

SECTION 16999

ELECTRICAL ACCEPTANCE TESTS

PART 1 2. AND 3. COMBINED

1.1 SUMMARY

A. Description of Systems

1. Furnish all labor, materials, test equipment, and technical supervision to perform and record the electrical tests as specified, and perform and record all electrical tests as required, including tests on medium voltage wire and cable, 600 volt wire and cable, switchgear, unit substations, distribution transformers, rotating equipment, busways, motor control centers, control devices, grounding, special service systems, relays, and transformer insulation liquids, unless otherwise specified.
 - a. Preliminary inspections 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.
 - b. Electrical acceptance tests. Those inspections and tests required to show that the workmanship, methods, inspections, and materials used in erection and installation of the electrical equipment conforms to accepted engineering practices, IEEE ICEA and NEMA Standards, the National Electrical Code, National Electric Testing Association (NETA) Specifications, manufacturers instructions, and 16000 Series SECTIONS, and to determine that the equipment involved may be energized for operational tests.
 - c. Operating tests. Those tests performed on all electrical equipment installed under 16000 Series SECTIONS, and under other SECTIONS, to show that the electrical equipment will perform the functions for which it was designed.
2. Furnish all labor, materials, test equipment and technical supervision to perform and record the electrical test as specified for the Chilled Water and Instrument Air System Control Panels including site presence during PLC control system commissioning by the PLC Programming Consultant under a separate contract with the owner.
3. Testing organization shall meet federal OSHA criteria for accreditation of testing laboratories, Title 29, Part 1910.7.

B. Related Work Specified Under Other Sections

1. Refer to SECTION 16025.
2. Operating tests on mechanical and electrical equipment installed under other SECTIONS to prove capability of such equipment to perform as specified in the SECTION covering specific equipment.
3. Repair or replacement of equipment installed under other SECTIONS and not meeting acceptance tests specified in this SECTION and therefore not acceptable.
4. Uncoupling of motors installed under other SECTIONS where reverse rotation could damage equipment during acceptance tests for proper rotation.

1.2 FINAL ACCEPTANCE

- A. Final acceptance of electrical equipment will not only depend on equipment integrity as determined by the electrical acceptance test, but will also depend on complete operational tests, whether performed under this or other SECTIONS.

1.3 TEST REPORT SUBMITTALS

- A. *Test reports [T]*: Submit, including complete data on actual readings taken and corrected values, to the ARCHITECT-ENGINEER for approval after each test period. Have all test reports signed by the authorized witnesses present at tests prior to submission. Do not energize any equipment or material for operating tests until test data has been approved. Refer to SECTION 01340 for requirements regarding submittals.

1.4 RECORD DOCUMENTS

- A. Submit, per SECTION 01720, the final approved test reports to the OWNER at the completion of the work under this SECTION.

1.5 ENVIRONMENTAL REQUIREMENTS

- A. Humidity
 - 1. Do not perform megger or high potential tests during times of high relative humidity.
- B. Weather
 - 1. Do not perform tests on outdoor equipment during inclement weather. Do not perform tests on direct burial bare ground conductors or on ground rods within a 48 hour period following rainfall.

1.6 PROTECTION OF PERSONNEL

- A. During cable tests, station a man at each point where cable has exposed connections.

1.7 SCHEDULING OF TESTS

- A. Perform all acceptance and operating tests in the presence of the ARCHITECT-ENGINEER.
- B. Schedule sequence of tests so that equipment can be energized immediately after completion of the applicable tests and approval of test reports. Notify the ARCHITECT-ENGINEER of time of test at least 48 hours prior to testing.
- C. 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. Obtain list of manufacturers of OWNER furnished equipment from the ARCHITECT-ENGINEER.

1.8 GENERAL TESTING REQUIREMENTS

A. Preliminary Work

1. Perform preliminary inspections and tests immediately prior to performing acceptance tests. Fuses and protective devices, such as circuit breakers and cable limiters, shall be omitted from cable tests and tests involving cables.

B. High Potential Tests

1. Do not perform more than one high potential test on any conductor unless specifically authorized by the ARCHITECT-ENGINEER.

C. Megger Tests

1. Megger readings specified are the minimum readings desired at an ambient temperature of 60 degF (15.56 degC) and at a low relative humidity. When megger readings are taken at other than 60 degF, convert readings to equivalent values at 60 degF.
2. When megger readings fall below the specified minimum values at 60 degF, devise some means of applying heat for the purpose of drying out the equipment subject to the approval of the ARCHITECT-ENGINEER. 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.

D. Continuity Tests

1. Perform continuity tests with a DC type device using a bell or buzzer. Do not use phones for continuity test; use phones only for communication.

1.9 TESTS ON 15 KV POWER CABLES

A. General

1. Give each 15 KV cable a high potential test after all splices and permanent connections are made, except as otherwise specified, and a dielectric absorption test before and after the high potential test. Check continuity and phase identification for each cable.

B. Connections

1. 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. Feeder cables looped between each piece of equipment shall have each segment tested individually. Apply high potential and dielectric absorption tests between each conductor and ground with the other two conductors, its shield, lead sheath, conduit or armor grounded to the same ground. Test each conductor in the same manner. Do not include building steel as a necessary part of the test ground circuit.

C. Dielectric Absorption Tests

1. Use a 2500 volt megger 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 readings 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.

D. High Potential Tests

1. Apply a DC test voltage equal to 80% of the factory DC test voltage on each conductor, except when testing interlocked armor cable do not apply a test voltage greater than 75% of factory DC test voltage. Nominal test voltages for 15 KV cable are 65 KV DC for 133% insulation level.
2. 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 ten minutes.
3. During the DC high potential tests, take leakage current readings at 30 second intervals during the first two minutes of the test and at one minute intervals during the remainder of the test. If, after the first minute, the leakage current increases, stop the test. Do not make further tests without the approval of the ARCHITECT-ENGINEER. No test will be accepted where there is a continual increase in leakage current throughout the test.

E. Acceptance

1. The cable must withstand the specified high voltage without breakdown, have steady or decreasing leakage current during the high potential test and have satisfactory comparable megger readings in each megger test.

F. Records

1. Include the following information in test report on each cable:
 - a. Complete identification of cable, including approximate length.
 - b. Megger readings versus time data, including converted values.
 - c. High potential versus time data.
 - d. Leakage current versus time data.
 - e. Approximate average cable temperature.

1.10 TESTS ON POWER CABLE IN 4160 VOLT SERVICE

A. General

1. Give each power cable a continuity test and a megger test after all splices and permanent connections are made. Check phase identification for each cable.

B. Connections

1. Isolate cable by opening switches or breakers at each end of cable prior to testing, where such disconnecting means exists. Where cables are direct connected without disconnecting means, do not disconnect cables; test as connected.

C. Megger Tests

1. Use a 2500 volt megger for each megger test.
2. Apply megger tests between each conductor and ground with the other two conductors, its shields, and conduit or armor grounded to the same ground. Test each conductor in the same manner. Do not include building steel as a necessary part of the test ground circuit.
3. Minimum acceptable reading. For disconnected cables, 100 megohms; for connected cables, 5 megohms.
4. Record all megger readings. Testing of cables having megger readings markedly lower than average, even though meeting minimum requirements, shall be stopped and await further instructions from the ARCHITECT-ENGINEER.

D. Acceptance

1. Cable must pass all tests.

E. Records

1. Include the following in test report on each cable:
 - a. Complete cable identification and description of isolation means.
 - b. Megger readings, including converted values and ambient temperature at time of test.
 - c. Approximate average cable temperature.

1.11 TESTS ON WIRE AND CABLE IN 480 VOLT AND LOWER SERVICE

A. General

1. Give each 480 volt power feeder and subfeeder cable a continuity test and a megger test. Verify phase identification for each power feeder and subfeeder cable. Verify identification of all lighting circuits and 120 volt circuits on panel directories and make operational checks on all lighting circuits and 120 volt circuits to prove that the circuits perform all functions for which they are designed. Check all power feeder and subfeeder cable connections for workmanship and conformance with standard practice by visual inspection.

B. Connections

1. Isolate power cables 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 direct connected without a disconnecting means, do not disconnect cables; test as connected after verifying that the connected equipment can safely withstand the applied test voltage.

C. Megger Tests

1. Use a 1000 volt megger for each megger test.
2. 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.
3. Minimum acceptable reading. For disconnected cables, 100 megohms; for connected cables, 1 megohm if conductor size is No. 14 or No. 12 AWG; 250,000 ohms for conductors No. 10 and larger.
4. Record all megger readings. Testing of cables having megger readings lower than average, even though meeting minimum requirements, shall be stopped and await further instructions from the ARCHITECT-ENGINEER.

D. Acceptance

1. Cable must pass all inspections and tests.

E. Records

1. Include the following information in test report on each 480 volt power cable:
 - a. Complete cable identification and description of isolation means.
 - b. Megger readings, including converted values.
 - c. Approximate average cable temperature.

1.12 TESTS ON CONTROL WIRING

A. General

1. Give each single conductor and multi-conductor control wire or cable a continuity test and an insulation strength test. Verify identification of conductors.

B. Connections

1. Disconnect and fan out conductors to be tested.

C. Insulation Strength Tests

1. Subject each control wire to a 1000 volt, 60 hertz test.
2. 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 insuring 1000 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.
3. In lieu of the above insulation strength test, megger each control wire as specified for 480 volt power conductors.

D. Acceptance

1. Wires must pass all tests.

E. Records

1. Include the following information in test report on each wire group.
 - a. Wire and group identification.
 - b. Type of test, insulation strength or megger.
 - c. When megger testing is selected, include information as specified for 480 volt power cables.

1.13 TESTS ON UNIT SUBSTATION TRANSFORMERS

A. General

1. Check and test ground connections per TESTS ON GROUNDING Article hereinafter. Check continuity and correctness of all windings and check tap settings for compliance with reviewed shop drawings. Give each transformer winding a high potential test and a megger test both before and after the high potential test.

B. Connections

1. Isolate transformer by opening primary switch and transformer main secondary breaker. Tie conductors together on each winding. Remove fuses on potential transformers, and short and ground secondaries of all current transformers.

C. Megger Tests

1. Use a 2500 volt megger for megger tests on 15 KV class 7.2 KV class, and 5 KV class windings and a 1000 volt megger for megger tests on 480 volt windings.
2. 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.

3. Hold all 2500 volt megger tests for at least five 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.
4. Hold all 1000 volt megger tests until the reading reaches a constant value and until three consecutive equal readings one minute apart are obtained.
5. 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 evidence of injury to the transformer during the high potential test.

<u>Equipment</u>	<u>Minimum Megger Reading-Megohms</u>
35 KV class primary winding	2000
25 KV class primary winding	1000
15 KV class primary winding	800
7200 volt winding	200
4800 volt winding	100
4160 volt winding	100
2400 volt winding	100
480 volt winding	50

D. High Potential Tests

1. Apply the following 60 hertz test voltages, unless advised otherwise by the manufacturer, for specific voltage windings for one minute:

<u>Equipment</u>	<u>Test Voltage</u>
35 KV class primary winding	50 KV; verify with manufacturer
25 KV class primary winding	37 KV; verify with manufacturer
15 KV class primary winding	23 KV; verify with manufacturer
7200 volt winding	14KV
4800 volt winding	9KV
4160 volt winding	9KV
2400 volt winding	7.5 KV
480 volt winding	3.0 KV

2. Apply the test voltage uniformly and gradually with the initial application being no greater than the rated voltage of the winding.

E. Acceptance

1. The transformers must pass all inspections and tests, withstand the specified high potential test voltage without breakdown, and have satisfactory comparable megger readings in each megger test.

F. Records

1. Include the following information in test report on each transformer:
 - a. Complete transformer identification.
 - b. High potential versus time data.
 - c. Megger readings versus time data including converted values.
 - d. Approximate average transformer temperature.

1.14 TESTS ON MEDIUM VOLTAGE SWITCHGEAR

A. General

1. Check and test all ground connections per TESTS ON GROUNDING Article hereinafter. Give each breaker a megger test. Give each bus a high potential test and a megger test both before and after the high potential test. Perform operational tests on switchgear, relays, breakers and control devices. Perform ratio and polarity tests on all instrument transformers and give each potential transformer a megger test. Give each current transformer secondary a megger test. Perform tests on relays per TESTS ON RELAYS Article hereinafter.

B. Connections

1. Prior to performing any test on main bus, isolate bus to be tested by racking out all breakers, short and ground current transformer secondaries, remove potential transformer primary fuses and ground housing.
2. Perform high potential and megger tests on breakers in the withdrawn position.

C. Megger Tests

1. Apply megger tests on switchgear bus and breakers between each phase and ground with the other phases grounded to the same ground.
2. Apply megger tests on potential transformers between each winding and ground with windings not under test grounded to the same ground.
3. Apply megger tests on current transformer secondaries and associated wiring between all phases tied together and ground.
4. Hold all 2500 volt megger tests at least 5 minutes and until three consecutive equal readings one minute apart are obtained. Take readings every 30 seconds during the first two minutes and every minute thereafter.
5. Hold all 1000 volt megger tests until the reading reaches a constant value and until three consecutive equal readings one minute apart are obtained.
6. Minimum acceptable megger readings and megger voltages 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 equipment during the high potential test.

<u>Equipment</u>	<u>Megger Volts</u>	<u>Minimum Megger Reading in Megohms</u>
Main buses	2500	50
Breakers	2500	100
Potential transformer primary winding	2500	50
Current and potential transformer secondary winding	1000	5

D. High Potential Tests

1. Apply high potential tests on main bus between each phase and ground with the other phases grounded. Test each phase in the same manner.

2. Apply the following 60 hertz test voltages, unless advised otherwise by the manufacturer, for specific voltage equipment for one minute:

<u>Equipment</u>	<u>High Potential Test Voltage</u>
35 KV class bus	50 KV; verify with manufacturer
25 KV class bus	37 KV; verify with manufacturer
15 KV class bus	23 KV
7200 volt bus	14 KV
4800 volt bus	9 KV
4160 volt bus	9 KV
2400 volt bus	7.5 KV

E. Instrument Transformer Ratio Tests

1. Perform ratio tests on each potential transformer with proper voltmeters and approximately normal secondary burden connected.
2. Perform a two point ratio test on each current transformer applying one-half and rated primary current to the primary of the transformer and measuring both primary and secondary currents for each point. For high ratio transformers, primary current may be reduced to capabilities of test equipment available but no lower than 500 amperes.

F. Operational Tests On Each Breaker

1. Inspect each breaker mechanism for correct alignment, freedom from binding, and good contact.
2. 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.
3. Operate each breaker through three open-close-open cycles in both the operating and test position by both manual and automatic operation as follows:
 - a. Manually operate the breaker from both the local switchgear mounted control switch and remote control switches, if applicable. Observe indicating lights and position indicating target for correct operation.
 - b. Manually close each breaker by control switch and trip automatically. Observe indicating lights, alarms and targets for proper operation, including remote devices if applicable.
 - c. Where individual breakers are electrically interlocked for automatic closing or opening of another breaker, operate breakers to determine that operation is proper.

G. Acceptance

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

H. Records

1. Make complete and accurate records of each test. Include the following in each test report:
 - a. Megger readings versus time data, including converted values and ambient temperature at time of test.
 - b. Voltage and current readings on instrument transformer ratio tests.
 - c. High potential versus time data on bus.

1.15 TESTS ON 480 VOLT SWITCHGEAR

A. General

1. Check and test all ground connections per TESTS ON GROUNDING Article hereinafter. Give each breaker and bus a megger test. Perform operational tests on switchgear, relays, breakers and control devices. Perform ratio and polarity tests on all instrument transformers and give each potential transformer a megger test. Give each current transformer secondary a megger test. Perform tests on relays, overcurrent trip devices and ground fault relays per TESTS ON RELAYS Article hereinafter.

B. Connections

1. Prior to performing megger test on main bus, isolate bus to be tested by racking-out breakers, short and ground current transformer secondaries, remove potential transformer primary fuses, and ground housing.
2. Perform megger tests on breakers in the withdrawn position.

C. Megger Tests

1. Apply megger tests on switchgear bus and breakers between each phase and ground with the other phases grounded to the same ground.
2. Apply megger tests on potential transformers between each winding and ground with windings not under test grounded to the same ground.
3. Apply megger tests on current transformer secondaries and associated wiring between all phases tied together and ground.
4. Hold all megger tests until the reading reaches a constant value and until three consecutive equal readings one minute apart are obtained.
5. Minimum acceptable megger readings and megger voltages are as follows:

<u>Megger Equipment</u>	<u>Minimum Megger Volts</u>	<u>Reading-Megohms</u>
Main buses	1000	1,000
Breakers	1000	1,000
Potential transformer primary winding	1000	1,500
Current and potential transformer secondary winding	500	1,500

D. Instrument Transformer Ratio Tests

1. Perform ratio tests on each potential transformer with proper voltmeters and approximately normal secondary burden connected.
2. Perform a two point ratio test on each current transformer applying one-half and rated primary current to the primary of the transformer and measuring both primary and secondary currents for each point. For high ratio transformers, primary current may be reduced to capabilities of test equipment available but no lower than 500 amperes.

E. Operational Tests On Each Breaker

1. Inspect each breaker for correct alignment, freedom from binding, and good contact.
2. 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 operating position with the main contacts closed. Check position indicating target operation.

3. Operate each breaker through three open-close-open cycles in both the operating and test position by both manual and automatic operation if applicable, as follows:
 - a. Manually operate the breaker from both the local switchgear mounted control means and remote control switches, if applicable. Observe indicating lights and position indicating target for correct operation as applicable.
 - b. Manually close each breaker by the local switchgear mounted control means and trip automatically. Observe indicating lights, alarms, and targets for proper operation, including remote devices if applicable.
 - c. Where individual breakers are electrically interlocked for automatic closing or opening of another breaker, operate breakers to determine that operation is proper.

F. Acceptance

1. Equipment must pass all inspections and tests.

G. Records

1. Make complete and accurate records of each test. Include the following in each test report:
 - a. Megger readings versus time data, including converted values and ambient temperature at time of test.
 - b. Voltage and current readings on instrument transformer ratio tests.

1.16 TESTS ON DISTRIBUTION TRANSFORMERS

A. General

1. Check continuity and correctness of connections of windings and give each winding a megger test.

B. Connections

1. Isolate transformer by opening the line side switch or circuit breaker and disconnect secondary conductors at panels. Tie conductors together on each winding.

C. Megger Tests

1. Apply 1000 volts for megger tests on 480 volt windings and 500 volts megger tests on lesser voltage windings.
2. Apply a megger test between each transformer winding tied together and ground. Ground all windings not included in the test to the same ground.
3. Minimum acceptable readings. 480 volt winding to ground, 45 megohms; lesser voltage winding to ground, 30 megohms.
4. Hold all megger tests for at least one minute or until the reading maintains a constant value for 15 seconds.

D. Acceptance

1. Transformers must pass all inspections and tests.

E. Records

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

- b. Megger readings, including converted values and ambient temperature at time of test.

1.17 TESTS ON ROTATING EQUIPMENT

A. General

- 1. Inspect all motors installed under all other SECTIONS 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. Give each motor a megger test.

B. Connections

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

C. Megger 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>Megger Volts</u>	<u>Minimum Megger Reading-Megohms</u>
4000 volt, 3 phase induction motor	2500	100
2300 volt, 3 phase induction motor	2500	100
460 volt, 3 phase induction motor	1000	20
230 volt, 3 phase induction motor	500	20
200 volt, 3 phase induction motor	500	20
115 volt, 1 phase induction motor	500	5

D. Operating Tests

- 1. Run motor long enough to prove satisfactory performance including operating temperature, lubrication, vibration.

E. Acceptance

- 1. Motor must pass all inspections and tests.

F. Records

- 1. Make complete and accurate records of all tests and inspections. Include the following in each test report:
 - a. Megger readings, including converted values.
 - b. Ambient temperature at time of test.

1.18 TESTS ON 480 VOLT BUSWAYS

- A. General
 - 1. Inspect busway installation for conformance to design specifications and installation workmanship. Give each busway a megger test.
- B. Connections
 - 1. Isolate busway by opening supply switch or breaker, and opening load disconnecting means. Include cable back to the supply switch or breaker in test.
- C. Megger Tests
 - 1. Apply megger tests at 1000 volts.
 - 2. Apply megger tests from phase to ground with the other phases to the same ground. Test each phase in a similar manner.
 - 3. Minimum acceptable readings. 10 megohms.
- D. Acceptance
 - 1. Busway must pass all inspections and tests.
- E. Records
 - 1. Include complete busway identification and megger readings, with converted values and ambient temperature at time of test.

1.19 TESTS ON MOTOR CONTROL CENTERS

- A. General
 - 1. Give control center bus a megger test. Perform operating tests on control equipment as specified under TESTS ON CONTROL DEVICES Article hereinafter.
- B. Connections
 - 1. For megger tests, isolate bus by opening supply switch or breaker, and opening load disconnects. Include cable back to the open supply switch or breaker.
- C. Megger Tests
 - 1. Apply megger tests at 1000 volts.
 - 2. Apply a megger test between each phase and ground with all other phases grounded to the same ground. Test each phase in the same manner.
 - 3. Minimum acceptable readings. 100 megohms.
- D. Acceptance
 - 1. Control center must pass megger tests and operating tests.
- E. Records
 - 1. Make complete records of all tests; including control center identification and megger readings with converted values and ambient temperature at time of test.

1.20 START-UP AND TESTING PROCEDURE FOR CHILLED WATER AND INSTRUMENT AIR SYSTEM CONTROL PANELS

- A. Detailed factory and field test procedures shall be submitted for approval at least four weeks before the actual testing begins.
- B. All systems' final testing shall be coordinated with the Owner and shall take place in the presence of the Owner.
- C. Closely coordinate with the various equipment/system contractors and the Owner during the test scheduling phase and provide all necessary manpower to properly execute the acceptance testing of the control panels and installation.
- D. Assist in the systems' start-up and final testing by others that are under a separate contract with the owner.
- E. Check-Out, Start-Up, and Commissioning
 - 1. Factory testing
 - a. The control panels shall be factory tested prior to shipment. The factory test shall prove all wiring in the panel(s) is correct and matches the approved schematic drawings. The Contractor shall submit his recommended test procedures to the Owner for review and concurrence at least four weeks in advance of the scheduled test date. The Contractor shall notify the Owner at least two weeks before the beginning of the test. The Owner may witness and actively participate in the test.
 - b. The PLC Programming Consultant will provide a copy of the PLC and HMI program to the Contractor for use in conducting the control panel factory acceptance tests.
 - c. Minimum factory test requirements shall be:
 - 1) The Contractor shall, prior to beginning the test, "ring out" all panel wiring and panel interconnecting wiring in the presence of the Owner to substantiate that all wiring is correct. This shall consist of the following:
 - a) Verify panel construction meets specifications, and wiring agrees with approved drawings.
 - b) Each input point shall be simulated at the terminal strip of each PLC panel. Observe that the PLC acknowledges the change of state.
 - c) Each output signal shall be forced through the programming terminal. Test the PLC outputs signal at the I/O terminal strip for the appropriate digital voltage at each PLC panel.
 - d) Each analog input point shall be simulated at the terminal strip of each PLC panel. Observe that the analog signal change is received by the PLC.
 - e) Simulate data communications between the PLC and auxiliary devices. All data communications modules shall be adequately tested.
 - f) Simulate communication to and from intelligent modules within the input/output structure. Where required by the module application, calculations by the module shall be proven.
 - g) All control fuses shall be checked for correct size and fuse type in accordance with the specifications.

- 2) All operator interface equipment shall be included as part of the factory test to verify proper operation of the interface equipment.
 - d. The Contractor shall supply all personnel, equipment, and facilities at the factory site to properly conduct the test. The testing period shall continue until the Contractor and the Owner have mutually agreed that the test is acceptable.
2. Field Testing
- a. The Plant Control system commissioning effort shall be completed by the Contractor in the presence of the Owner. The Contractor shall, as a minimum, complete the following procedures as part of the commissioning effort:
 - 1) In verifying loop completeness, the Contractor shall perform the following physical checks:
 - a) Each loop shall be continually tested completely from start to finish including all remote devices.
 - b) Each wire in a loop shall be verified at each end for correct termination and wire number labeling.
 - c) All contacts within a loop shall be verified for correct contact sense, NO or NC.
 - d) Each junction of an analog loop shall be checked for correct polarity and grounding continuity.
 - e) All control loops shall be checked for grounding potential.
 - f) The Contractor shall verify all wiring within loops for correct size, type, and color.
 - 2) Upon verification of wiring, the Contractor shall perform the following “hot tests:”
 - a) All analog devices shall be set and calibrated to the appropriate zero, mid-point and span.
 - b) All devices shall be checked that correct device, model number, range, ect., was installed.
 - c) All local pushbutton stations shall be exercised to assure functioning of local devices.
 - d) Upon an incorrect or absent signal, either discrete or analog signal to the PLC and HMI (LMI) systems, the Contractor shall measure the signal starting at the primary element and continuing through each junction to identify where loss of signal occurs.
3. Commissioning
- a. The Plant Control system commissioning effort shall be completed by the PLC Programming Consultant in the presence of the Owner. The Contractor shall be present in support of the Consultant during the commissioning process.
 - b. Before proceeding with any system start-up and testing, the PLC Programming Consultant shall submit a start-up procedure for approval by the Owner and confirm that preliminary testing has taken place and equipment/system is ready for automatic operation. Detailed field test procedures shall be submitted for approval at least 60 days before the actual testing begins.
 - c. All systems’ start-up and final testing shall be coordinated with the Owner and shall take place in the presence of the Owner.
 - d. Conduct the systems’ start-up and final testing per approved start-up procedures. Make available, to all parties required to be present for the start-up, copies of the approved start-up procedure.

- e. Closely coordinate with the various equipment/system contractors and the Owner during the scheduling phase and provide all necessary manpower to properly execute the systems' start up and acceptance testing of the systems.
- f. The Consultant shall, as a minimum, complete the following procedures as part of the commissioning effort:
 - 1) Verify that all of the control sequences as defined in the software will respond with the proper output when changing process conditions are simulated.
 - 2) Completely check all control loops in the presence of the Owner. Loops shall be defined as, but not limited to:
 - a) Motor control logic.
 - b) Local control logic.
 - c) Analog control logic.
 - d) Discrete input to the PLC.
 - e) Analog input to the PLC.
 - f) Discrete output from the PLC.
 - g) Analog output from the PLC.
 - 3) Upon verification of wiring, the Consultant shall perform the following "hot tests":
 - a) All analog devices shall be measured at point of final termination at the following ranges: 0, 25, 50, 75, 100 percent, with actual measured value recorded.
 - b) All discrete sensor switch points to be verified according to selected settings, including deadband resets.
 - c) All loops shall be measured for correct current and appropriate voltage level on DC power supply.
 - d) All local control logic shall be energized and checked by forcing process conditions to set points to assure proper shutdown by any safety devices.
 - e) All discrete indication to the PLC and HMI (LMI) systems shall be checked to appropriate I/O points and all indication of such points on all operator interface operation displays.
 - f) All analog systems shall be forced by process conditions through the range as specified to check response from the element through the PLC and HMI systems.
 - g) PLC and HMI interface outputs to field elements shall be tested in the following manner:
 - All discrete outputs shall be forced manually through the operator interface. Each field device shall be measured for correct voltage and fully motion checked. Valves shall be fully stroked, and motors run to prove operation.
 - All discrete outputs shall be stopped by local stop button. Local stops shall be then reset to assure PLC logic properly reset.
 - All analog outputs shall be forced through thru operator interface at each level: 0, 25, 50, 75 and 100 percent. At each level, the signal shall be measured at each device in the loop and this measured value recorded through the final field element.

- The final element in an analog loop shall be tested to assure proper reaction to analog signals. The Consultant shall adjust these elements as necessary to achieve proper performance.

F. Acceptance

1. Control panels and circuitry must pass all tests to prove that all design functions are satisfactorily performed, including manual and automatic operation and interlocking.

G. Records

1. Make complete records of all tests.

1.21 TESTS ON CONTROL DEVICES

A. General

1. Perform operating tests on all control, alarm or indicating devices installed under DIVISION 16000 Series SECTIONS.

B. Connections

1. Include motors and protective control devices in test circuitry where operation of motors will not damage attached equipment.
2. Where equipment could be damaged by energizing motors, disconnect motor leads at the load side of starters.
3. Jumper or disconnect, as applicable, control devices installed under all other Sections as necessary to permit testing those devices and circuitry installed under 16000 Series SECTIONS.
4. Coordinate these connections and tests with the trade responsible for the installation of motors.

C. Acceptance

1. Control devices and circuitry must pass all tests to prove that all design functions are satisfactorily performed, including manual and automatic operation and interlocking.

D. Records

1. Make complete records of all tests.

1.22 TESTS ON GROUNDING

A. General

1. Inspect ground conductors and connections for conformance with design specifications and for satisfactory workmanship. Test resistance to earth of each ground rod and each ground grid.

B. Connections

1. Maintain each ground rod isolated from the associated ground grid for tests on individual rods for resistance to earth.
2. Include associated ground rods and interconnecting wiring in tests on each grid system for resistance to earth.

C. Tests On Individual Ground Rods

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 No. 118, paragraph 5.5.2. 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. 25 ohms.
2. If the resistance is found to be higher than 25 ohms, drive additional rods with a minimum separation of 10 feet and connect in parallel with the rod under test until 25 ohms or less is obtained, or increase the length of the rod under test until 25 ohms maximum is obtained.

D. Tests On Each Ground Grid

1. Test each isolated ground grid as specified for maximum acceptable resistance to earth of five ohms. In tests on total ground systems, the maximum acceptable resistance to earth is two ohms.

E. Acceptance

1. Grounding materials and connections must pass all inspections and must meet all specified maximum and minimum values.

F. Records

1. Make complete records of all tests. Include resistance values obtained, calculations of same, and methods of test and calculation.

1.23 TESTS ON SPECIAL SERVICE SYSTEMS

- A. Perform operating tests on all special service systems to prove that all design functions are satisfactorily performed.

1.24 TESTS ON RELAYS

A. General

1. Consult with the Owner on securing the services of a reputable firm acceptable to the OWNER to determine the settings on all protective relays, overcurrent trip devices and ground fault relays on switchgear installed under 16000 Series SECTIONS, including OWNER-furnished switchgear, to set all relays and devices to perform properly in the electrical system indicated, to coordinate the work with the utility serving the site, and to perform automatic operation tests as specified in Article "TESTS ON HIGH VOLTAGE SWITCHGEAR" hereinbefore and Article "TESTS ON 480 VOLT SWITCHGEAR" hereinbefore as applicable.
2. Do not remove any protective relay from its case without the prior approval of the ARCHITECT-ENGINEER.
3. Perform all automatic operation tests on switchgear breakers with all breakers and other equipment in the switchgear in normal operating position and with only temporary control power applied to the control bus where a control bus is provided. Do not energize main buses with rated potentials, unless otherwise specified. Set relays and devices per recommended relaying requirements.

- B. Protective Overcurrent Relays
 - 1. Apply test currents to current transformer secondary terminals with all secondary wiring connected and test switches normal.
 - 2. Test time overcurrent element for minimum pickup current and approximate time lapse from test current application to breaker trip. Verify pickup and time values with relaying requirements.
 - 3. Test instantaneous element for minimum pickup value. Verify pickup value with relaying requirements.
 - 4. Test time overcurrent element at five times minimum pickup current.
- C. Protective Undervoltage Relays
 - 1. Apply test voltage to potential transformer secondary terminals with all secondary wiring connected and test switches normal.
 - 2. Test time undervoltage element for minimum dropout voltage and approximate time lapse from voltage depression to breaker trip. Verify dropout and time values with relaying requirements.
- D. Overcurrent Trip Devices
 - 1. Apply test currents to low voltage breaker bus connections at rear of switchgear.
 - 2. Test long and short time elements for minimum pickup current and approximate time lapse from test current application to breaker trip. Verify pickup and time values with relaying requirements.
 - 3. Test instantaneous element for minimum pickup value. Verify pickup value with relaying requirements.
 - 4. Test long time element at 2 and 3 times minimum pickup current.
- E. Ground Fault Protection Devices
 - 1. Perform tests on zero sequence type ground relays energized from toroid current transformers with test currents equal to normal current on the phase conductor at the low voltage breaker.
 - 2. Insert an additional wire (test conductor) through the toroid and apply unbalancing test current to the test conductor, increasing the current until the minimum unbalance current to trip the breaker is obtained. Verify pickup and time values with relaying requirements.
- F. Acceptance
 - 1. Relays and devices must pass all tests for conformance with relaying requirements.
- G. Records
 - 1. Make complete and accurate records of each test. Include the following in each test report:
 - a. Complete identification of each breaker, relay and device associated.
 - b. Final set points on all equipment, to agree with relaying requirements.

1.25 TESTS ON TRANSFORMER INSULATING LIQUIDS

- A. General
 - 1. Clean all liquid-filled transformers including OWNER-furnished transformers, with particular care for valves, plugs, gauges, thermometers, relief diaphragms, breathers, tap

changers, bushings, fans, air vents, etc., and check for leaks and broken parts. Check liquid levels in all tanks. Perform dielectric strength tests on liquid prior to energization of transformer and again after the transformer has been continuously energized for a period of four days.

B. Liquid Level Checks

1. Verify that liquid levels are within required tolerance limits. Add liquid to transformers furnished under this CONTRACT. Inform the ARCHITECT-ENGINEER of any low levels in OWNER-furnished equipment and await direction. Do not add liquid to OWNER-furnished equipment without the approval of the ARCHITECT-ENGINEER. Furnishing of additional liquid for OWNER-furnished equipment is not part of this CONTRACT.
2. Where liquid must be added to transformers furnished or installed under this CONTRACT, check the underside of the manhole cover for condensation. Remove all condensation prior to adding liquid. Add only liquid identical to existing liquid as approved by the ARCHITECT-ENGINEER.
3. Final check liquid levels when liquid temperature reaches 25 degC.

C. Test Equipment

1. Sample Containers. 16 ounce capacity clear glass type having glass stoppers. Do not use stoppers of rubber or compositions of rubber. Prior to first use of containers in testing, rinse containers and stoppers in dry, lead-free gasoline and dry thoroughly. When thoroughly dry, wash containers and stoppers in strong soap suds, rinse thoroughly with water, and dry in an oven at 105 degC before using. Store cleaned and dried stoppered containers in a warm, dry, protected place between tests. Do not use containers for sampling more than one type of liquid without thoroughly cleaning and drying as specified.
2. Test Set. 1/2 KVA, 35,000 volt rated portable test set, having one inch diameter electrodes in the test cup with a gap of 0.1 inch between adjacent electrode faces. Prior to first use of the test cup in testing, rinse the test cup with dry, lead-free gasoline and dry in an oven at moderate temperature. Store rinsed and dried test cup in warm, dry, protected place between tests. Do not use test cup for sampling more than one type of liquid without rinsing and drying as specified.

D. Taking Samples

1. Immediately before drawing a sample, carefully clean each sampling valve, then open each valve, allowing sufficient liquid to drain out into a waste container to insure the removal of any moisture which may have collected in the valve. Dispose of waste liquid properly. Take samples from outdoor equipment on a clear day.
2. Before filling any container, rinse the container three times with liquid obtained from the same sample source.
3. Take sufficient sample liquid to perform a minimum of 5 tests. Hold filled stoppered containers in a room having an ambient temperature between 20 degC and 30 degC until sample liquid temperature has stabilized at ambient temperature. Fill each sample container with approximately equal quantities of liquid from sample valves at the top and bottom of a tank.

E. Visual Inspection

1. Visually inspect each liquid sample to determine that the liquid is essentially clean, free from carbon, clear, contains no obvious water, and is not highly discolored.
2. Inform the ARCHITECT-ENGINEER when visual inspection indicates liquid is not essentially clean.

F. First Dielectric Strength Tests

1. Perform tests in the same room or ambient temperature in which samples have been held.
2. Immediately before performing each test, rinse the test cup with the liquid to be tested.
3. Mix the sample in the container with a swirling motion to avoid introducing air, and fill the test cup with the sample liquid to a height of not less than 0.79 inches (20 MM) above the top of the electrodes. Gently rock the cup and then allow the liquid to stand in the cup without agitation for three minutes before test voltage is applied, to allow air bubbles to escape.
4. Apply the test voltage gradually at a rate of 3000 volts (RMS) per second until breakdown occurs, as indicated by a continuous discharge across the gap. Open the test circuit immediately after breakdown. After testing, jar the test vessel to loosen particles of carbon adhering to the electrodes, but not with sufficient force to introduce air bubbles. Empty the test cup after each test.
5. Make one breakdown test on each of five fillings of the test cup and average the five breakdown voltages. If the average deviation from the mean exceeds 10% or if any individual test deviates more than 25% from the average, make additional tests. Determine the dielectric strength by averaging the first five tests that conform to the allowable variations.
6. Minimum Acceptable Average Breakdown Voltage. 30 KV. If the average breakdown voltage is less than 30 KV, inform the ARCHITECT-ENGINEER that filtering is required. Filter and retest liquid in transformer tanks furnished under this CONTRACT. Do not filter and retest liquid in OWNER-furnished transformer tanks without the approval of the ARCHITECT-ENGINEER. Filtering and retesting of liquid furnished by the OWNER is not part of this CONTRACT.

G. Second Dielectric Strength Tests

1. Four days after each piece of equipment is energized, make a second series of dielectric strength tests on each piece of equipment, observing all necessary precautions and procedures as specified.

H. Acceptance

1. Each piece of equipment must pass all inspections and tests.

I. Records

1. Make complete and accurate records of each test. Include the following in each test report:
 - a. Complete identification of each liquid insulated equipment.
 - b. Breakdown voltage on each test sample whether used in determination of average breakdown voltage or not.
 - c. Calculations of average and mean values for each series of tests.

2. Approximate liquid temperature at time of each test.

END OF SECTION

Revision History	
Date	Rev. No.
A	0
B	0
D	0
E	0
F	0
02-19-09	0

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