

SECTION 26 90 00 - FIELD TESTING ELECTRICAL SYSTEMS

1.01 SUMMARY:

- A. ^{A7}**Basic Function:**^{A7} ^{A17}Field testing of electrical system components and subsystems shall constitute part of the quality control function that is under the responsibility of the Contractor and shall be performed before the commissioning of the electrical system. Testing under this section shall be part of the pre-commissioning tests required by Section 01 91 00 (*Tests on Completion and Tests after Completion*).^{A17} This section includes the minimum requirements for field testing and shall be complemented by the manufacturer's recommended field testing procedures, which needs to be performed before energization of any electrical equipment.
- B. ^{A17}**Scope of Works:** This Section contains the technical performance requirements for furnishing all labor, materials, test equipment, and technical supervision to perform and record the electrical tests set forth in these requirements, including tests on medium ^{A17} voltage wire and cable, 600 volt wire and cable, unit substations, distribution transformers, power transformers, rotating equipment, bus ducts, grounding, and relays, unless otherwise set forth in these requirements. Tests included in this Section include preliminary inspection and tests, electrical start-up tests and operating tests, as defined in paragraph 1.03 D. Factory tests and commissioning test are not included in this Section.
- C. ^{A17}**Work by Others:** Tests on Diesel Engine Driven Emergency Generators and related Automatic Transfer Equipment.^{A17}

^{A16}1.02 REFERENCES: ^{A16}

- A. **Institute of Electrical and Electronics Engineers (IEEE) Standards:**
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|--------|---|
| 43-06 | Testing Insulation Resistance of Rotating Machinery |
| 81-83 | Guide for Measuring Earth Resistance, Ground Impedance and Earth Surface Potentials of Ground Systems |
| 118-97 | Test Code for Resistance Measurement |
- B. **National Electrical Manufacturers Association (NEMA) Standards:**
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| MG 1-06. | Motors and Generators |
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- C. **National Fire Protection Association (NFPA) Standards:**
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| 70-08 | National Electrical Code |
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D. Code of Federal Regulations Standards:

29CFR 1910 Occupational Safety and Health Standards
Accident Prevention Manual for Industrial
Operations, Seventh Edition, National Safety
Council, Chapter 4.

E. Panama Canal Authority Publications:

--05 Manual de Seguridad para Operaciones en Alto
Voltaje

^{A17}2600SEG-131 -- 05 ^{A17} Manual de Prácticas de Trabajo Seguro para
Electricistas de Bajo Voltaje

F. International Electrical Testing Association, Inc. (NETA) Publications:

ATS -- 07 Acceptance Testing Specifications

G. National Institute of Standards and Technology (NIST)

H. Comité International des Poids et Mesures (CIPM)

1.03 REQUIREMENTS:

A. General: As part of the pre-commissioning tests required by Section 01 91 00 (*Tests on Completion and Tests after Completion*), the Contractor shall test major electrical system components; electrical systems shall be tested so that the Contractor detects and corrects all deviations from the Employer's Requirements and from the Contractor's design, specifications, and drawings.

1. The Contractor shall engage the services of a testing organization for the purpose of performing final inspections and tests as contained in these requirements and the Contractor's specifications.
2. The testing organization shall meet OSHA criteria for accreditation of testing laboratories, Title 29, Part 1910.7. Membership to the International Electric Testing Association, Inc. (NETA) constitutes proof of meeting such criteria.
3. Inspections and tests shall be witnessed by the ^{A17}Employer's Representative, ^{A17} in accordance with Section 01 40 00 (*Quality Requirements*).
4. The Contractor shall notify the Employer's Representative in writing, in advance of testing date, in accordance with Section 01 40 00 (*Quality Requirements*).
5. The Contractor shall provide all material, test instruments, equipment, labor and technical supervision to perform such tests and inspections.

6. It is the intent of these tests to verify that electrical equipment is operational within industry and manufacturer's tolerances, and is installed in accordance with the Employer's Requirements, the Contractor's design drawings and specifications, and manufacturer's recommendations.
7. The Contractor shall perform tests, calibration, adjustment of relays and inspections prior to energizing any equipment. Relay settings shall be made using relay setting reports.
8. Upon completion of the tests and inspections specified, the Contractor shall provide a label in accordance with NETA ATS.
9. Tests shall be non-destructive and shall not alter the equipment.

B. Test Instrument Service and Calibration:

1. The testing organization shall have a calibration program which maintains applicable test instrumentation within rated accuracy in accordance with manufacturer's recommendations and standard industry practice.
2. The accuracy shall be traceable to the National Institute of Standards and Technology (NIST) or the Comité International des Poids et Mesures (CIPM) in an unbroken chain.
3. Instruments shall be calibrated in accordance with the following frequency schedule:
 - a. ^{A7}**Field Instruments:** 1 year maximum.^{A7}
 - b. ^{A7}**Laboratory Instruments:** 1 year maximum.^{A7}
4. Dated calibration labels shall be visible on test equipment.

C. Safety and Precautions:

1. Safety practices shall include, but are not limited to, the following requirements:
 - a. 29CFR 1910; ACP "Manual de Seguridad para Operaciones en Alto Voltaje" and ^{A17}2600SEG-131.^{A17}
2. Acceptance tests shall be performed with equipment de-energized, unless otherwise specified in the Contractor's design or set forth in the Employer's Requirements.

3. The Contractor's designated safety representative shall supervise testing operations with respect to safety.
4. In all cases, work shall not proceed until the Contractor's designated safety representative has determined that it is safe to do so.
5. The Contractor's testing company shall have available sufficient protective barriers and warning signs. The Contractor shall place the protective barriers and warning signs in close proximity to the area where testing is being performed.

D. Definition of Tests:

1. **Preliminary Inspection and Tests:** Visual inspections of electrical equipment, wire checks of factory wiring and any other preliminary work required to prevent delays during performance of electrical acceptance tests.
2. **Electrical Startup Tests:** Those inspections and tests required to show that the workmanship, methods, inspections, and materials used in erection and installation of the electrical equipment conform to accepted engineering practices, and applicable standards, NFPA 70, manufacturers instructions, and to determine that the equipment involved may be energized for operational tests.
3. **Operating Tests:** Those tests performed on all electrical equipment installed, to show that the electrical equipment will perform in accordance with Employer's Requirements.
- ^{A5}4. **Factory Test on Prototypes and Samples:** Test performed by the factory on prototypes and samples are acceptable substitute to performing tests on each and every equal unit. Factory test certifications of such test are required to be submitted. ^{A5}

E. Authorized Witnesses:

1. ^{A17}The Contractor shall perform all startup and operating tests in the presence of the Employer's Representative. The Contractor shall notify the Employer's Representative, in writing, of proposed testing, in accordance with Section 01 40 00 (*Quality Requirements*). ^{A17}
2. The Contractor shall notify vendors and manufacturers of electrical equipment of the time of tests and extend reasonable cooperation to them or their representatives to permit them to witness tests should they so request.

F. Data to be Recorded:

1. Provide reproducible test data sheets showing results of tests described in the accepted test procedures, listing acceptable or specified test limits and values actually measured.
2. Provide data sheets showing test set-up, equipment and instrument used, names of persons performing test, names of witnesses, date, location, and serial number of equipment under test. If additional tests are required because initial test results do not comply with Employer's Requirements, document the re-testing and re-submit as before at no additional cost to the Employer.
3. The Contractor shall schedule sequence of tests so that equipment can be energized immediately after completion of the applicable tests and review of test reports by the ^{A17}Employer's Representative. ^{A17}

G ^{A7}General Testing Requirements: ^{A7}

1. Perform preliminary inspections and tests immediately prior to performing startup tests.
2. Do not perform more than one high potential test on any conductor unless specifically authorized by the ^{A17}Employer's Representative. ^{A17}
3. **Megger Tests:**
 - a. Megger readings provided in these requirements are the minimum readings desired at an ambient temperature of 60 degrees F (15.55 degrees Celsius) and at a relative humidity of less than 60 percent. When megger readings are taken at other than 60 degrees F (15.55 degrees Celsius), readings taken shall be temperature and humidity compensated.
 - b. When megger readings fall below the specified minimum values at 60 degrees F (15.55 degrees Celsius), devise some means of applying heat for the purpose of drying out the equipment, the procedure for drying out the equipment shall be submitted for review by the ^{A17}Employer's Representative. ^{A17} If drying is to be done by applying an electric potential to a piece of equipment, do not exceed the continuous voltage or current ratings of the equipment being dried either directly or by induction.
 - c. For circuits with conductor sizes # 8 AWG and smaller, insulation resistance testing is not required.

4. **Continuity Tests:** Perform continuity tests with a dc type device using a bell, buzzer or multi-meter.
5. Conduct phase-rotation tests on all three phase circuits using a phase rotation indicating instrument.
6. **Test on Metering and Instrumentation:** If the instrument being tested has a precision of plus or minus 10 percent, the precision of the calibration instrument shall be plus or minus 5 percent or better.
7. Restore all connections and equipment to operating conditions after testing has been completed.

H. ^{A7}**Tests on Diesel Engine Driven Emergency Generators:**^{A7}

1. **Preliminary Field Tests:**

- a. The **Employer** shall perform preliminary tests of each individual system to verify proper installation. Testing shall be done as recommended by the equipment manufacturer and as required herein.
- b. The **Employer** shall thoroughly verify using appropriate instrumentation, the fuel system, the lubrication system, the exhaust system, and the cooling system for leakage or blockage, alignment of rotating equipment, proper fastening of electrical power cables, and proper functioning of all indicating lights, switches, local and remote indicators.
- c. The **Employer** shall verify that the software installed in the operating station computer in the main control room [MCR] is working properly, including each of the indications and control functions.
- d. ^{A7}**Visual and Mechanical Inspection:**^{A7}
 - 1) Inspect physical and mechanical condition.
 - 2) Compare equipment nameplate data with Contractor's drawings and specifications.
 - 3) Inspect anchorage and grounding.
 - 4) Special tests as recommended by the manufacturer, such as air gap spacing and pedestal alignment, shall be performed where applicable.

2. **Electrical Tests:**

- a. The **Employer** shall perform insulation-resistance tests on the main field winding, the exciter-field winding, and the exciter-armature winding in accordance with IEEE 43.
- b. Perform a high-potential test on the excitation system in accordance with NEMA MG 1.

- c. Measure and record resistance of generator field winding, exciter-stator winding, and exciter-rotor windings.

3. **Final Field Inspection Tests (FFIT):**

- a. **General:** After preliminary testing, the **Employer** shall perform final field inspection tests as recommended by the manufacturer of each system. Testing shall include functional tests to demonstrate all devices and equipment are fully functional, stable, and ready for operation. Testing shall be done as recommended by the equipment manufacturer and as required herein.
- b. ^{A7}**Service Personnel:**^{A7} Testing shall be performed by manufacturer certified service personnel. Service personnel shall be an engineer or technician, qualified and experienced in the inspection, testing, installation, and maintenance of emergency generator systems. Such personnel shall be trained in the equipment furnished and shall be certified by the manufacturer.
- c. The **Employer** shall furnish materials, equipment, and instruments required for the tests. Fourteen (14) days before the tests, the Contractor shall provide a list of all the test equipment he proposes to use during the tests and shall show proof of recent calibration (not older than 18 months).
- d. The system shall be demonstrated to operate in accordance with the design intent, the requirements of this specification, and the manufacturer's specifications.
- e. **Reserved.**

4. **Test Values:**

- a. Insulation-resistance test results shall be a minimum of 100 megohms. Investigate dielectric absorption ratios less than 1.4 and polarization index ratios less than 2.0 for Class B insulation and Class F insulation.

NOTE: Over-potential and surge comparison tests shall not be made on generators having insulation-resistance test values lower than those indicated above.

- b. Stator winding DC over-potential test voltage shall be in accordance with NEMA MG 1. Test results are dependent on ambient conditions, and evaluation is on a withstand basis. If phase windings can be separately tested, values of leakage current may be compared for similar windings.
- c. The measured resistance values of generator-field winding, exciter-stator winding, and exciter-rotor windings shall be compared to manufacturer's recommended values.

I. ^{A7}**Tests on Medium Voltage Power Cables:**^{A7}

1. **General:** Apply each medium volt cable a high potential tests after all splices and permanent connections are made, except as otherwise indicated in these requirements or the Contractor's specifications, and a dielectric absorption test before and after the high potential tests. Check continuity and phase identification for each cable. Check continuity of cable shield.

a. ^{A7}**Visual and Mechanical Inspections:**^{A7}

- 1) Inspect exposed cable sections for physical damage.
 - 2) Verify cable is supplied and connected in accordance with one-line diagram.
 - 3) Inspect for shield grounding cable support, and termination.
 - 4) Cable bends shall be checked against manufacturer's minimum allowable bending radius.
2. **Connections:** Isolate cable by opening switches or breakers at each end of cable prior to testing, except, where cables are directly connected without disconnecting means, disconnect and fan out cable. Apply high potential and dielectric absorption tests between each conductor and ground with the other two conductors, its shield, conduit or armor grounded to the same ground. Test each conductor in the same manner. Do not include building steel as part of the test ground circuit.
 3. **Dielectric Absorption Tests:** Use a 10,000 Volt megger for 15,000 Volt cable for each dielectric absorption test. Continue each test for a time sufficient to charge the cable. Take megger readings every 15 seconds during the first three minutes and at one minute intervals thereafter. Continue test until three equal reading one minute apart are obtained. Megger readings taken during the second test, after the high potential test, must be reasonably parallel with those of the initial test, to show no evidence of injury to the cable during the high potential test.
 4. **High Potential Tests:**
 - a. Terminations shall be properly corona suppressed by guard ring, field reduction sphere or other suitable method.
 - b. Apply a direct current (DC) test voltage equal to 80 percent of the factory dc test voltage, or, the value recommended by NETA, based upon insulation type, rated cable voltage, and insulation level on each conductor as outlined below. Shields shall be grounded.
 - c. A direct current (DC) high-potential shall be applied in at least eight equal increments until maximum test voltage is reached.

DC leakage current shall be recorded at each step, after a constant stabilization time consistent with system charging current decay. Apply the test voltage uniformly and gradually during the first minute, with the initial application being not greater than the rated voltage of the cable. Continue test for a total duration of 15 minutes.

- d. A graphic plot shall be made of leakage current (X-axis) versus voltage (Y-axis) at each increment.
- e. The test conductor shall be raised to a maximum test voltage and held for a total of 10 minutes. Readings of leakage current (Y-axis) versus time (X-axis) shall be recorded and plotted on 30 second intervals for the first 2 minutes and every minute thereafter. If the leakage current continues to increase, stop the test. Do not make further tests until the Employer's Representative is notified. No test will be accepted where there is a continuous increase in leakage current throughout the tests.
- f. The applied conductor test potential shall be reduced to zero and grounds applied for a period adequate to drain all insulation stored potential.

5. **Test Values:**

- a. ^{A7}**DC High-Potential Test Results:**^{A7}

- 1) Step voltage slope shall be linear.
- 2) Absorption slope shall be flat or negative. In no case should slope exhibit positive characteristic.
- 3) Maximum leakage current shall not exceed IL, corrected to 60 degrees F when:

$$IL = \frac{E}{K \log D/d}$$

K = insulation specific resistance Megohm, MFT at 60 degrees F
D = diameter over insulation
d = diameter under insulation
E = maximum test voltage

6. Perform a shield continuity test by ohm meter method. Ohmic value shall be recorded.
7. **Acceptance:** The cable shall withstand the specified high voltage without breakdown, have steady or decreasing leakage current during the high potential tests and have satisfactory comparable megger readings in each megger test.
8. **Records:** Include the following information in tests report on each cable:
 - a. Complete identification of cable, including approximate length.
 - b. Megger readings versus time data, including converted values.
 - c. Leakage current versus time data.
 - d. Approximate average cable temperature.
 - e. Shield ohmic value.

J. ^{A7}**Tests on Wire And Cables Rated 600 Volt and Below:**^{A7}

1. **General:** For each power feeder and branch circuit cable perform a continuity test and a megger test. Verify phase identification for each power feeder and branch circuit. Verify identification of all lighting circuits and branch circuits on panel directories and make operational checks on all lighting circuits and branch circuits to prove that the circuits perform all functions for which they are designed. Check all power feeder cable connections for workmanship and conformance with standard practice by visual inspection.
2. ^{A7}**Visual and Mechanical Inspection:**^{A7}
 - a. Cables shall be inspected for physical damage and proper connection in accordance with one-line diagram.
 - b. Cable connections shall be torque tested to manufacturer's recommended values.
3. **Connections:** Isolate power cable to be megger tested by opening switches or breakers at each end of cable prior to testing where such disconnecting means exists. Where cables are directly connected without a disconnecting means, do not disconnect cables: Test as connected.
4. **Megger Tests:**
 - a. Use a 500-Volt megger for each megger test. Insulation resistance tests shall be performed at 500 volts dc for 30 seconds.
 - b. Apply megger tests between each conductor and ground with the other two conductors in the conduit or cable grounded to the same ground. Test each conductor in the same manner.
 - c. **Minimum acceptable readings:** For disconnected cables, 5

megohm.

- d. When insulation resistance is to be determined with all switchboards, panel boards, fuse holders, switches, and overcurrent devices in place, the insulation resistance when tested at 500 Volts dc shall be no less than 1,000,000 Ohms.
 - e. Megger readings provided in these requirements are the minimum readings desired at an ambient temperature of 60 degrees F (15.55 degrees Celsius) and at a relative humidity of less than 60 percent. When megger readings are taken at other than 60 degrees F (15.55 degrees Celsius), readings taken shall be temperature and humidity compensated.
5. **Acceptance:** Cable must pass all inspections and tests.
6. **Records:** Include the following information in tests report on each power and branch circuit cable rated below 600 volts:
- a. Complete cable identification and description of isolation means.
 - b. Megger readings, including compensated values.
 - c. Approximate average cable temperature.

K. ^{A7}**Tests on Control Wiring:**^{A7}

- 1. **General:** Each single conductor and multi-conductor control wire or cable shall be tested for continuity and insulation strength. Verify identification of conductors.
- 2. **Connections:** Disconnect and fan out conductors to be tested.
- 3. **Insulation Strength Tests:**
 - a. Test each control wire to 500 Volt, 60 Hertz.
 - b. Apply test between each conductor in a wire group and ground with all other conductors in the wire group grounded to the same ground. Use a test set having an accurate means of ensuring 500 volt test voltage and provide a series resistance to limit fault when a ground is found. Hold test voltage only long enough to read instruments. Test each conductor in the same manner.
 - c. In lieu of the above insulation strength test, megger each control wire as required for 480 Volt power conductors.
- 4. **Acceptance:** Wires must pass all tests.
- 5. **Records:**
 - a. Include the following information in test report on each wire group.

- 1) Wire and group identification.
- 2) Type of test, insulation strength or megger.
- 3) When megger testing is selected, include information as required for 480 Volt power cables.

L. ^{A7}**Tests on Pad-Mounted Transformers:**

1. **Visual and Mechanical Inspection:**

- a. Check primary, secondary and ground connections.
- b. Check all bolted connections are tight.

2. **Auxiliary Devices:**

- a. Check winding temperature device.
- b. Check auxiliary cooling if provided.

3. **Insulation Resistance Test:**

- a. Megger transformer windings and calculate polarization index for:
 - 1) High to low and ground.
 - 2) Low to high and ground.
 - 3) High and low to ground.

4. **Megger Tests:**

- a. Use a 10,000 Volt megger for megger tests on 15 kV class windings, and a 500 Volt megger for megger tests on 480 Volt windings.
- b. Apply a megger test between each transformer winding tied together and ground. Ground all windings and breaker contacts not included in the test to the same ground.
- c. Hold all 10,000-Volt absorption tests for at least 10 minutes and until three consecutive readings one minute apart are obtained. Take readings every 30 seconds during the first two minutes and every minute thereafter.
- d. Hold all 500-Volt insulation tests until the reading reaches a constant value and until three (3) consecutive equal readings one minute apart are obtained.
- e. Minimum acceptable readings are as listed below. Megger readings taken after the high potential tests must be reasonably parallel with those of the initial test to show no evidence of

injury to the transformer during the high potential test.

**Minimum Megger
Equipment**

15 kV class primary winding

Reading-Megohms

800

5. **High Potential Tests:**

- a. Apply the following 60 Hertz test voltages for specific voltage windings for one minute:

Equipment	High Potential Test Voltage (kV)
15 kV class primary winding	23
480 volt winding	3.0

6. **Acceptance:** The transformers shall pass all inspections and tests, withstand the required high potential test voltage without breakdown, and have satisfactory comparable megger readings in each megger test.

7. **Records:**

- a. Include the following information in test report on each transformer:
- 1) Complete transformer identification.
 - 2) Megger readings versus time data including temperature and humidity compensated values.
 - 3) Approximate average transformer temperature.

8. **Testing the Insulation Fluid:** The Employer's Representative reserves the right to conduct any of the oil tests listed in part Section 26 12 19 (*Pad Mounted Transformer Liquid Filled Medium Voltage Transformer*). The comparison parameters shall be supplied by the oil manufacturer. When tested, the dielectric breakdown voltage of the oil shall be greater than 50 kV. The Employer's Representative will not accept a transformer that does not pass this test. Test that does not meet the pass criteria shall be paid by the Contractor.

9. **Testing the Insulation of the Windings:** The Contractor will perform tests in accordance with current Standards to assure that the insulation of the windings is acceptable. The tests will be performed with a 2500 VDC Megger and Biddle power factor test set before the transformers are energized. The Employer's Representative shall be notified at least one week in advance to witness these tests. If the transformers fail these tests, the Contractor will be requested to solve this

deficiency to the satisfaction of the ^{A17}Employer's Representative. ^{A17} If it is not corrected adequately, the Employer's Representative will request a warranty extension of five years without any cost to the Employer or the replacement of the unit.

M. ^{A7}**Tests on Switchgear Medium Voltage Section:**^{A7}

1. **General:** Check and test all ground connections per paragraph "Tests on Grounding System". Apply to each breaker an insulation test. Apply to each bus a megger test first and after it, apply a high potential test. Perform operational tests on switchgear, relays, breakers and control devices. Perform ratio and polarity tests on all instrument transformers and apply to each potential transformer a megger test. Apply to each current transformer secondary a megger test. Perform test on relays as per paragraph "Tests on Protective Relays".
2. **Visual and Mechanical Inspection:**
 - a. Inspect for physical damage.
 - b. Compare equipment nameplate information with latest one-line diagram and report discrepancies to the ^{A17}Employer's Representative.^{A17}
 - c. Inspect for proper alignment, anchorage and grounding.
 - d. Check tightness of accessible bolted bus joints by calibrated torque wrench method. Refer to manufacturer's instructions for proper tightness levels.
 - e. Key interlock system shall be physically tested to insure proper function.
 - 1) Closure attempt shall be made on locked open devices. Opening attempt shall be made on locked closed devices.
 - 2) Key exchange shall be made with devices operated in off-normal positions.
 - f. All doors, panels and sections shall be inspected for paint, dents, scratches and fits. Repair, replace or repaint unacceptable items ^{A17}at no additional cost.^{A17}
3. **Connections:**
 - a. Prior to performing any test on main bus, isolate bus to be tested by racking out or otherwise disconnecting all breakers, short and ground current transformer secondary, remove potential transformer primary fuses, and ground housing.
 - b. Perform high potential and megger tests on breakers in the withdrawn or disconnected position.
 - c. Check tightness of bolted joints by calibrated torque wrench

method. Bus torque values shall be in accordance with manufacturers recommended values.

- d. Measure resistance from line to load side on each phase of breakers.

4. **Megger Tests:**

- a. Apply megger tests on switchgear bus and breakers between each phase to ground and phase to phase with the other phases grounded to the same ground.
- b. Apply megger tests on potential transformers between each winding and ground with windings not under test grounded to the same ground.
- c. Apply megger tests on current transformers secondary and associated wiring between all phases tied together and ground.
- d. Hold all 10,000-Volt megger tests at least 10 minutes. Take readings every 30 seconds during the first two minutes and every minute thereafter.
- e. Hold all 500 Volt megger tests until the reading reaches a constant value and until three consecutive equal readings one minute apart are obtained.
- f. Minimum acceptable megger readings and megger voltage are as listed below. Megger readings taken after the high potential tests shall be reasonably parallel with those of the initial test to show no evidence of injury to the equipment during the high potential test.

Equipment	Megger Voltage	Minimum Megger Reading in Megohms
Main buses	10,000	50
Breakers	10,000	100
Potential transformer primary windings	10,000	50
Current and potential transformer secondary windings	500	5

5. **High-Potential Tests:**

- a. Apply high-potential tests on main bus between each phase and ground with the other phases grounded. Test each phase in the same manner.
- b. Apply the following 60 Hertz test voltages for specified

equipment for one minute:

<u>Equipment</u>	<u>High Potential Test Voltage (kV)</u>
15 kV class bus	23

6. **Instrument Transformer Ratio Tests:**

- a. Perform ratio tests on each potential transformer.
- b. Perform a two-point ratio test on each current transformer.
- c. Using inductive kick method, check the polarity of each current transformer.

7. **Operational Tests on Each Breaker:**

- a. Inspect each breaker mechanism for correct alignment, freedom from binding, and good contact.
- b. Check each breaker for ease of rack-in and rack-out. Check interlocking to determine that the breaker cannot be racked-out-of or into the operating position with the main contacts closed. Check position indicating target operation.
- c. Operate each breaker through three open-close-open cycles in both the operating and test position by both manual and automatic operation as follows:
 - 1) Manually operate the breaker from both the local switchgear mounted control switch and remote control switches, after SCADA system has been tested. Observe indicating lights and position indicating target for correct operation.
 - 2) Manually close each breaker by control switch and trip automatically. Observe indicating lights, alarms and targets for proper operation, including remote devices if applicable.
 - 3) Where individual breakers are electrically interlocked for automatic closing and opening of another breaker, operate breakers to determine that operation is proper.

8. **Acceptance:** The equipment must pass all inspections and tests, withstand the specified high potential tests voltage without breakdown, and have satisfactory comparable megger readings in each megger test.

9. **Records:**

- a. Make complete and accurate records of each test. Include the following in each test report:
 - 1) Complete switchgear identification.

- 2) Megger readings versus time data, including temperature and humidity compensated values and ambient temperature at time of test.
- 3) Voltage and current readings on instrument transformer ratio tests.

N. ^{A7}**Tests on Transformers Rated 600 Volts and Below:**^{A7}

1. **General:** Check continuity and correctness of connections of windings and give each winding a megger test.
 - a. ^{A7}**Visual and Mechanical Inspection:**^{A7}
 - 1) Inspect for physical damage.
 - 2) Compare equipment nameplate information with latest one-line diagram and report discrepancies to the ^{A17}Employer's Representative.^{A17}
 - 3) Verify proper auxiliary device operation for components including, but not limited to, fans, indicators and tap changer.
 - 4) Check tightness of accessible bolted electrical joints in accordance with manufacturer's recommendations. Check hardware, bushings and vibration mats.
 - 5) Perform specific inspections and mechanical tests in accordance with the manufacturer's instructions.
2. **Connections:** Isolate transformer by opening the line side circuit breaker and disconnect secondary conductors at panels. Tie conductors together on each winding.
3. **Megger Tests:**
 - a. Use a 500 Volt megger for megger tests on 480 Volt and lower voltage windings. Appropriate guard circuit shall be utilized under bushings.
 - b. Apply a megger test between each transformer winding tied together and ground. Ground all windings not included in the test to the same ground. Winding resistance tests shall be made for each winding at nominal tap position. Perform a megger test of the secondary windings.
 - c. Minimum acceptable readings: 480 Volt winding to ground, 45 megohms; lower voltage winding to ground, 30 megohms.
 - d. Hold all megger tests for at least one minute or until the reading maintains a constant value for 15 seconds.
4. **Electrical Tests:**
 - a. A dielectric absorption test shall be made winding to winding

and winding to ground for 10 minutes. The polarization index shall be computed.

- b. A turns ratio test shall be performed between windings for all tap positions. The final tap setting shall be determined and set by the testing company upon completion of acceptable ratio testing acceptable values.
- c. AC overpotential test shall be made on all high and low voltage winding to ground.
- d. Individual exciting current tests shall be performed on each phase in accordance with established procedure.
- e. Perform special test and adjustments in accordance with the manufacturer's instructions for tap changer, fan and controls, and alarm functions.
- f. Perform a core ground test.
- g. Test temperature control panel and verify alarm stages and interlock for shutdown.
- h. Measure primary and secondary voltages for proper tap settings

5 **Test Values:**

- a. Insulation resistance and absorption test voltage shall be 165 megohm minimum and 500 Volts minimum, respectively. Results shall be temperature and humidity compensated.
- b. The absorption test polarization index shall be above 2.0 unless an extremely high value is obtained at the end of 1 minute, that when doubled will not yield a meaningful value with the available test equipment.
- c. AC high potential test voltage shall not exceed 75 percent of factory test voltage for one (1) minute duration. Evaluation shall be on go, no-go, basis.
- d. Winding resistance test results shall compare within 1 percent of adjacent windings.
- e. Turns ratio test results shall not deviate more than 0.50 percent from calculated ratio

6. **Acceptance:** Transformers must pass all inspections and tests.

7. **Records:**

- a. Make complete and accurate records of each test. Include the following in each test report:
 - 1) Complete identification of transformer.

- 2) Megger readings, including temperature and humidity compensated values and ambient temperature at time of test.
- 3) Values of insulation resistance (IR) less than manufacturer's minimum, or $kV + 1$ in megohms, shall be investigated. Over-potential tests shall not proceed until IR levels are raised to specified minimum.

O. ^{A7}**Tests on Circuit Breakers, Low Voltage (Molded Case):**^{A7}

1. **Visual and Mechanical Inspection:**

- a. Circuit breakers shall be checked for proper mounting, conductor size and feeder designation.
- b. Operate circuit breakers to ensure smooth operation.
- c. Inspect case for cracks and other defects.
- d. Check tightness of connection with torque wrench in accordance with manufacturer's instructions.

2. **Electrical Tests:**

- a. Contact resistance shall be measured.
- b. Time-current characteristic tests shall be performed by passing 300 percent rated current through each pole separately. Trip time shall be determined.
- c. Instantaneous pickup current shall be determined by run-up or pulse method. Clearing times shall be within four cycles or less.
- d. Insulation resistance shall be determined pole to pole, across pole and pole to ground. Test voltage shall be 500 Volts DC.

3. **Test Values:**

- a. Contact resistance shall be compared to adjacent poles and similar breaker. Deviations of more than 50 percent shall be investigated.
- b. Insulation resistance shall not be less than 50 megohms.
- c. All trip times shall fall within manufacturer's published time-current curves, including adjustment factors. Circuit breakers exceeding maximum 300 percent time shall be replaced.
- d. Instantaneous pickup current levels shall be within manufacturer's published values.

P. ^{A7}**Tests on Protective Relays:**^{A7}

1. **Visual and Mechanical Inspection:**

- a. Relays shall be inspected for physical damage and compliance with these specifications.
- b. All settings shall be determined by the results of the power systems studies described in Section 26 05 73 (*Short Circuit and Load Flow Coordination Study*).

2. **Electrical Tests:**

- a. Perform insulation resistance test on each phase to frame. Do not perform this test on solid state relays.
- b. Perform the following tests on the nominal settings determined by the results of the power system studies described in Section 26 05 73 (*Short Circuit and Load Flow Coordination Study*).
 - 1) Pickup parameters on each operating element.
 - 2) Timing test shall be performed at three points on time dial curve.
 - 3) Pickup target and seal in units.
 - 4) Special test as required to check operation of restraint, directional and other elements in accordance with the manufacturer's instructions.
- c. Perform phase angle and magnitude contribution tests on differential and directional type relays after energization to vectorially prove proper polarity and connection.

3. **Test Values:** Pass or no pass.

Q. ^{A7}**Tests on Instrument Transformers:**^{A7}

1. **Visual and Mechanical Inspection:**

- a. Inspect for physical damage and compliance with the drawings.
- b. Check mechanical clearances and proper operations of all disconnecting and grounding devices associated with voltage transformers (VT).
- c. Verify proper operation of grounding or shorting devices.

2. **Electrical Tests:**

- a. Current transformers (CT) shall have secondary saturation tests done at a minimum of three points below and one point above knee of saturation curve.

- b. Confirm transformer polarity electrically.
- c. Burden tests shall be performed at the secondary leads of the CT to assure accurate translation of primary current.
- d. Verify connection at secondary CT leads by driving a low current through the leads and checking for this current at applicable devices.
- e. Confirm transformer ratio.
- f. Measure insulation resistance of transformer secondary and leads with 500 Volt megohm meter.
- g. Measure transformer primary insulation with applicable over-potential tests.
- h. Verify connection of secondary voltage transformer (VT) leads by applying a low voltage to the leads and checking for this voltage at applicable devices.
- i. Check for VT secondary load with secondary voltage and current measurements. Load shall less than voltage ampere capacity of the VT.

R. ^{A7}**Tests on Metering and Instrumentation:**^{A7}

1. **Visual and Mechanical Inspection:**

- a. Examine devices for broken parts, indication of shipping damage and wire connection tightness.
- b. Verify meter connections.

2. **Electrical Tests:**

- a. Calibrate all meters at mid scale. Calibration instrument precision shall be 50 percent or less than the precision of the instrument being tested.
- b. Calibrate watt-hour meters to 0.50 percent.
- c. Verify instrument multipliers.

3. **Test Values:** Pass or no pass.

S. ^{A7}**Tests on Ground Fault Systems:**^{A7}

1. **Visual and Mechanical Inspection:**

- a. Inspect for physical damage and compliance with the Contractor's drawings and specifications.
- b. Inspect neutral main bonding connection to assure:
 - 1) Zero sequence system is grounded upstream of sensor.

- 2) Ground strap systems are grounded through sensing device.
 - 3) Ground connection is made ahead of neutral disconnect link.
 - c. Inspect control power transformer to insure adequate capacity for system.
 - d. **Monitor panels shall be manually operated for:**
 - 1) Trip test
 - 2) No trip test
 - 3) Non-automatic reset
 - 4) Proper operation and test sequence shall be recorded.
 - e. Zero sequence systems shall be inspected for symmetrical alignment of core balance transformers about all current carrying conductors.
 - f. Ground fault device circuit nameplate identification shall be verified by device operation.
 - g. Pickup and time delay settings shall be set in accordance with the results of the power system studies required by Section 26 05 73 (*Short Circuit and Load Flow Coordination Study*).
2. **Electrical Test:**
 - a. System neutral insulation resistance shall be measured to ensure no shunt ground paths exist, Neutral-ground disconnect link shall be removed, neutral insulation resistance measured and link replaced.
 - b. The relay pickup current shall be determined by primary injection at the sensor and the circuit interrupting device operated.
 - c. The relay timing shall be tested by injecting 150 percent and 300 percent of pickup current into sensor. Total trip time shall be electrically monitored.
 - d. System operation shall be tested at 55 percent rated voltage.
 - e. Zone interlock systems shall be tested by simultaneous sensor current injection and monitoring zone blocking function.
3. **Test Parameters:**
 - a. System neutral insulation shall be a minimum of 1 megohm or greater.
 - b. Relay pickup current shall be within 10 percent of device dial or fixed setting, but in no case greater than 1200 Amperes.

- c. Relay timing shall be in accordance with manufacturer's published time-current characteristic curves, but in no case longer than 1 second.

T. ^{A7}**Tests on Grounding Systems:**^{A7}

1. **General:** For the purpose of testing and inspection, the Contractor shall design and construct inspection access or inspection boxes at every building location and at strategic locations in order to provide the required inspection and testing access. During construction and after completing the installation the Contractor shall inspect ground conductors, ground busses and connections for conformance with design specifications and workmanship.
 - a. Visual and Mechanical Inspection: Inspect ground system for compliance with the drawings and specifications.
2. **Connections:** Inspect ground conductors, ground busses and connections for conformance with design specifications and for adequacy.
 - a. Maintain each ground rod isolated from the associated ground rods for tests on individual rods for resistance to earth.
 - b. Include associated ground rods and interconnecting wiring in test for resistance to earth.
 - c. Include ground bus on equipment, room and pullbox connections, and associated intermediate copper ground conductors in tests on ground paths for electrical equipment.
 - d. Include structural steel or reinforcing bar connection, rod connection and intermediate conductor in tests on ground paths for structural steel or reinforcing bars.
3. **Electrical Tests:**
 - a. Perform fall of potential test in accordance with IEEE 81, Section 9.04, on the main grounding electrode or system.
 - b. Perform the two point method test in accordance with IEEE No. 81, Section 9.03, to determine the ground resistance between the main grounding system and major electrical equipment frames, system neutral and/or derived neutral points.
 - c. Perform fall of potential test in accordance with IEEE 81, Section 9.04, on the main grounding electrode or system.
 - d. Alternate method: Perform ground continuity test between main ground system and equipment frame, system neutral and/or derived neutral point. This test shall be made by passing a minimum of 10 amperes DC current between ground reference system and the ground point to be tested. Voltage drop shall be measured and resistance calculated by voltage drop method.

e. ^{A7}**Tests on Individual Ground Rods:**^{A7}

- 1) Test each ground rod for resistance to earth by a standard method. Use a Biddle ground tester or the method of using two auxiliary ground rods as described in IEEE Standard 118. The IEEE method requires the use of AC test current. Place auxiliary test rods sufficiently far away from the rod under test so that the regions in which their resistance is localized do not overlap. Calculate ground resistance from the readings taken. Maximum acceptable resistance to earth: 5 ohms, for individual rods. Each building's grounding point shall also comply with this value.
- 2) If the resistance is found to be higher than 5 ohms, drive additional rods with a minimum separation of 10 feet and connect in parallel with the rod under test until 5 ohms or less is obtained, or increase the length of the rod under test until 5 ohms maximum is obtained.

f. **Tests on Ground Paths:** Test ground paths for electrical equipment, structural steel or reinforcing bars for continuity by applying a low voltage dc source of current, capable of furnishing up to 100 Amperes. The ground path for electrical equipment, structural steel or reinforcing bars must conduct 100 amperes. Resistance as calculated from the current and voltage must not exceed 0.010 ohms.

4. **Records:** Contractor shall make complete records of all tests. Include resistance values obtained, calculations of same, and methods of test and calculation. The Contractor shall submit all records of tests to the Employer's Representative for review.
5. **Acceptance:** Grounding materials and connections must pass all inspections and must meet all specified maximum and minimum values contained in the Contractor's specifications.

U. ^{A7}**Tests on Motor Control Centers:**^{A7}

1. **Visual and Mechanical Inspection:**

- a. Inspect for physical damage, proper anchorage and grounding.
- b. Compare equipment nameplate data with the drawings or starter schedule.
- c. Compare overload heaters with motor full load current for proper size.
- d. Check tightness of bolted connections.
- e. Measure contactor's resistance values and compare with manufacturer's tolerances.

2. **Electrical Test:**

a. ^{A7}**Insulation Tests.**^{A7}

- 1) Measure insulation resistance of each bus section phase to phase, and phase to ground for 1 minute. Test voltage and minimum acceptable values shall be 1000 Volts and 100 megohms, respectively.
 - 2) Measure insulation resistance of each starter section phase to phase, and phase to ground with starter contacts closed and the protective device open. Test voltage and minimum acceptable values shall be 1000 Volts and 100 megohms, respectively.
 - 3) Measure insulation resistance of each control circuit with respect to ground.
- b. Motor overload units shall be tested by injecting primary current through overload unit and monitoring trip time. Overload tests shall be made at 300 percent of motor full load current. Trip times shall be in accordance with manufacturer's tolerances. Values in excess of 120 seconds shall be investigated.
- c. Perform operational tests by initiating control devices to effect proper operation.
- d. Control wiring insulation test voltage shall be 500 VDC. Manufacturer shall be consulted for test voltage where solid state control devices are utilized.

V. ^{A7}**Tests on Rotating Equipment (Motors):**^{A7}

1. **General:** The Contractor shall inspect all motors installed under other sections of the Employer's Requirements for damage, moisture, alignment, proper lubrication, oil leaks, phase identification and cleanliness. Check for proper rotation. Coordinate uncoupling of motors where reverse rotation would damage equipment. Perform a megger test on each motor.

a. **Visual and Mechanical Inspection**

- 1) Inspect for physical damage.
- 2) Compare equipment nameplate information with single line diagram and report discrepancy to the ^{A17}Employer's Representative.^{A17}
- 3) Inspect for proper anchorage, mounting, grounding and connection.
- 4) Special tests as recommended by the manufacturer such as gap spacing and pedestal alignment shall be performed where applicable.

2. **Connections:**

- a. For three-phase motors, include cable back to the open starter.
- b. For single-phase motors, disconnect motor from service.

3. **Electrical Tests:**

- a. ^{A7}**Large Motors:**^{A7} For the purpose of the related tests, motors larger than 200 HP shall be considered large motor. A dielectric absorption test shall be performed on motor and starter circuit. Polarization index shall be determined for motor winding.
- b. Perform insulation resistance test on pedestal in accordance with the manufacturer's instructions, where applicable.
- c. A rotation test shall be performed to insure proper shaft direction.
- d. Measure no-load and full-load running current and compare to nameplate.
- e. Observe proper operation and sequence of reduced voltage starters.
- f. ^{A7}**Large Motors:**^{A7} Perform vibration base line test. Amplitude shall be plotted versus frequency. Submit plot.
- g. ^{A7}**Small Motors:**^{A7} Perform vibration amplitude test.
- h. Check protective devices in accordance with other sections of these specifications.
- i. Perform overpotential test on winding to ground.
- j. **Megger Tests (Insulation Resistance Tests)**
 - 1) Apply megger tests on three phase motors between all phases tied together and ground, with motor at ambient temperature.
 - 2) For single phase motors, apply megger test between phase and neutral conductor tied together and ground, with motor at ambient temperature.
 - 3) Hold all megger tests for one minute or until the reading maintains a constant value for 15 seconds.
 - 4) Minimum acceptable megger readings and megger voltage are listed below:

<u>Equipment</u>	<u>Minimum Voltage</u>	<u>Megger Reading-Megohms</u>
480 Volt, 3 phase induction motor	1000 V	20
115/208 Volt, 1 phase induction motor	500 V	5

4. **Operating Tests:** Run motor long enough to prove satisfactory performance including operating temperature, lubrication and vibration.
5. **Test Values:**
 - a. Dielectric absorption tests shall be made at 1000 Volts only for large motors rated up to 600 V. Polarization tests shall be for 10 minute duration. Sixty/thirty second ratio tests shall be performed for 1 minute duration. Polarization index readings less than three shall be investigated. Sixty/thirty second ratio readings less than 1.4 shall be investigated.
 - b. Motor measured full load current shall not exceed nameplate value.
 - c. Over-potential test shall be made at 80 percent of twice rated voltage plus 1000 volts.
 - d. Vibration amplitudes shall not exceed values shown in the following table.

MAXIMUM ALLOWABLE VIBRATION AMPLITUDE

<u>Speed, rpm</u>	<u>Amplitude, inches peak to peak</u>
3000 and above	0.001
1500 - 2999	0.002
1000 - 1499	0.0025
999 and below	0.003

6. **Acceptance:** Motor must pass all inspections and tests.
7. **Records:**
 - a. Make complete and accurate records of all test and inspections. Include the following in each test report:
 - 1) Megger readings, including temperature and humidity compensated values.
 - 2) Ambient temperature at time of test.

W. ^{A7}**Tests on Control Devices:**^{A7}

1. **General:** The Contractor shall perform operating tests on all control, alarm or indicating devices installed under Paragraph K.
2. **Connections:**
 - a. Include motors and protective control devices in test circuitry where operation of motors will not damage attached equipment.
 - b. Where equipment could be damaged by energizing motors, disconnect motor leads at the load side of starters.
 - c. Jumper or disconnect, as applicable, control devices installed under other divisions of the specifications as necessary to permit testing those devices and circuitry installed.
3. **Acceptance:** Control devices and circuitry must pass all tests to prove that all design functions are satisfactorily performed, including manual and automatic operation and interlocking.
4. **Records:** Make complete records of all tests.

X. ^{A7}**Tests on Automatic Transfer Equipment:**^{A7}

1. As part of his design responsibilities the Contractor shall develop a testing program for the Employer to execute. In addition to the testing program supplied by the Contractor, the testing shall include visual and mechanical inspection see Section 26 13 00 (*Medium Voltage Switchgear*), and the items listed in subparagraphs 1, 2 & 3:
 - a. Inspect for physical damage.
 - b. Compare equipment nameplate information and connections with single line diagram and report any discrepancies to the ^{A17}Employer's Representative.^{A17}
 - c. Check **breakers** to ensure positive interlock between normal and alternate sources.
 - d. Check tightness of cable connections and bus joints.
 - e. Perform manual transfer operation.
2. **Electrical Tests:**
 - a. Perform insulation resistance test phase to phase, and phase to ground with switch in both source positions.
 - b. Set and calibrate in accordance with the results of the power system studies described in Section 26 05 73 (*Short Circuit and Load Flow Coordination Study*).
 - 1) Voltage sensing relays.

- 2) Transfer time delay relay.
 - c. ^{A7}**Perform Automatic Transfer by:**^{A7}
 - 1) Simulating loss of normal power.
 - 2) Return to normal power.
 - d. ^{A7}**Monitor and Verify Correct Operation and Timing of:**^{A7}
 - 1) Normal voltage sensing relays.
 - 2) Time delay upon transfer.
 - 3) Alternate voltage sensing relays.
 - 4) Automatic transfer operation.
 - 5) Interlocks and limit switch function.
 - 6) Timing delay and retransfer upon normal power restoration.
 - e. Interface to remote monitoring and control unit and power SCADA system.
 - f. Perform functional tests on auxiliary contacts, interface positions, alarms, and status conditions for each digital input/output.
 - 3. **Test Values:**
 - a. Insulation resistance test voltages and minimum values shall be 1000 Volts, and 100 megohms, respectively.
- Y. ^{A7}**Tests on Battery System:**^{A7}
- 1. **Visual and Mechanical Inspection:**
 - a. Inspect for physical damage.
 - b. Verify system configuration with the specifications and single line diagram.
 - c. Check intercell bus link integrity.
 - 2. **Electrical Tests:**
 - a. Measure system charging voltage and each individual cell voltage.
 - b. Measure electrolyte specific gravity and level.
 - c. Perform infrared scan of the intra cell links under battery current discharge conditions.
 - 3. **Test Values:**
 - a. Compare measured values with the manufacturer's tolerances.

- b. Intra cell connector links shall exceed 10 degrees C temperature differential.

Z. ^{A7}Tests on Surge Arresters:^{A7}

- 1. **Visual and Mechanical Inspection:**
 - a. Inspect for physical damage.
 - b. Verify location and nameplate rating with the drawings and the specifications.
 - c. Inspect ground and discharge counter connections for integrity.
- 2. **Electrical Tests:**
 - a. Perform ground continuity test to ground grid system.
 - b. Perform megger test.
- 3. **Test Values:**
 - a. Ground grid connections shall not exceed 0.5 ohms, maximum.

AA. ^{A7}Tests on DC Power Systems:^{A7}

- 1. **Site acceptance Tests:** The Contractor shall conduct the site acceptance tests in accordance with a site acceptance tests procedure prepared by the system manufacturer. Submit test procedure to the Employer's Representative at least 30 days before the test.
- 2. Supply a load bank and any other test equipment required to the site for these tests. The tests shall include but not be limited to verification of the following:
 - a. A 4 hour burn in.
 - b. Battery operation, support and recharge time (twice in succession).
 - c. Voltage regulation.
 - d. Operation of all controls, meters and alarms.
 - e. Response to faults.
 - f. Measure total harmonic distortion.

1.04 SUBMITTALS:

A. Before Testing:

- 1. Submit the testing company's qualifications and the resumes of the personnel proposed to be assigned to this project.

2. Test procedures shall be as recommended by the equipment/system manufacturer.
3. Submit proposed testing program and test procedures for review by the Employer's Representative before beginning any testing. Each procedure shall include the following as a minimum:
 - a. Statement of procedure objective and scope.
 - b. List of equipment and instruments required to set up and perform the procedure.
 - c. List of equipment, instruments or services required from areas outside Contractor's control.
 - d. List of prerequisite tests that need to be completed before the procedure can be performed.
 - e. Description of the required procedure setup, including diagrams illustrating test equipment connections and identifying test points, where applicable.
 - f. Step-by-step instructions for performing the procedure, identifying the points where data is to be recorded and the limits for acceptable data, in accordance with referenced standards.
 - g. Provisions for recording pertinent test conditions and environment at time of test.
 - h. Instructions for recording data on data sheets and verifying that procedure steps have been completed.
- B. **Instruments:** Submit list of instruments and certification indicating that instruments, which will be used for testing, have been calibrated and their accuracy certified. List types of instruments to be used, manufacturer, model, serial number, latest date of calibration, and calibrating organization.
- C. **Before Taking Over:**
 1. Test Report (Draft and Final)
 - a. The draft and final test reports, shall include, but not be limited to, the following (Draft Report shall be submitted before acceptance, Final Report shall be submitted after acceptance):
 - 1) Equipment identification number as per Section 26 05 53 (*Identification for Electrical Systems*).
 - 2) Description of equipment tested.

- 3) Description of test.
 - 4) List of test equipment used in calibration and calibration date.
 - 5) Humidity, temperature, and other atmospheric conditions that may affect the results of the tests/calibrations.
 - 6) Test results, including plots/graphs and actual readings/measurements taken including corrected values.
 - 7) Conclusions and recommendations.
 - 8) Appendix, including appropriate test forms.
 - 9) All test reports shall be signed by the authorized witness present at the test.
- b. The final test report shall be bound and its contents certified.

END OF SECTION