

SECTION 26 08 00
COMMISSIONING OF ELECTRICAL SYSTEMS

PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
 - a. D877/D877M, Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes.
 - b. D923, Standard Practices for Sampling Electrical Insulating Liquids.
 - c. D924, Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids.
 - d. D971, Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Method.
 - e. D974, Standard Test Method for Acid and Base Number by Color-Indicator Titration.
 - f. D1298, Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method.
 - g. D1500, Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale).
 - h. D1524, Standard Test Method for Visual Examination of Used Electrical Insulating Liquids in the Field.
 - i. D1533, Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration.
 - j. D1816, Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using VDE Electrodes.
2. Institute of Electrical and Electronics Engineers (IEEE):
 - a. 43, Recommended Practice for Testing Insulation Resistance of Electric Machinery.
 - b. 81, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.
 - c. 450, Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.
 - d. C2, National Electrical Safety Code.
 - e. C37.23, Standard for Metal-Enclosed Bus.
 - f. C62.33, Standard Test Methods and Performance Values for Metal-Oxide Varistor Surge Protective Components.

3. National Electrical Manufacturers Association (NEMA):
 - a. AB 4, Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications.
 - b. PB 2, Deadfront Distribution Switchboards.
4. InterNational Electrical Testing Association (NETA): ATS, Acceptance Testing Specifications for Electrical Power Equipment and Systems.
5. National Fire Protection Association (NFPA):
 - a. 70, National Electrical Code (NEC).
 - b. 70B, Recommended Practice for Electrical Equipment Maintenance.
 - c. 70E, Standard for Electrical Safety in the Workplace.
 - d. 101, Life Safety Code.
6. National Institute for Certification in Engineering Technologies (NICET).
7. Occupational Safety and Health Administration (OSHA): CFR 29, Part 1910, Occupational Safety and Health Standards.

1.02 SUBMITTALS

A. Informational Submittals:

1. Submit 30 days prior to performing inspections or tests:
 - a. Testing firm qualifications.
 - b. Schedule for performing inspection and tests.
 - c. List of references to be used for each test.
 - d. Sample copy of equipment and materials inspection form(s).
 - e. Sample copy of individual device test form.
 - f. Sample copy of individual system test form.
2. Energization Plan:
 - a. Prior to initial energization of electrical distribution equipment, include the following:
 - 1) Contracting Officer sign-off form for complete and accurate arc flash labeling and proper protective device settings for equipment to be energized.
 - 2) Staged sequence of initial energization of electrical equipment.
 - 3) Lock-Out-Tag-Out plan for each stage of the progressive energization.
 - 4) Barricading, signage, and communication plan notifying personnel of newly energized equipment.
3. Submit test or inspection reports and certificates for each electrical item tested within 30 days after completion of test.

4. Operation and Maintenance Data:
 - a. In accordance with Section 01 78 23, Operation and Maintenance Data.
 - b. After test or inspection reports and certificates have been reviewed by Contracting Officer and returned, insert a copy of each in Operation and Maintenance Manual.
5. Programmable Settings:
 - a. At completion of Performance Demonstration Test, submit final hardcopy printout and electronic files on compact disc of as-left setpoints, programs, and device configuration files for:
 - 1) Protective relays.
 - 2) Intelligent overload relays.
 - 3) Adjustable frequency drives.
 - 4) Power metering devices.
 - 5) Uninterruptible power supplies.
 - 6) Electrical communications modules.
6. Submit control circuit continuity tests prior to start of Pre-Commissioning phase.

1.03 QUALITY ASSURANCE

A. Testing Firm Qualifications:

1. Corporately and financially independent organization functioning as an unbiased testing authority.
2. Professionally independent of manufacturers, suppliers, and installers of electrical equipment and systems being tested.
3. Employer of engineers and technicians regularly engaged in testing and inspecting of electrical equipment, installations, and systems.
4. Supervising engineer accredited as Certified Electrical Test Technologist by NICET or NETA and having a minimum of 5 years' testing experience on similar projects.
5. Technicians certified by NICET or NETA.
6. Assistants and apprentices assigned to Project at ratio not to exceed two certified to one noncertified assistant or apprentice.
7. Registered Professional Engineer to provide comprehensive Project report outlining services performed, results of such services, recommendations, actions taken, and opinions.
8. In compliance with OSHA CFR 29, Part 1910.7 criteria for accreditation of testing laboratories or a full member company of NETA.

B. Test equipment shall have an operating accuracy equal to or greater than requirements established by NETA ATS.

C. Test Instrument Calibration: In accordance with NETA ATS.

1.04 SEQUENCING AND SCHEDULING

- A. Perform inspection and electrical tests after equipment listed herein has been installed.
- B. Perform tests with apparatus de-energized whenever feasible.
 - 1. Scheduled with Contracting Officer prior to de-energization.
 - 2. Minimized to avoid extended period of interruption to the operating plant equipment.
- C. Notify Contracting Officer at least 24 hours prior to performing tests on energized electrical equipment.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 GENERAL

- A. Perform tests in accordance with requirements of Section 01 91 14, Equipment Testing and Facility Startup.
- B. Tests and inspections shall establish:
 - 1. Electrical equipment is operational within industry and manufacturer's tolerances and standards.
 - 2. Installation operates properly.
 - 3. Equipment is suitable for energization.
 - 4. Installation conforms to requirements of Contract Documents and NFPA 70, NFPA 70E, NFPA 101, and IEEE C2.
- C. Perform inspection and testing in accordance with NETA ATS, industry standards, and manufacturer's recommendations.
- D. Set, test, and calibrate, circuit breakers, fuses and other applicable devices in accordance with values established by studies as specified in Section 26 05 70, Electrical Systems Analysis.
- E. Adjust mechanisms and moving parts of equipment for free mechanical movement.
- F. Adjust and set electromechanical electronic relays and sensors to correspond to operating conditions, or as recommended by manufacturer.
- G. Verify nameplate data for conformance to Contract Documents and approved Submittals.

- H. Realign equipment not properly aligned and correct unlevelness.
- I. Properly anchor electrical equipment found to be inadequately anchored.
- J. Tighten accessible bolted connections, including wiring connections, with calibrated torque wrench/screw driver to manufacturer's recommendations, or as otherwise specified in NETA ATS.
- K. Clean contaminated surfaces with cleaning solvents as recommended by manufacturer.
- L. Provide proper lubrication of applicable moving parts.
- M. Inform Contracting Officer of working clearances not in accordance with NFPA 70.
- N. Investigate and repair or replace:
 - 1. Electrical items that fail tests.
 - 2. Active components not operating in accordance with manufacturer's instructions.
 - 3. Damaged electrical equipment.
- O. Electrical Enclosures:
 - 1. Remove foreign material and moisture from enclosure interior.
 - 2. Vacuum and wipe clean enclosure interior.
 - 3. Remove corrosion found on metal surfaces.
 - 4. Repair or replace, as determined by Contracting Officer door and panel sections having dented surfaces.
 - 5. Repair or replace, as determined by Contracting Officer poor fitting doors and panel sections.
 - 6. Repair or replace improperly operating latching, locking, or interlocking devices.
 - 7. Replace missing or damaged hardware.
 - 8. Finish:
 - a. Provide matching paint and touch up scratches and mars.
 - b. If required because of extensive damage, as determined by Contracting Officer refinish entire assembly.
- P. Replace fuses and circuit breakers that do not conform to size and type required by the Contract Documents or approved Submittals.

3.02 CHECKOUT AND STARTUP

A. Voltage Field Test:

1. Check voltage at point of termination of power company supply system to Project when installation is essentially complete and is in operation.
2. Check voltage amplitude and balance between phases for loaded and unloaded conditions.
3. Unbalance Corrections:
 - a. Make written request to power company to correct condition if balance (as defined by NEMA) exceeds 1 percent, or if voltage varies throughout the day and from loaded to unloaded condition more than plus or minus 4 percent of nominal.
 - b. Obtain written certification from responsible power company official that voltage variations and unbalance are within their normal standards if corrections are not made.

B. Equipment Line Current Tests:

1. Check line current in each phase for each piece of equipment.
2. Make line current check after power company has made final adjustments to supply voltage magnitude or balance.
3. If phase current for a piece of equipment is above rated nameplate current, prepare Equipment Line Phase Current Report that identifies cause of problem and corrective action taken.

A. Control Circuit Continuity Tests:

1. Check continuity of all control circuits using a digital multimeter, Use I/O wiring diagrams included as part of the integration package as the basis of continuity checks.
2. Perform checks in conjunction with Contracting Officer.
3. Notify Contracting Officer 14 days prior to start date of continuity tests.
4. Check all field and device wiring at every termination point in the system.
5. Perform corrections as required to achieve design functionality intent. Continuity test shall be repeated until successful results are achieved.
6. Record and submit continuity test result for review.

3.03 SWITCHBOARD ASSEMBLIES

A. Visual and Mechanical Inspection:

1. Insulator damage and contaminated surfaces.
2. Proper barrier and shutter installation and operation.
3. Proper operation of indicating devices.
4. Improper blockage of air-cooling passages.

5. Proper operation of drawout elements.
6. Integrity and contamination of bus insulation system.
7. Check door and device interlocking system by:
 - a. Closure attempt of device when door is in OFF position.
 - b. Opening attempt of door when device is in ON position.
8. Check key interlocking systems for:
 - a. Key captivity when device is in ON position.
 - b. Key removal when device is in ON position.
 - c. Closure attempt of device when key has been removed.
 - d. Correct number of keys in relationship to number of lock cylinders.
 - e. Existence of Other Keys Capable of Operating Lock Cylinders:
Destroy duplicate sets of keys.
9. Check nameplates for proper identification of:
 - a. Equipment title and tag number with latest one-line diagram.
 - b. Pushbutton.
 - c. Control switch.
 - d. Pilot light.
 - e. Control relay.
 - f. Circuit breaker.
 - g. Indicating meter.
10. Verify fuse and circuit breaker ratings, sizes, and types conform to those specified.
11. Check bus and cable connections for high resistance by low resistance ohmmeter and thermographic survey applied to bolted joints.
 - a. Ohmic value to be zero.
 - b. Thermographic survey temperature gradient of 2 degrees C or less.
12. Check operation and sequencing of electrical and mechanical interlock systems by:
 - a. Closure attempt for locked open devices.
 - b. Opening attempt for locked closed devices.
 - c. Key exchange to operate devices in OFF-NORMAL positions.
13. Verify performance of each control device and feature.
14. Control Wiring:
 - a. Compare wiring to local and remote control and protective devices with elementary diagrams.
 - b. Proper conductor lacing and bundling.
 - c. Proper conductor identification.
 - d. Proper conductor lugs and connections.
15. Exercise active components.
16. Perform phasing check on double-ended equipment to ensure proper bus phasing from each source.

B. Electrical Tests:

1. Insulation Resistance Tests:
 - a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1.
 - b. Each phase of each bus section.
 - c. Phase-to-phase and phase-to-ground for 1 minute.
 - d. With breakers open.
 - e. With breakers closed.
 - f. Control wiring except that connected to solid state components.
 - g. Insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
2. Overpotential Tests:
 - a. Applied ac or dc voltage and test procedure in accordance with IEEE C37.20.1 C37.20.2 C37.20.3 and NEMA PB 2. Alternatively use NETA ATS, Table 100.2.
 - b. Each phase of each bus section.
 - c. Phase-to-phase and phase-to-ground for 1 minute.
 - d. Test results evaluated on a pass/fail basis.
3. Current Injection Tests:
 - a. For entire current circuit in each section.
 - b. Secondary injection for current flow of 1 ampere.
 - c. Test current at each device.
4. Control Wiring:
 - a. Apply secondary voltage to control power and potential circuits.
 - b. Check voltage levels at each point on terminal boards and each device terminal.
5. Operational Test:
 - a. Initiate control devices.
 - b. Check proper operation of control system in each section.

3.04 PANELBOARDS

A. Visual and Mechanical Inspection:

1. Include the following inspections and related work:
 - a. Inspect for defects and physical damage, labeling, and nameplate compliance with requirements of up-to-date Drawings and panelboard schedules.
 - b. Exercise and perform operational tests of mechanical components and other operable devices in accordance with manufacturer's instruction manual.

- c. Check panelboard mounting, area clearances, and alignment and fit of components.
- d. Check tightness of bolted electrical connections with calibrated torque wrench. Refer to manufacturer's instructions for proper torque values.
- e. Perform visual and mechanical inspection for overcurrent protective devices.

B. Electrical Tests:

- 1. Include the following items performed in accordance with manufacturer's instruction:
 - a. Insulation Resistance Tests:
 - 1) Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1.
 - 2) Each phase of each bus section.
 - 3) Phase-to-phase and phase-to-ground for 1 minute.
 - 4) With breakers OPEN.
 - 5) With breakers CLOSED.
 - 6) Control wiring except that connected to solid state components.
 - 7) Insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
 - b. Ground continuity test ground bus to system ground.

3.05 DRY TYPE TRANSFORMERS

A. Visual and Mechanical Inspection:

- 1. Physical and insulator damage.
- 2. Proper winding connections.
- 3. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturer.
- 4. Defective wiring.
- 5. Proper operation of fans, indicators, and auxiliary devices.
- 6. Removal of shipping brackets, fixtures, or bracing.
- 7. Free and properly installed resilient mounts.
- 8. Cleanliness and improper blockage of ventilation passages.
- 9. Verify tap-changer is set at correct ratio for rated output voltage under normal operating conditions.
- 10. Verify proper secondary voltage phase-to-phase and phase-to-ground after energization and prior to loading.

B. Electrical Tests:

1. Insulation Resistance Tests:
 - a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.5 for each:
 - 1) Winding-to-winding.
 - 2) Winding-to-ground.
 - b. Test Duration: 10 minutes with resistances tabulated at 30 seconds, 1 minute, and 10 minutes.
 - c. Results temperature corrected in accordance with NETA ATS, Table 100.14.
 - d. Temperature corrected insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
 - e. Insulation resistance test results to compare within 1 percent of adjacent windings.
2. Perform tests and adjustments for fans, controls, and alarm functions as suggested by manufacturer.

3.06 LIQUID FILLED TRANSFORMERS

A. Visual and Mechanical Inspection:

1. Physical and insulator damage.
2. Proper winding connections.
3. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturer.
4. Defective wiring.
5. Proper operation of fans, indicators, and auxiliary devices.
6. Verify alarm, control, and trip settings on temperature and level indicators are as specified. Verify operation of alarm, control, and trip circuits from temperature and level indicators, pressure relief device, gas accumulator, and fault pressure relay.
7. Effective core and equipment grounding.
8. Removal of shipping brackets, fixtures, or bracing.
9. Tank leaks and proper liquid level.
10. Integrity and contamination of bus insulation system.
11. Verify tap-changer is set at correct ratio for rated voltage under normal operating conditions.

B. Electrical Tests:

1. Insulation Resistance Tests:
 - a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.5 for each:
 - 1) Winding-to-winding.
 - 2) Winding-to-ground.

- b. Test Duration: 10 minutes with resistances tabulated at 30 seconds, 1 minute, and 10 minutes.
 - c. Results temperature corrected in accordance with NETA ATS, Table 100.14.
 - d. Temperature corrected insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
 - e. Insulation resistance test results to compare within 1 percent of adjacent windings.
2. Perform resistance measurements through bolted electrical connections with low-resistance ohmmeter. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
 3. Verify proper secondary voltage phase-to-phase and phase-to-ground after energization and prior to loading.
 4. Perform tests and adjustments for fans, controls, and alarm functions as suggested by manufacturer.
 5. Sample insulating oil in accordance with ASTM D923 and have laboratory test for:
 - a. Dielectric breakdown voltage in accordance with ASTM D877/D877M or ASTM D1816.
 - b. Acid neutralization number in accordance with ASTM D974.
 - c. Interfacial tension in accordance with ASTM D971.
 - d. Color in accordance with ASTM D1500.
 - e. Visual condition in accordance with ASTM D1524.
 - f. Specific gravity in accordance with ASTM D1298.
 - g. Water content, in parts per million, in accordance with ASTM D1533.
 - h. Dielectric fluid test results in accordance with NETA ATS, Table 100.4.
 - i. Power factor at 25 degrees C and at 100 degrees, in accordance with ASTM D924.
 - j. Maximum power factor, corrected to 20 degrees C, in accordance with manufacturer's specifications.

3.07 MEDIUM-VOLTAGE CABLES, 15 KV MAXIMUM

A. Visual and Mechanical Inspection:

1. Inspect each individual exposed cable for:
 - a. Physical damage plus jacket and insulation condition.
 - b. Proper connections in accordance with single-line diagram or approved Submittals.
 - c. Proper shield grounding.
 - d. Proper cable support.
 - e. Proper cable termination.

- f. Cable bends not in conformance with manufacturer's minimum allowable bending radius.
 - g. Proper arc and fireproofing in common cable areas.
 - h. Proper circuit and phase identification.
- 2. Mechanical Connections:
 - a. Proper lug type for conductor material.
 - b. Proper lug installation.
 - c. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturers.
- 3. Conductors Terminated Through Window Type CTs: Verify neutrals and grounds are terminated for correct operation of protective devices.

B. Electrical Tests:

- 1. Insulation Resistance Tests:
 - a. Utilize 5,000-volt megohmmeter for 8 kV and 15 kV conductors.
 - b. Test each cable individually with remaining cables and shields grounded.
 - c. Test each conductor with respect to ground and to adjacent conductors for 1 minute.
 - d. Evaluate ohmic values by comparison with conductors of same length and type.
 - e. Investigate values less than 50 megohms.
- 2. Shield Continuity Tests:
 - a. By ohmmeter method on each section of conductor.
 - b. Investigate values in excess of 10 ohms per 1,000 feet of conductors.
- 3. Acceptance Tests:
 - a. In accordance with IEEE 400, ICEA S-93-639, NEMA WC 74, ICEA S-94-649, and ICEA S-97-682 for insulated conductors.
 - b. Each conductor section tested with:
 - 1) Splices and terminations in place but disconnected from equipment.
 - 2) Remaining conductors and shields grounded in accordance with IEEE 400.
 - c. Apply maximum test voltage per NETA ATS, Table 100.6, based on method (DC, AC, PD, or VLF) used.
 - d. Measure only leakage current associated with conductor.
 - e. Utilize guard ring or field reduction sphere to suppress corona at disconnected terminations.
 - f. Maximum test voltage shall not exceed limits for terminators specified in IEEE 48, IEEE 386, or manufacturer's specifications.

- g. Apply test voltage in a minimum of five equal increments until maximum acceptable test voltage is reached:
 - 1) Increments not to exceed ac voltage rating of conductor.
 - 2) Record dc leakage current at each step after a constant stabilization time consistent with system charging current.
- h. Raise conductor to specified maximum test voltage and hold for 15 minutes or as specified by conductor manufacturer. Record leakage current at 30 seconds and 1 minute, and at 1-minute intervals, thereafter.
- i. Immediately following test, ground conductor for adequate time period to drain insulation stored charge.
- j. Test results evaluated on a pass/fail basis.
- 4. New Conductors Spliced to Existing Conductors:
 - a. Prior to performing splices, high potential dc test new conductor sections.
 - b. After splicing new conductors to existing conductors, disconnect existing conductors and perform the following tests:
 - 1) Shield continuity test.
 - 2) Insulation resistance test.
 - 3) High potential test with test voltage not to exceed 60 percent of applied acceptance dc test voltage.

3.08 LOW VOLTAGE CABLES, 600 VOLTS MAXIMUM

A. Visual and Mechanical Inspection:

- 1. Inspect each individual exposed power cable No. 6 and larger for:
 - a. Physical damage.
 - b. Proper connections in accordance with single-line diagram.
 - c. Cable bends not in conformance with manufacturer's minimum allowable bending radius where applicable.
 - d. Color coding conformance with specification.
 - e. Proper circuit identification.
- 2. Mechanical Connections for:
 - a. Proper lug type for conductor material.
 - b. Proper lug installation.
 - c. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturer.
- 3. Shielded Instrumentation Cables for:
 - a. Proper shield grounding.
 - b. Proper terminations.
 - c. Proper circuit identification.

4. Control Cables for:
 - a. Proper termination.
 - b. Proper circuit identification.
5. Cables Terminated Through Window Type CTs: Verify neutrals and grounds are terminated for correct operation of protective devices.

B. Electrical Tests for Conductors No. 6 and Larger:

1. Insulation Resistance Tests:
 - a. Utilize 1,000-volt dc megohmmeter for 600-volt insulated conductors.
 - b. Test each conductor with respect to ground and to adjacent conductors for 1 minute.
 - c. Evaluate ohmic values by comparison with conductors of same length and type.
 - d. Investigate values less than 50 megohms.
2. Continuity test by ohmmeter method to ensure proper cable connections.

C. Low-voltage cable tests may be performed by installer in lieu of independent testing firm.

3.09 SAFETY SWITCHES, 600 VOLTS MAXIMUM

A. Visual and Mechanical Inspection:

1. Proper blade pressure and alignment.
2. Proper operation of switch operating handle.
3. Adequate mechanical support for each fuse.
4. Proper contact-to-contact tightness between fuse clip and fuse.
5. Cable connection bolt torque level in accordance with NETA ATS, Table 100.12.
6. Proper phase barrier material and installation.
7. Verify fuse sizes and types correspond to one-line diagram or approved Submittals.
8. Perform mechanical operational test and verify electrical and mechanical interlocking system operation and sequencing.

B. Electrical Tests:

1. Insulation Resistance Tests:
 - a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1.
 - b. Phase-to-phase and phase-to-ground for 1 minute on each pole.
 - c. Insulation resistance values equal to, or greater than, ohmic values established by manufacturer.

2. Contact Resistance Tests:
 - a. Contact resistance in microhms across each switch blade and fuse holder.
 - b. Investigate deviation of 50 percent or more from adjacent poles or similar switches.

3.10 MOLDED AND INSULATED CASE CIRCUIT BREAKERS

- A. General: Inspection and testing limited to circuit breakers rated 100 amperes and larger and to motor circuit protector breakers rated 50 amperes and larger.
- B. Visual and Mechanical Inspection:
 1. Proper mounting.
 2. Proper conductor size.
 3. Feeder designation according to nameplate and one-line diagram.
 4. Cracked casings.
 5. Connection bolt torque level in accordance with NETA ATS, Table 100.12.
 6. Operate breaker to verify smooth operation.
 7. Compare frame size and trip setting with circuit breaker schedules or one-line diagram.
 8. Verify that terminals are suitable for 75 degrees C rated insulated conductors.
- C. Electrical Tests:
 1. Insulation Resistance Tests:
 - a. Utilize 1,000-volt dc megohmmeter for 480-volt and 600-volt circuit breakers.
 - b. Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute.
 - c. Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
 - d. Test values to comply with NETA ATS, Table 100.1.
 2. Contact Resistance Tests:
 - a. Contact resistance in microhms across each pole.
 - b. Investigate deviation of 50 percent or more from adjacent poles and similar breakers.
 3. Primary Current Injection Test to Verify:
 - a. Long-time minimum pickup and delay.
 - b. Short-time pickup and delay.
 - c. Ground fault pickup and delay.
 - d. Instantaneous pickup by run-up or pulse method.

- e. Trip characteristics of adjustable trip breakers shall be within manufacturer's published time-current characteristic tolerance band, including adjustment factors.
- f. Trip times shall be within limits established by NEMA AB 4, Table 5-3. Alternatively, use NETA ATS, Table 100.7.
- g. Instantaneous pickup value shall be within values established by NEMA AB 4, Table 5-4. Alternatively, use NETA ATS, Table 100.8.

3.11 INSTRUMENT TRANSFORMERS

A. Visual and Mechanical Inspection:

- 1. Visually check current, potential, and control transformers for:
 - a. Cracked insulation.
 - b. Broken leads or defective wiring.
 - c. Proper connections.
 - d. Adequate clearances between primary and secondary circuit wiring.
- 2. Verify Mechanically:
 - a. Grounding and shorting connections have good contact.
 - b. Withdrawal mechanism and grounding operation, when applicable, operate properly.
- 3. Verify proper primary and secondary fuse sizes for potential transformers.

B. Electrical Tests:

- 1. Current Transformer Tests:
 - a. Insulation resistance test of transformer and wiring-to-ground at 1,000 volts dc for 30 seconds.
 - b. Polarity test.
 - c. Ratio and accuracy test.
- 2. Potential Transformer Tests:
 - a. Insulation resistance test at test voltages in accordance with NETA ATS, Table 100.9, for 1 minute on:
 - 1) Winding-to-winding.
 - 2) Winding-to-ground.
 - b. Polarity test to verify polarity marks or H1-X1 relationship as applicable.
 - c. Ratio and accuracy test.
- 3. Insulation resistance measurement on instrument transformer shall not be less than that shown in NETA ATS, Table 100.5.

3.12 METERING

A. Visual and Mechanical Inspection:

1. Verify meter connections in accordance with appropriate diagrams.
2. Verify meter multipliers.
3. Verify meter types and scales conform to Contract Documents.
4. Check calibration of meters at cardinal points.
5. Check calibration of electrical transducers.

3.13 GROUNDING SYSTEMS

A. Visual and Mechanical Inspection:

1. Equipment and circuit grounds in motor control center, panelboard, switchboard, and switchgear assemblies for proper connection and tightness.
2. Ground bus connections in motor control center, panelboard, switchboard, and switchgear assemblies for proper termination and tightness.
3. Effective transformer core and equipment grounding.
4. Accessible connections to grounding electrodes for proper fit and tightness.
5. Accessible exothermic-weld grounding connections to verify that molds were fully filled, and proper bonding was obtained.

B. Electrical Tests:

1. Fall-of-Potential Test:
 - a. In accordance with IEEE 81, Section 8.2.1.5 for measurement of main ground system's resistance.
 - b. Main ground electrode system resistance to ground to be no greater than 1 ohm(s).
2. Two-Point Direct Method Test:
 - a. In accordance with IEEE 81, Section 8.2.1.1 for measurement of ground resistance between main ground system, equipment frames, and system neutral and derived neutral points.
 - b. Equipment ground resistance shall not exceed main ground system resistance by 0.50 ohm.

3.14 GROUND FAULT SYSTEMS

A. Inspection and testing limited to:

1. Zero sequence grounding systems.
2. Residual ground fault systems.

B. Visual and Manual Inspection:

1. Neutral main bonding connection to ensure:
 - a. Zero sequence sensing system is grounded ahead of neutral disconnect link.
 - b. Ground strap sensing system is grounded through sensing device.
 - c. Neutral ground conductor is solidly grounded.
2. Verify control power has adequate capacity for system.
3. Manually operate monitor panels for:
 - a. Trip test.
 - b. No trip test.
 - c. Nonautomatic rest.
4. Zero sequence system for symmetrical alignment of core balance transformers about current carrying conductors.
5. Relay check for pickup and time under simulated ground fault conditions.
6. Verify nameplate identification by device operation.

C. Electrical Tests:

1. Test system neutral insulation resistance with neutral ground link removed; minimum 1 megohm.
2. Determine relay pickup by primary current injection at the sensor. Relay pickup current within plus or minus 10 percent of device dial or fixed setting.
3. Test relay timing by injecting 300 percent of pick-up current or as specified by manufacturer. Relay operating time in accordance with manufacturer's time-current characteristic curves.
4. Test system operation at 55 percent rated control voltage, if applicable.
5. Test zone interlock system by simultaneous sensor current injection and monitoring zone blocking functions.

3.15 AC INDUCTION MOTORS

A. General: Inspection and testing limited to motors rated 1 horsepower and larger.

B. Visual and Mechanical Inspection:

1. Proper electrical and grounding connections.
2. Shaft alignment.
3. Blockage of ventilating air passageways.
4. Operate motor and check for:
 - a. Excessive mechanical and electrical noise.
 - b. Overheating.
 - c. Correct rotation.

- d. Check vibration detectors, resistance temperature detectors, or motor inherent protectors for functionality and proper operation.
 - e. Excessive vibration, in excess of values in NETA ATS, Table 100.10.
 - 5. Check operation of space heaters.
- C. Electrical Tests:
 - 1. Insulation Resistance Tests:
 - a. In accordance with IEEE 43 at test voltages established by NETA ATS, Table 100.1 for:
 - 1) Motors above 200 horsepower for 10-minute duration with resistances tabulated at 30 seconds, 1 minute, and 10 minutes.
 - 2) Motors 200 horsepower and less for 1-minute duration with resistances tabulated at 30 seconds and 60 seconds.
 - b. Insulation resistance values equal to, or greater than, ohmic values established by manufacturers.
 - 2. Calculate polarization index ratios for motors above 200 horsepower. Investigate index ratios less than 1.5 for Class A insulation and 2.0 for Class B insulation.
 - 3. Insulation resistance test on insulated bearings in accordance with manufacturer's instructions.
 - 4. Measure running current and voltage, and evaluate relative to load conditions and nameplate full-load amperes.

3.16 LOW-VOLTAGE MOTOR CONTROL

- A. Visual and Mechanical Inspection:
 - 1. Proper barrier and shutter installation and operation.
 - 2. Proper operation of indicating and monitoring devices.
 - 3. Proper overload protection for each motor.
 - 4. Improper blockage of air-cooling passages.
 - 5. Proper operation of drawout elements.
 - 6. Integrity and contamination of bus insulation system.
 - 7. Check door and device interlocking system by:
 - a. Closure attempt of device when door is in OFF position.
 - b. Opening attempt of door when device is in ON position.
 - 8. Check key interlocking systems for:
 - a. Key captivity when device is in ON position.
 - b. Key removal when device is in OFF position.
 - c. Closure attempt of device when key has been removed.

- d. Correct number of keys in relationship to number of lock cylinders.
 - e. Existence of other keys capable of operating lock cylinders; destroy duplicate sets of keys.
- 9. Check nameplates for proper identification of:
 - a. Equipment title and tag number with latest one-line diagram.
 - b. Pushbuttons.
 - c. Control switches.
 - d. Pilot lights.
 - e. Control relays.
 - f. Circuit breakers.
 - g. Indicating meters.
- 10. Verify fuse and circuit breaker sizes and types conform to Contract Documents.
- 11. Verify current and potential transformer ratios conform to Contract Documents.
- 12. Check bus connections for high resistance by low-resistance ohmmeter and thermographic survey:
 - a. Ohmic value to be zero.
 - b. Thermographic survey temperature gradient of 2 degrees C, or less per NETA ATS, Table 100.18.
- 13. Check operation and sequencing of electrical and mechanical interlock systems by:
 - a. Closure attempt for locked OPEN devices.
 - b. Opening attempt for locked CLOSED devices.
 - c. Key exchange to operate devices in OFF-NORMAL positions.
- 14. Verify performance of each control device and feature furnished as part of motor control center.
- 15. Control Wiring:
 - a. Compare wiring to local and remote control, and protective devices with elementary diagrams.
 - b. Check for proper conductor lacing and bundling.
 - c. Check for proper conductor identification.
 - d. Check for proper conductor lugs and connections.
- 16. Exercise active components.
- 17. Inspect contactors for:
 - a. Correct mechanical operations.
 - b. Correct contact gap, wipe, alignment, and pressure.
 - c. Correct torque of connections.
- 18. Compare overload heater rating with full-load current for proper size.
- 19. Compare motor protector and circuit breaker with motor characteristics for proper size.
- 20. Perform phasing check on double-ended motor control centers to ensure proper bus phasing from each source.

B. Electrical Tests:

1. Insulation Resistance Tests:
 - a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1.
 - b. Bus section phase-to-phase and phase-to-ground for 1 minute on each phase.
 - c. Contactor phase-to-ground and across open contacts for 1 minute on each phase.
 - d. Starter section phase-to-phase and phase-to-ground on each phase with starter contacts CLOSED and protective devices OPEN.
 - e. Test values to comply with NETA ATS, Table 100.1.
2. Current Injection through Overload Unit at 300 Percent of Motor Full-Load Current and Monitor Trip Time:
 - a. Trip time in accordance with manufacturer's published data.
 - b. Investigate values in excess of 120 seconds.
3. Control Wiring Tests:
 - a. Apply secondary voltage to control power and potential circuits.
 - b. Check voltage levels at each point on terminal board and each device terminal.
 - c. Insulation resistance test at 1,000 volts dc on control wiring, except that connected to solid state components; 1 megohm minimum insulation resistance.
4. Operational test by initiating control devices to affect proper operation.

3.17 AUTOMATIC TRANSFER CONTROLLER

A. Visual and Mechanical Inspection:

1. Check doors and panels for proper interlocking.
2. Check connections for high resistance by low-resistance ohmmeter.
3. Check positive mechanical and electrical interlock between normal and alternate sources.
4. Check for proper operation:
 - a. Manual transfer function switch.
 - b. Generator under load and nonload conditions.
 - c. Auto-exerciser of generator under load and no-load conditions.
5. Verify settings and operation of control devices.

B. Electrical Tests:

1. Insulation Resistance Tests:
 - a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1, for each phase with switch CLOSED in both source positions.

- b. Phase-to-phase and phase-to-ground for 1 minute.
 - c. Test values in accordance with manufacturer's published data.
- 2. Contact Resistance Test:
 - a. Contact resistance in microhms across each switch blade for both source positions.
 - b. Investigate values exceeding 500 micro-ohms.
 - c. Investigate values deviating from adjacent pole by more than 50 percent.
- 3. Set and calibrate in accordance with specifications, manufacturer's recommendations, and Coordination Study.
 - a. Voltage and frequency sensing relays.
 - b. Time delay relays.
 - c. Engine start and shutdown relays.
- 4. Perform automatic transfer tests by:
 - a. Simulating loss of normal power.
 - b. Return to normal power.
 - c. Simulating loss of alternate power.
 - d. Simulating single-phase conditions for normal and alternate sources.
- 5. Monitor and verify operation and timing of:
 - a. Normal and alternate voltage sensing relays.
 - b. Engine-start sequence.
 - c. Timing delay upon transfer and retransfer.
 - d. Engine cool down and shutdown.
 - e. Interlocks and limit switch functions.
 - f. Engine cool down and shutdown feature.

3.18 STANDBY GENERATOR SYSTEMS

A. Visual and Mechanical Inspection:

- 1. Proper grounding.
- 2. Blockage of ventilating passageways.
- 3. Proper operation of jack water heaters.
- 4. Integrity of engine cooling and fuel supply systems.
- 5. Excessive mechanical and electrical noise.
- 6. Overheating of engine or generator.
- 7. Proper installation of vibration isolators.
- 8. Proper cooling liquid type and level.
- 9. Operate engine-generator and check for:
 - a. Excessive mechanical and electrical noise.
 - b. Overheating.
 - c. Correct rotation.
 - d. Check resistance temperature detectors or generator inherent thermal protectors for functionality and proper operation.
 - e. Excessive vibration.

10. Verify voltage regulator and governor operation will cause unit speed and output voltage to stabilize at proper values within reasonable length of time.
11. Proper operation of meters and instruments.
12. Compare generator nameplate rating and connection with one-line diagram or approved Submittal.
13. Verify engine-generator operation with adjustable frequency drives energized and operating under normal load conditions.

B. Electrical and Mechanical Tests:

1. Cold start test by interrupting normal power source with test load consisting of connected building load to verify:
 - a. Transfer switch operation.
 - b. Automatic starting operation.
 - c. Operating ability of engine-generator.
 - d. Overcurrent devices capability to withstand inrush currents.
2. Phase rotation tests.
3. Test engine protective shutdown features for:
 - a. Low oil pressure.
 - b. Overtemperature.
 - c. Overspeed.
4. Load bank test with resistors for each load step. Record voltage, frequency, load current, oil pressure, and engine coolant temperature at 15-minute intervals:
 - a. 25 percent applied load for 30 minutes.
 - b. 50 percent applied load for 30 minutes.
 - c. 75 percent applied load for 30 minutes.
 - d. 100 percent applied load for 3 hours.
 - e. Load test results to demonstrate ability of unit to deliver rated load for test period.
5. One-Step Rated kW Load Pickup Test:
 - a. Perform test immediately after performing load bank test.
 - b. Apply rated load, minus largest rated hp motor, to generator.
 - c. Start largest rated horsepower motor and record voltage drop for 20 cycles minimum with high-speed chart recorder or digital storage oscilloscope.
 - d. Compare voltage drop with maximum allowable voltage dip for specified starting situation.

3.19 THERMOGRAPHIC SURVEY

- A. Provide thermographic survey per NETA ATS Table 100.18 of connections associated with incoming service conductors, bus work, and branch feeder conductors No. 4 and larger at each switchboard.

- B. Provide thermographic survey of feeder conductors No. 4 and larger terminating at:
 - 1. Switchboard.
 - 2. Low-voltage motor control center.
 - 3. Panelboard.
 - 4. Generator Terminals.
- C. Remove necessary enclosure metal panels and covers prior to performing survey.
- D. Perform with equipment energized during periods of maximum possible loading per NFPA 70B, Section 20.17.
- E. Do not perform survey on equipment operating at less than 40 percent of rated load.
- F. Use thermographic equipment capable of:
 - 1. Detecting emitted radiation.
 - 2. Converting detected radiation to visual signal.
 - 3. Detecting 1 degree C temperature difference between subject area and reference point of 30 degrees C.
- G. Temperature Gradients:
 - 1. 3 degrees C to 7 degrees C indicates possible deficiency that warrants investigation.
 - 2. 7 degrees C to 15 degrees C indicates deficiency that is to be corrected as time permits.
 - 3. 16 degrees C and above indicates deficiency that is to be corrected immediately.
- H. Provide written report of:
 - 1. Areas surveyed and the resultant temperature gradients.
 - 2. Locations of areas having temperature gradients of 3 degrees C or greater.
 - 3. Cause of heat rise, and actions taken to correct cause of heat rise.
 - 4. Detected phase unbalance.

END OF SECTION