "Keep an eye on it"
   Grade D - Poor Condition. Past assigned useful life. Failure is not critical. "Poor" or "Problematic"
   Grade F - Critical Condition. Needs immediate attention. "Failing" or "Critical"

j. Protective Device Settings:

1. For all adjustable and fixed protective devices, provide tables to show existing settings and new settings where changes are recommended for proper protection.
2. If adjustments will not provide adequate protection, provide recommendations to update or replace the existing underrated equipment and include cost estimates to accomplish the necessary corrections.
3. Provide table in Excel format to show ONLY the devices that require that their settings need adjustment.

k. Cost Estimates:

1. For each building included in the electrical study at each Medical Center, where recommendations are to replace or update the existing electrical

system to provide adequate protection, provide estimated construction costs for the necessary work.

2. Total costs for each building shall be included in addition to an itemized breakdown to identify major items requiring replacement or upgrading.
3. Costs shall be totaled for each Medical Center.
4. Cost estimates shall not include adjustments for anticipated phasing, shut downs or overtime work.
5. An electronic copy of the Cost Estimate in an editable MS Excel spreadsheet shall be included in the submission of the final, corrected study (see para. 4. B.ii.7). The Excel spreadsheet will be used to track mitigation efforts.

V. SCHEDULE

a. Site survey work shall begin immediately, and be coordinated with VAMC after award of contract. All final reports shall be completed, submitted and approved within 150 calendar days after the Notice to Proceed.

b. The study will provide an independent and documented overview of the entire electrical infrastructure conditions in each building at the Medical Center. The Medical Center shall be contacted at least three (3) weeks in advance of the site visit to allow ample time for the Medical Center to arrange the staffs and prepare the necessary documents.

c. This electrical study shall take no longer than 150 calendar days. Draft final reports shall be submitted 30 days before the submission of the complete final report. The draft final report will be reviewed by the government with comments, edits and corrections provided to the contractor within three weeks after receipt of the draft final report. The contractor shall provide a schedule for the start and submission/completion of this awarded study over a time period of 150 calendar days.

d. Draft final reports (90% submission) shall be submitted 30 days before the submission of the complete final report. The draft final report will be reviewed by the government with comments, edits and corrections provided to the contractor within three weeks after receipt of the draft final report.

e. Contractor shall submit a tentative delivery schedule for approval prior to any work.

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. Inspect, verify appropriate anchorage, grounding, 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.
5. Verify that current and voltage transformer ratios correspond to drawings.

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 **7.1**.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.
    3. Perform thermographic survey in accordance with Section 9.
7. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
    a. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
    b. 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 bolted electrical connections 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 an over potential test on each bus section, each phase to ground with phases not under test grounded, in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 100.2. The test voltage shall be applied for one minute.
6. Perform insulation-resistance tests on control wiring with respect to ground. Applied potential shall be 500 volts dc for 300 volt rated cable and 1000 volts dc for 600 volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
7. Perform system function tests in accordance with Section **8**.
8. Perform an over-potential test on each bus section, each phase to ground with phases not under test grounded, in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 100.2. The test voltage shall be applied for one minute.
9. Perform insulation-resistance tests on control wiring with respect to ground. Applied potential shall be 500 volts dc for 300 volt rated cable and 1000 volts dc for 600 volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
10. 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. Perform secondary wiring integrity test. Disconnect transformer at secondary terminals and connect secondary wiring to a rated secondary voltage source. Verify correct potential at all devices.
    3. Verify correct secondary voltage by energizing primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.

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

11 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. Perform secondary wiring integrity test. Verify correct potential at all devices.
3. Verify secondary voltages by energizing primary winding with system voltage.

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.
6. Insulation-resistance values for control wiring shall be a minimum of 2.0 megohms.

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. Compare equipment nameplate data with latest one-line diagram.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.

4. Verify that resilient mounts are free and that any shipping brackets have been removed.
5. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
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 **7.2.1.1.**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.
    3. Perform thermographic survey in accordance with Section 9.

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section **7.2.1.1.**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. Compare equipment nameplate data with latest one-line diagram.
    2. Inspect physical, electrical, and mechanical condition including evidence of moisture, corona, or brittleness.
    3. Inspect anchorage, alignment, and grounding.
    4. Verify that control and alarm settings on temperature indicators are as specified.
    5. Verify that cooling fans operate.
    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 **7.2.1.2.**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.
        3. Perform thermographic survey in accordance with Section 9.
    7. Perform specific inspections and mechanical tests as recommended by manufacturer.
    8. Verify that resilient mounts are free and that any shipping brackets have been removed.
    9. Verify that the core, frame, and enclosure are grounded.
    10. Verify the presence of transformer surge arresters.
    11. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
    12. 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 (1) megohm at 500 volts dc.

10. AC over-potential test shall not exceed 75 percent of factory test voltage for one minute duration. DC over-potential test shall not exceed 100 percent of the ac rms test voltage specified in ANSI/IEEE C57.12.91, Section 10.2 for one minute duration. The insulation shall withstand the over-potential test voltage applied.

3. Liquid-Filled

1. **Visual and Mechanical Inspection**

1. Compare equipment nameplate data with drawings and specifications.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Verify that alarm, control, and trip settings on temperature indicators are as specified.
5. Verify bushings are clean.
5. Verify that cooling fans and/or pumps operate correctly and that fan and pump motors have correct over-current protection, if applicable.
6. Verify operation of all alarm, control, and trip circuits from temperature and level indicators, pressure relief device, gas accumulator, and fault pressure relay, if applicable.
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 7.2.
    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. Perform Thermographic Survey in accordance with Section 9.
8. Verify correct liquid level in all tanks and bushings.
9. Verify that positive pressure is maintained on nitrogen-blanketed transformers.
10. Perform specific inspections and mechanical tests as recommended by manufacturer.
11. Verify correct equipment grounding.
12. Test load tap-changer in accordance with Section 7.12, if applicable.
13. 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.
10. Test instrument transformers in accordance with Section 7.10.
11. Test transformer neutral grounding impedance device, 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. 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 (1) megohm at 500 volts dc.
12. Investigate presence of oxygen in nitrogen gas blanket.
13. Insulating liquid test results shall be in accordance with Table 10.4.
14. Evaluate results of dissolved-gas analysis in accordance with ANSI/IEEE Standard C57.104.
15. Compare grounding impedance device results to manufacturer's published data.

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. Compare cable data with drawings and specifications. Verify cable labeling. Provide missing labeling using color coded electrical tape. Replace weathered or worn tape.
        2. Inspect exposed sections of cables for physical damage and evidence of overheating.
        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 **7.3.1.**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. Perform thermographic survey in accordance with Section 9.
        4. Inspect compression-applied connectors for correct cable match and indentation.

5. Inspect and provide for correct identification and arrangements.
6. Inspect jacket insulation and condition.

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. Perform continuity tests to insure correct cable connection.
4. Verify uniform resistance of parallel conductors.

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 (2) megohms.
5. Insulation-resistance values should not be less than 50 megohms.
6. Investigate deviations in resistance between parallel conductors.
7. Investigate deviations between adjacent phases.

2. Medium-Voltage, 69 kV Maximum

1. Visual and Mechanical Inspection

1. Compare cable data with drawings and specifications.
2. Inspect exposed sections of cables for physical damage and evidence of overheating and corona.
3. Inspect terminations and splices for evidence of overheating and corona.
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 **7.3.2.**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.

3. Perform thermographic survey in accordance with Section 9.

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

6. Inspect for shield grounding, cable support, and termination.

7. Verify that visible cable bends meet or exceed ICEA and/or manufacturer's minimum allowable bending radius.

8. Inspect fireproofing in common cable areas.

9. 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.

10. Inspect for correct identification and arrangements.

11. Inspect jacket and insulation condition.

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.
        3. Inspect compression-applied connectors for correct cable match and indentation.
        4. Inspect for shield grounding, cable support, and termination.
        5. Verify that visible cable bends meet or exceed ICEA and/or manufacturer's minimum allowable bending radius.
        6. Inspect fireproofing in common cable areas.
        7. 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.
    3. Confirm physical orientation in accordance with manufacturer's labels to insure adequate cooling.
    4. Examine outdoor busway for removal of "weep-hole" plugs, if applicable, and the correct installation of joint shield.
    5. 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 Measured sis ce x Length of Run 1000ft 1000 = Re tan

   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.
6. 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 over-potential 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 over-potential 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 (over-potential) 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. Perform insulation-resistance test on all control wiring at 1000 volts dc. For units with solid-state components, follow manufacturer's recommendations.
7. Perform an over-potential 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 anti-pump 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.

h. 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 under-voltage 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 anti-pump 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 (2) megohms.
6. Trip characteristics of breakers shall fall within manufacturer's published time-current tolerance bands.

3. 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. SF6 (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 SF6 interrupters.
    7. Verify correct SF6 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. E. 27 Under-voltage 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 (I2)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 (under-voltage 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 Over-current Relay
    1. Determine pickup.
    2. Determine dropout.
    3. Determine time delay.
14. 51 Time Over-current
    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 Over-current 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 over-current unit pickup.
 6. Determine over-current 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 over-current lockout.

22. 81 Frequency Relay

 1. Verify frequency set points.
 2. Determine time delay.
 3. Determine under-voltage cutoff.

23. 85 Pilot Wire Monitor

 1. Determine over-current 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 Used

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 Used

7.16 Motor Control

1. Motor Starters

1. Low-Voltage

1. Visual and Mechanical Inspection
    1. Inspect physical and mechanical condition.
    2. Inspect contactors.
    3. Verify mechanical operation.
    4. Inspect and adjust contact gap, wipe, alignment, and pressure in accordance with manufacturer's published data.
    5. 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.

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 7.16.1.1.2.1 (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.
7. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
8. 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 - Not Used

7.18 Direct-Current Systems - Not Used

7.19 Surge Arresters – Not Used

7.20 Capacitors and Reactors – Not Used

7.21 Outdoor Bus Structures – Not Used

7.22 Emergency Systems

7.22.1 Emergency Systems, Engine Generator

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

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.

2. Electrical and Mechanical Tests

1. Test generator in accordance with Section 7.15.

2. Test protective relay devices in accordance with Section 7.9.
3. Perform phase-rotation test to determine compatibility with load requirements.
4. Functionally test engine shutdown for low oil pressure, over-temperature, over-speed, and other protection features as applicable.
5. Perform vibration test for each main bearing cap.
6. Conduct performance test in accordance with ANSI/NFPA 110.7. Verify correct functioning of governor and regulator.

3. **Test Values**
    1. Phasing shall meet the requirements of the connected load.2. Vibration levels shall be in accordance with manufacturer's published data.3. Performance tests shall conform to manufacturer's published data and ANSI/NFPA 110.

7.22.2 Emergency Systems, Uninterruptible Power Systems

1. **Visual and Mechanical Inspection**
    1. Compare equipment nameplate data with drawings and specifications.
    2. Inspect physical and mechanical condition.
    3. Inspect anchorage, alignment, grounding, and required clearances.
    4. Verify that fuse sizes and types correspond to drawings.
    5. Verify the unit is clean.
    6. Test all electrical and mechanical interlock systems for correct operation and sequencing.
    7. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.22.2.2.2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.3. Perform thermographic survey in accordance with Section 9.
    8. Verify operation of forced ventilation.
    9. Verify that filters are in place and/or vents are clear.
2. **Electrical Tests**
    1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.22.2.1.
    2. Test static transfer from inverter to bypass and back. Use normal load, if possible.
    3. Set free running frequency of oscillator.

4. Test dc under-voltage trip level on inverter input breaker. Set according to manufacturer's published data.
5. Test alarm circuits.
6. Verify synchronizing indicators for static switch and bypass switches.
7. Perform electrical tests for UPS system breakers in accordance with Section 7.6.
8. Perform electrical tests for UPS system automatic transfer switches in accordance with Section 7.22.3.
9. Perform electrical tests for UPS rotating machinery in accordance with Section 7.15.

3. Test Values

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels should be in accordance with Table 100.12 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 50 percent of the lowest value.
4. For breaker performance, refer to Section 7.6.
5. For automatic transfer switch performance, refer to Section 7.22.3.
6. For rotating machinery, refer to Section 7.15.

3. Emergency Systems, Automatic Transfer Switches

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required clearances.
4. Lubrication
    1. Verify appropriate contact lubricant on moving current-carrying parts.
    2. Verify appropriate lubrication on moving and sliding surfaces.
5. Verify that manual transfer warnings are attached and visible.
6. Verify tightness of all control connections.
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 **7.22.3.**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.
3. Perform thermographic survey in accordance with Section 9.

8. Perform manual transfer operation.
9. Verify positive mechanical interlocking between normal and alternate sources.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.22.3.1.
2. Perform insulation resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300 volt rated cable and 1000 volts dc for 600 volt rated cable. Test duration shall be one minute. For units with solid-state components or for control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
3. Perform a contact/pole-resistance test.
4. Verify settings and operation of control devices.
5. Calibrate and set all relays and timers in accordance with Section 7.9.
6. Verify phase rotation, phasing, and synchronized operation as required by the application.
7. Perform automatic transfer tests:
    1. Simulate loss of normal power.
    2. Return to normal power.
    3. Simulate loss of emergency power.
    4. Simulate all forms of single-phase conditions.
8. Verify correct operation and timing of the following functions:
    1. Normal source voltage-sensing relays.
    2. Engine start sequence.
    3. Time delay upon transfer.
    4. Alternate source voltage-sensing relays.
    5. Automatic transfer operation.
    6. Interlocks and limit switch function.
    7. Time delay and retransfer upon normal power restoration.
    8. Engine cool down and shutdown feature.

3. Test Values

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels should 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 50percent of the lowest value.
4. Insulation-resistance values should be in accordance with Table 10.1.

7.23 Automatic Circuit Reclosers and Line Sectionalizers – Not Used

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.

9. THERMOGRAPHIC SURVEY

Equipment to be inspected shall include all current-carrying devices.

1. **Visual and Mechanical Inspection**
    1. Perform thermographic survey when load is applied to the system.
    2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
    3. Perform a follow-up thermographic survey within 12 months of final acceptance by the owner.
2. **Report -** Provide a report which includes the following:
    1. Description of equipment to be tested.

2. Discrepancies.
3. Temperature difference between the area of concern and the reference area.
4. Probable cause of temperature difference.
5. Areas inspected. Identify inaccessible and/or unobservable areas and/or equipment.
6. Identify load conditions at time of inspection.
7. Provide photographs and/or thermograms of the deficient area.
8. Recommended action.

3. Test Parameters

1. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
2. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
3. Thermographic surveys should be performed during periods of maximum possible loading. Refer to ANSI/NFPA 70B, Section 20.17.
4. Test Results

Suggested actions based on temperature rise can be found in Table 10.18.

Table 10.1

Insulation Resistance Test

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**	**Tetrachloroethylene 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 Voltage (kV, dc)

Insulation Type	**Rated Cable Voltage**	**Insulation Level**	**Test Voltage kV, dc**
Elastomeric: 5 kV 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: 5 kV 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 5 kV (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 Rating1	
	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	90	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	200	200	1 minute	240	120	3 minutes
345	300	300	1 minute	360	180	3 minutes
500	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)

Unit Rating	**60 Hertz (rms) Test**			**Direct Current Test**		
	Voltage kV (rms)	Maximum Allowable Current Microamperes	Time	Voltage kV	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	Time	Voltage kV	Allowable Current	Time

		Current Microamperes			Microamperes	
46 kV & below	40	400	1 minute	56	56	3 minutes
26 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 Microamperes	Time	Voltage kV	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)			
1/4	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
1/2	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
3/4	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	**Non-lubricated**	**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 SF6 circuit breaker gas tests, the NETA Technical Committee suggests the above representative values.
[(3)] Dominelli, N. and Wylie, L., Analysis of SF6 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 (1_ and 3_)	15.0	95	26.2
14.4 (1_ and 3_)	15.5	110	37.5
24.9 (1_ and 3_)	27.0	150	45.0
34.5 (1_ and 3_)	38.0	150	52.5
46.0 (3_)	48.3	250	78.7
69.0 (3_)	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 29.5 34.5	37.0 45.0 60.0	52.0 -- --
Isolated Phase for Other than Generator Leads	15.5 25.8 38.0	37.0 45.0 60.0	52.0 -- --
Nonsegregated Phase	0.635 4.76 15.0 25.8 38.0	1.6 14.2 27.0 45.0 60.0	2.3 20.0 37.0 63.0 --
Segregated Phase	15.5 25.8 38.0	37.0 45.0 60.0	52.0 63.0 --
DC Bus Duct	0.3 0.8 1.2 1.6 3.2	1.6 2.7 3.4 4.0 6.6	2.3 3.9 4.8 5.7 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.