POWER DISTRIBUTION ACCEPTANCE TESTS
SECTION 26 08 12

PART 1 - GENERAL

1.1 DESCRIPTION

A. Section includes acceptance testing requirements for assessing the suitability for service and reliability of the power distribution system.

B. Contractor to ensure all tested electrical equipment, both contractor and Owner supplied, is operational and within industry and manufacturer's tolerances and is installed in accordance with design specifications.

C. Tests and inspections shall be performed after installation.

D. Tests and inspections shall determine suitability for energization.

E. Electrical systems shall pass tests prior to substantial completion or Owner occupancy.

F. This specification requires contractor to engage services of testing agency.

H. Items to be tested and inspected as follows:

1. 600-volt conductors and cables
2. Electrical metering
3. Dry type transformers (small)
4. Dry type transformers (large)
5. Low-voltage switchgear
6. Switchboard
7. Low-voltage power circuit breakers
8. Low-voltage insulated-case/molded-case circuit breakers
9. Low-voltage disconnect switches
10. Medium-voltage surge arresters
11. Grounding systems
12. Protective relays (as applicable)
13. Instrument transformers
14. Thermographic survey

1.2 REFERENCE STANDARDS

A. ANSI/IEEE C2 – National Electrical Safety Code

B. ANSI/IEEE C37 – Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses

C. ANSI/IEEE C37.04 – Standard Rating Structure for AC High Voltage Circuit Breaker

D. ANSI/IEEE C57 – Distribution, Power, and Regulating Transformers

E. ANSI/IEEE C57.13.1 – Guide for Field Testing of Relaying Current Transformers

F. ANSI/IEEE C57.13.3 – Grounding of Instrument Transformer Secondary Circuits and Gases

G. ANSI/IEEE C57.104 – Guide for the Interpretation of Gases Generated in Oil-immersed

Transformers

H. ANSI/IEEE C62 – Surge Protection

I. ANSI/IEEE Std. 43 – IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery

J. ANSI/IEEE Std. 48 – Standard Test Procedure and Requirements for High-Voltage Alternating-Current Cable Terminations

K. ANSI/IEEE Std. 81 – Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

L. ANSI/IEEE Std. 141 – IEEE Recommended Practice for Electrical/Power Distribution for Industrial Plants (IEEE Red Book)

M. ANSI/IEEE Std. 142 – IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)

N. ANSI/IEEE Std. 241 – IEEE Recommended Practice for Electrical Power Systems in Commercial Buildings (IEEE Gray Book)

O. ANSI/IEEE Std. 242 – IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book)

P. ANSI/IEEE Std. 399 – IEEE Recommended Practice for Power Systems Analysis (IEEE Brown Book)

Q. ANSI/IEEE Std. 400 – Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field

R. ANSI/IEEE Std. 446 – IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book)

S. ANSI/IEEE Std. 493 – IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book)

T. ANSI/IEEE Std. 1100 – IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book)

U. ASTM D877 – Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes

V. ASTM D823 – Standard Practices for Sampling Electrical Insulating Liquids

W. ASTM D924 – Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids

X. ASTM D971 – Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Methods

Y. ASTM D974 – Standard Test Method for Acid and Base Number by Color-Indicator Titration

Z. ASTM D1298 – Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

AA. ASTM 1500 – Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)

BB. ASTM D1524 – Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field

CC. ASTM D1816 – Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes

DD. ASTM D2285 – Standard Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin Against Water by the Drop-Weight Method

EE. ASTM D3612 – Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography

FF. ASTM D3613 – Standard Practice for Sampling Insulating Liquids for Gas Analysis and Determination of Water Content

GG. NETA – Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems

HH. NEMA AB 4 – Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications

II. NEMA MG1 – Motors and generators

JJ. NFPA 70 – National Electrical Code

KK. NFPA 70B – Recommended Practice for Electrical Equipment Maintenance

LL. NFPA 70E – Electrical Safety Requirements for Employee Workplaces MM.

NFPA 101 – Life Safety Code

NN. NFPA 110 – Emergency and Standby Power Systems

OO. NIST – National Institute of Standards and Technology

PP. OSHA – Part 1910 – Subpart S – 1910.308 – Special Systems

1.3 SUBMITTALS

A. Test Reports: Include the following:
   1. Summary of project
   2. Description of equipment tested
   3. Equipment used to conduct the test
   4. Description of test
   5. Test results, as compared to manufacturers' or industry accepted standards and tolerances
   6. Conclusions and recommendations
   7. Signature of responsible test organization authority

B. List of equipment used to perform tests. Identify the following:
   1. Type
   2. Manufacturer
   3. Model number
   4. Serial number
   5. Date of last calibration
   6. Documentation of calibration leading to NIST standards

1.4 QUALITY ASSURANCE

A. Qualifications of Testing Agency:
   1. Testing firm shall be a corporately and financially independent testing organization that can function as an unbiased testing authority, professionally independent of the

manufacturer, supplier, and installers of equipment or system evaluated by the testing firm.

2. Testing firm shall be regularly engaged in testing of electrical equipment, devices, installations and systems.
3. Testing firm shall meet Federal Occupational Safety and Health Administration (OSHA) requirements for accreditation of independent testing laboratories.
4. On-site technical person shall be currently certified by the International Electrical Testing Association in electrical power distribution system testing.
5. Testing firm shall use technicians who are regularly employed by the firm for testing services.
6. Testing firm shall submit proof of above qualifications with bid documents when requested.

PART 2 - PRODUCTS

2.1 NOT APPLICABLE TO THIS SECTION.

PART 3 - EXECUTION

3.1 PREPARATION

A. Documentation: Deliver the following to testing firm, minimum two weeks prior to commencement of testing:
   1. Complete set of electrical plans and specifications, with available short circuit indicated on power riser diagrams.
   2. Approved submittals and shop drawings of equipment being tested.
   3. Pertinent change orders.
   4. Evaluation, overcurrent protective device coordination and arc flash studies, per requirements in Sectiona260573-75.

B. Schedule: Notify Owner and Engineer 10 working days prior to performance of any tests.

C. Coordination: Coordinate with Construction Manager/Owner/Engineer the testing schedule and availability of equipment ready for testing.

D. Test Power: Provide test power (including specialized) for equipment testing before and after service energizing.

3.2 FIELD QUALITY CONTROL

A. Inspection and Test Procedures: Comply with NETA.
   1. 600 V Conductors and Cables:
      a. Visual and Mechanical Inspection:
         1) Compare cable data with drawing and specifications.
         2) Inspect exposed sections of cables for physical damage.
         3) Verify tightness of accessible bolted electrical connections by calibrated torque wrench in accordance with manufacturer’s published data or Table 12.
         4) Perform thermographic survey of bolted electrical connections in

accordance with paragraph "Thermographic Survey."

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

6) Verify visible cable bends meet or exceed ICEA and manufacturer's minimum allowable bending radius.

7) For cables are terminated through window-type current transformers, provide an inspection to verify neutral and ground conductors are correctly placed for operation of protective devices.

8) Inspect for correct identification and arrangements.

9) Inspect jacket and insulation condition.

b. Electrical Tests:

1) Perform insulation-resistance test using megohm meter. Applied potential to be 1000 VDC. Individually test each conductor with other conductors grounded. Test duration shall be one minute.

2) Perform continuity tests to ensure correct cable connection.

c. Test Values:

1) Insulation-resistance values should not be less than 50 megohms.

2. Electrical Metering:

a. Visual and Mechanical Inspection:

1) Compare equipment nameplate data with drawings and specifications.

2) Inspect physical and mechanical condition.

3) Verify tightness of electrical connections.

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

5) Verify freedom of movement, correct travel and alignment, and tightness of mounting hardware.

b. Electrical Tests:
   1) Check calibration of meters at cardinal points.
   2) Calibrate watt-hour meters according to manufacturer's published data.
   3) Verify instrument multipliers.
   4) Electrically confirm current transformer and voltage transformer secondary circuits are intact.

3. Dry Type Transformers (Small):
   a. Visual and Mechanical Inspection:
      1) Compare equipment nameplate data with drawings and specifications.
      2) Inspect physical and mechanical condition.
      3) Inspect anchorage, alignment, and grounding.
      4) Verify that resilient mounts are free and that any shipping brackets have been removed.
      5) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 12.
      6) Perform thermographic survey of bolted electrical connections, in accordance with paragraph "Thermographic Survey."
      7) Verify that as-lift tap connections are as specified.
   b. Electrical Tests:
      1) Perform insulation-resistance tests winding-to-winding and each winding-to- ground with test voltage in accordance with Table 5. Calculate dielectric absorption ratio or polarization index.
   c. Test Values:
      1) Bolt-torque levels should be in accordance with Table 12, unless otherwise specified by manufacturer.
      2) Insulation-resistance test values at one minute should be in accordance with Table 5.
      3) The dielectric absorption or polarization index shall be greater than 1.0 and shall be recorded for future reference.

4. Dry Type Transformers (Large):
   a. Visual and Mechanical Inspection:
      1) Compare equipment nameplate data with drawings and specifications.
      2) Inspect physical and mechanical condition.
      3) Verify control and alarm settings on temperature indicators are as specified.
      4) Verify cooling fans operate correctly and fan motors have correct overcurrent protection.
      5) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 12.
      6) Perform thermographic survey of bolted electrical connections in accordance with paragraph "Thermographic Survey."
      7) Perform specific inspections and mechanical tests as recommended by

manufacturer.

8) Make a close examination of shipping brackets or fixtures that may not have been removed during installation. Ensure resilient mounts are free.

9) Verify seismic bracing is correct.

10) Verify winding core, frame, and enclosure grounding are correct.

11) Verify as-lift tap connections are as specified.

b. Electrical Tests:

1) Perform insulation-resistance tests winding-to-winding and each winding-to- ground with test voltage in accordance with Table 5.

2) Calculate polarization index.

3) Perform power-factor or dissipation-factor tests in accordance with test equipment manufacturer's instructions.

4) Perform turns-ratio test on tap connections. Verify winding polarities are in accordance with nameplate.

5) Perform an excitation-current test on each phase.

6) Measure resistance of each winding at each tap connection.
7) Verify core is solidly grounded. If core is insulated and removable core ground strap is available, perform core insulation-resistance test at 500 VDC.
8) Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.

c. Test Values:
1) Bolt-torque levels shall be in accordance with Table 12, unless otherwise specified by manufacturer.
2) Insulation-resistance test values at one minute should not be less than values recommended in Table 5. Results shall be temperature corrected in accordance with Table 14.
3) Polarization index should be compared to manufacturer's factory test results. If manufacturer's data is not available, acceptance test results will serve as baseline data.
4) Turns-ratio test results should not deviate more than 0.5% from either adjacent coils or calculated ratio.
5) C_H and C_L dissipation-factor/power-factor values will vary due to support insulators and bus work used on dry transformers. The following should be expected on C_{HL} power factors:
a) Power Transformers: 2% or less
b) Distribution Transformers: 5% or less
6) Consult transformer manufacturer's or test equipment manufacturer's data for additional information.
7) If winding-resistance test results vary more than 1% from adjacent windings, consult manufacturer.
8) Typical excitation current test data pattern for three-legged core transformer is two similar current readings and one lower current reading.
9) If core insulation resistance is less than one megohm at 500 VDC, consult manufacturer.

5. Low-Voltage Switchgear and Switchboard Assemblies:
a. Visual and Mechanical Inspection:
1) Compare equipment nameplate data with drawings and specifications.
2) Inspect physical and mechanical condition.
3) Confirm correct application of manufacturer's recommended lubricants.
4) Verify appropriate anchorage, required area clearances, grounding and correct alignment.
5) Inspect doors, panels, and sections for paint, dents, scratches, fit, and missing hardware.
6) Verify fuse and/or circuit breaker sizes and types correspond to drawings and coordination study as well as to circuit breaker's address for microprocessor-communication packages.
7) Verify that current and potential transformer ratios correspond to drawings.
8) Verify tightness of accessible bolted electrical connections by calibrated

torque-wrench. Refer to manufacturer's published data or Table 12 for proper torque values.

9) Perform thermographic survey of bolted electrical connections in accordance with paragraph "Thermographic Survey."

10) Confirm correct operation and sequencing of electrical and mechanical interlock systems.

a) Attempt closure on locked-open devices. Attempt to open locked-closed devices.

b) Make key exchange with devices operated in off-normal positions.

11) Inspect insulators for evidence of physical damage or contaminated surfaces.

12) Verify correct barrier and shutter installation and operation.

13) Exercise active components.

14) Inspect mechanical indicating devices for correct operation.

15) Verify filters are in place and/or vents are clear.

16) Perform visual and mechanical inspection of instrument transformers, in accordance with paragraph "Instrument Transformers."

17) Inspect control power transformers.

a) Inspect physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.

b) Verify that primary and secondary fuse ratings or circuit breakers match drawings.

c) Verify correct functioning of draw-out disconnecting and grounding contacts and interlocks.

b. Electrical Tests:

1) Perform tests on all instrument transformers in accordance with paragraph "Instrument Transformers."

2) Perform resistance tests through bus joints with low-resistance ohmmeter. Joints that cannot be directly measured due to permanently installed insulation wrap shall be indirectly measured from closest accessible connection.

3) Perform insulation-resistance tests in each bus section, phase-to-phase and phase-to-ground for one minute in accordance with Table 1.

4) Perform over-potential test on each bus section, each phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. In the absence of any published data, Table 2 shall apply. Test voltage shall be applied for one minute.

5) Perform insulation-resistance tests at 1000 VDC on control wiring. Test duration shall be one minute. Do not perform this test on wiring connected to solid-state components. Follow manufacturer's recommendation.

6) Perform current injection tests on the entire current circuit in each section of switchgear.

a) Perform current tests by primary injection, where possible, with magnitudes such that minimum of 1.0 amp flows in secondary circuit.

b) Where primary injection is impractical, utilize secondary injection with minimum current of 1.0 amp.

c) Test current at each device.

7) Determine accuracy of meters and calibrate watt-hour meters in accordance with paragraph "Electrical Metering." Verify multipliers.

8) Perform phasing check on double-ended switchboard/switchgear to ensure correct bus phasing from each source.

9) Perform the following tests on control power transformers:

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

b) Perform secondary wiring integrity test. Disconnect transformer at secondary terminals and connect secondary wiring to correct secondary voltage. Confirm potential at all devices.

c) Verify correct secondary voltage by energizing primary winding with system voltage. Measure secondary voltage with secondary wiring disconnected.

d) Verify correct function of control transfer relays located in switchboard/switchgear with multiple control power sources.

10) Potential Transformer Circuits:

a) Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with Table 1, unless otherwise specified by manufacturer.

b) Perform secondary wiring integrity test. Disconnect transformer at secondary terminals and connect secondary wiring to correct secondary voltage.

c) Verify secondary voltage by energizing primary winding with system voltage. Measure secondary voltage with secondary wiring disconnected.

11) Verify operation of switchgear/switchboard space heaters.

c. Test Values:

1) Bolt-torque levels shall be in accordance with Table 12, unless otherwise specified by manufacturer.

2) Compare bus connection resistances to values of similar connections.

3) Insulation-resistance values for bus, control wiring, and control power transformers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 1. Values of insulation resistance less than this table or manufacturer's minimum should be investigated. Over-potential tests should not proceed until insulation-resistance levels are raised above minimum values.

4) Bus insulation shall withstand the over-potential test voltage applied.

5) Contact resistance values shall not exceed high limit of normal range as

indicated in manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from similar bus by more than 50% of lowest value.

6. Low-Voltage Power Circuit Breakers:
   a. Visual and Mechanical Inspection:
      1) Compare nameplate data with drawings and specifications.
      2) Inspect physical and mechanical conditions.
      3) Confirm correct application of manufacturer's recommended lubricants.
      4) Inspect anchorage, alignment, and grounding.
      5) Inspect arc chutes.
      6) Inspect moving and stationary contacts for condition, wear, and alignment.
      7) Verify maintenance devices are available for serving and operating breaker.
      8) Verify primary and secondary contact wipe and other dimensions vital to satisfactory operation of breaker are correct.
      9) Perform mechanical operator and contact alignment tests on breaker and its operating mechanism.
      10) Verify tightness of accessible bolted bus connections by calibrated torque-wrench method. Refer to manufacturer's instructions or Table 12 for correct torque levels.
      11) Perform thermographic survey of accessible bolted bus connections in accordance with paragraph "Thermographic Survey."
      12) Check cell fit and element alignment.
      13) Check racking mechanism.
      14) Record as-found and as-left operation-counter readings.
   b. Electrical Tests:
      1) Perform contact-resistance test.
      2) Perform insulation-resistance test at 1000 VDC from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase. Test duration shall be one minute. Use a minimum test voltage in accordance with Table 1 or manufacturer's published data.
      3) Perform insulation-resistance test at 1000 VDC on control wiring. Test duration shall be one minute. Do not perform test on wiring connected to solid-state components. Follow manufacturer's recommendation.
      4) Make adjustments for final trip settings in accordance with overcurrent protective device coordination study.
      5) Determine minimum pickup current by primary current injection.
      6) Determine long-time delay by primary current injection.
      7) Determine short-time pickup and delay by primary currentinjection.
      8) Determine ground-fault pickup and delay by primary currentinjection.
      9) Determine instantaneous pickup value by primary currentinjection.
      10) Verify trip unit calibrations by secondary injection.
      11) Activate auxiliary protective devices, such as ground-fault or undervoltage relays, to ensure operation of shunt trip devices. Check operation of

electrically operated breakers in their cubicles. Perform minimum operation voltage on shunt trip and close coils in accordance with Table 20.

12) Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrically close and trip operations, trip-free, anti-pump function, and trip unit battery condition. Reset all trip logs and indicators.

13) Check charging mechanism.

14) Determine minimum operation voltage on shunt trip and close coils in accordance with Table 20.

c. Test Values:

1) Bolt-torque levels shall be in accordance with Table 12, unless otherwise specified by manufacturer.

2) Compare microhm or millivolt drop values to adjacent poles or similar breakers. Investigate deviations of more than 50% of the lowest value. Investigate any value exceeding manufacturer's recommendations.

3) Circuit breaker insulation resistance shall be in accordance with Table 1.

4) Control wiring insulation-resistance shall comply with manufacturer's published data. In the absence of manufacturer's published data, use Table 1. Values of insulation-resistance less than this table or manufacturer's minimum shall be investigated.

5) Trip characteristics of breakers shall fall within manufacturer's published time- current tolerance bands.

6) Minimum operation voltages on shunt trip and close coils shall be in accordance with manufacturer's published data. In the absence of manufacturer's data, refer to Table 20.

7. Low-Voltage Insulated-Case/Molded-Case Circuit Breakers, 225A and Larger:

a. Visual and Mechanical Inspection:

1) Compare nameplate date with drawings and specifications.

2) Inspect circuit breaker for correct mounting.

3) Check cell fit, element alignment and racking mechanism for draw-out breakers.

4) Operate circuit breaker to ensure smooth operation.

5) Inspect case for cracks or other defects.

6) Verify tightness of accessible bolted electrical connections and/or cable connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 12.

7) Inspect mechanism contacts and arc chutes in unsealed units.

b. Electrical Tests:

1) Perform a contact-resistance test.

2) Perform insulation-resistance test at 1000 VDC from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase. Test duration shall be one minute. Use a minimum test voltage in accordance with Table 1 or manufacturer's published data.

3) Perform insulation-resistance test at 1000 VDC on all control wiring. Test duration shall be one minute. Do not perform the test on wiring connected to solid-state components. Follow manufacturer's recommendation.

4) Perform adjustments for final trip settings in accordance with overcurrent protective device coordination study.

5) Perform long-time delay time-current characteristic tests by passing 300% rated current through each pole separately, unless series testing is required to defeat ground fault functions.

6) Determine short-time pickup and delay by primary current injection.

7) Determine ground-fault pickup and time delay by primary current injection.

8) Determine instantaneous pickup current by primary injection using run-up or pulse method.

9) Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and anti-pump function.

10) Verify trip unit calibrations by secondary injection.

11) Determine minimum operation voltage on shunt trip and close coils in accordance with Table 20.

12) Check charging mechanism.

c. Test Values:

1) Bolt-torque levels shall be in accordance with Table 12, unless otherwise specified by manufacturer.

2) Compare microhm or millivolt drop values to adjacent poles or similar breakers. Investigate deviations of more than 50% of lowest value. Investigate any value exceeding manufacturer's recommendations.

3) Circuit breaker insulation-resistance shall be in accordance with Table 1.

4) Control wiring insulation-resistance shall comply with manufacturer's published data. In the absence of manufacturer's published data, use Table 1. Values of insulation resistance less than this table or manufacturer's minimum shall be investigated.

5) Trip characteristic of breakers shall fall within manufacturer's published time- current characteristic tolerance band, including adjustment factors. If manufacturer's curves are not available, trip times shall not exceed thevalue shown in Table 7. Circuit breakers exceeding specified trip time at 300% of pickup shall be tagged defective.

6) For molded-case circuit breakers, instantaneous pickup values shall be within manufacturer's published data or tolerances shown in Table 8.

7) Minimum operation voltages on shunt trip and close coils shall be in accordance with manufacturer's published data. In the absence of manufacturer's data, refer to Table 20.

8. Low-Voltage Disconnect Switches:

a. Visual and Mechanical Inspection:

1) Compare equipment nameplate data with drawings and specifications.

2) Inspect physical and mechanical condition.

3) Inspect anchorage, alignment, grounding, and required clearances.
4) Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
5) Verify that fuse sizes and types are in accordance with drawings, short-circuit and overcurrent protective device coordination studies.
6) Verify that each fuse has adequate mechanical support and contact integrity.
7) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 12.
8) Perform thermographic survey of accessible bolted electrical connection in accordance with paragraph "Thermographic Survey."
9) Verify operation and sequencing of interlocking systems.
10) Verify correct phase barrier installation.
11) Verify correct operation of all indicating and control devices.
12) Confirm correct application of manufacturer's recommended lubricants.

b. Electrical Tests:
1) Measure contact resistance across each switchblade and fuseholder.
2) Perform insulation-resistance test at 1000 VDC from pole-to-pole and from each pole-to-ground. Test duration shall be one minute. Use a minimum test voltage in accordance with Table 1 or manufacturer's published data.
3) Measure fuse resistance.
4) Perform ground fault test, if applicable.

c. Test Values:
1) Compare bolted connection resistances to values of similar connections.
2) Bolt-torque levels should be in accordance with Table 12, unless otherwise specified by the manufacturer.
3) Compare microhm or millivolt drop values to adjacent poles or similar switches. Investigate deviations of more than 50% of lowest value. Investigate any value exceeding manufacturer's recommendations.
4) Minimum insulation-resistance shall be in accordance with manufacturer's published data or Table 1.
5) Investigate fuse-resistance values that deviate from each other by more than 15%.

9. Grounding Systems:
a. Visual and Mechanical Inspection:
1) Verify ground system is in compliance with drawings, specifications, and NFPA 70.
2) Inspect physical and mechanical condition.
3) Inspect anchorage.

b. Electrical Tests:
1) Perform fall-of-potential or alternative test in accordance with ANSI/IEEE 81 on the main grounding electrode or system.

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

3) Make resistance measurements in dry weather not earlier than 48 hours after rainfall.

c. Test Values:

1) The resistance between the main grounding electrode and ground should be no greater than five ohms. (Reference ANSI/IEEE 142.) Investigate any values above five ohms and notify Engineer immediately for further instructions.

2) Investigate point-to-point resistance values that exceed 0.5 ohm.

10. Protective Relays (as applicable):

a. Visual and Mechanical Inspection:

1) Compare equipment nameplate data with drawings and specifications.

2) Inspect relays and cases for physical damage. Remove shipping restraint material.

3) Tighten case connectors. Inspect cover for correct gasket seal. Clean cover glass. Inspect shorting hardware, connection paddles, and knife switches. Remove foreign material from case. Verify target reset.

4) Inspect relay for foreign material, particularly in disc slots of damping and electromagnets. Verify disk clearance. Verify contact clearance and spring bias. Inspect spiral spring convolutions. Inspect disk and contacts for freedom of movement and correct travel. Verify tightness of mounting hardware and connections. Burnish contacts. Inspect bearings and pivots.

5) Set relays in accordance with coordination study supplied.

b. Electrical Tests:

1) Perform insulation-resistance test on each circuit-to-frame. Determine from manufacturer's instructions allowable procedures for this test for solid-state and microprocessor-based relays.

2) Inspect targets and indicators. Determine pickup and dropouts of electromechanical targets. Verify operation of light-emitting diode indicators. Set contrast for liquid-crystal display readouts.

3) Functional Operation:

a) IEEE 2/62 Timing Relay

i) Determine time delay.

ii) Verify operation of instantaneous contacts.

b) IEEE 21 Distance Relay

i) Determine maximum reach.

ii) Determine maximum torque angle.

iii) Determine offset.

iv) Plot impedance circle.

c) IEEE 24 V/Hz Relay

i) Determine pickup frequency at rated voltage.

ii) Determine pickup frequency at second voltage level.

iii) Determine time delay.

d) IEEE 25 Sync Check Relay

i) Determine closing zone at rated voltage.

ii) Determine maximum voltage differential that permits closing at zero degrees.

iii) Determine live line, live bus, dead line, and dead bus set points.

iv) Determine time delay.

v) Verify dead bus/live line, dead line/live bus and dead bus/dead line control functions.

e) IEEE 27 Undervoltage Relay

i) Determine dropout voltage.

ii) Determine time delay.

iii) Determine time delay at second point on timing curve for inverse time relays.

f) IEEE 32 Directional Power Relay

i) Determine minimum pickup at maximum torque angle.

ii) Determine closing zone.

iii) Determine maximum torque angle.

iv) Determine time delay

v) Verify time delay at second point on timing curve for inverse time relays.

vi) Plot operating characteristic.

g) IEEE 40 Loss of Field (Impedance) Relay

i) Determine maximum reach.

ii) Determine maximum torque angle.

iii) Determine offset.

iv) Plot impedance circle.

h) IEEE 46 Current Balance Relay

i) Determine pickup of each unit.

ii) Determine percent slope.

iii) Determine time delay.

i) IEEE 46N Negative Sequence Current Relay

i) Determine negative sequence alarm level.

ii) Determine negative sequence minimum trip level.

iii) Determine maximum time delay.

iv) Verify two points on $(I_2)_2t$ curve.

j) IEEE 47 Phase Sequence or Phase Balance Voltage Relay

i) Determine positive sequence voltage to close normally open contact.

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

iii) Verify negative sequence trip.

iv) Determine time delay to close normally open contact with

sudden application of 120% of pickup.

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

k) IEEE 49R Thermal Replica Relay

i) Determine time delay at 300% of setting.

ii) Determine second point on operating curve.

iii) Determine pickup.

l) IEEE 49T Temperature (RTD) Relay

i) Determine trip resistance.

ii) Determine reset resistance.

m) IEEE 50 Instantaneous Overcurrent Relay

i) Determine pickup.

ii) Determine dropout.

iii) Determine time delay.

n) IEEE 51 Time Overcurrent

i) Determine minimum pickup.

ii) Determine time delays at 2 points on time current curve.

o) IEEE 55 Power Factor Relay

i) Determine tripping angle.

ii) Determine time delay.

p) IEEE 59 Overvoltage Relay

i) Determine overvoltage pickup.

ii) Determine time delay to close contact with sudden application of 120% of pickup.

q) IEEE 60 Voltage Balance Relay

i) Determine voltage difference to close contacts with one source at rated voltage.

ii) Plot operating curve for relay.

r) IEEE 63 Transformer Sudden Pressure Relay

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

ii) Verify operation of 63 FPX seal-in circuit.

iii) Verify trip circuit to remote breaker.

s) IEEE 64 Ground Detector Relay

i) Determine maximum impedance to ground causing relay pickup.

t) IEEE 67 Directional Overcurrent Relay

i) Determine directional unit minimum pickup at maximum torque angle.

ii) Determine closing zone.

iii) Determine maximum torque angle.

iv) Plot operating characteristics.

v) Determine overcurrent unit pickup.

vi) Determine overcurrent unit time delay at 2 points on time current curve.

u) IEEE 79 Reclosing Relay

i) Determine time delay for each programmed reclosing interval.

ii) Verify lockout for unsuccessful reclosing.

iii) Determine reset time.

iv) Determine close pulse duration.

v) Verify instantaneous overcurrent lockout.

v) IEEE 81 Frequency Relay

i) Verify frequency set points.

ii) Determine time delay.

iii) Determine undervoltage cutoff.

w) IEEE 85 Pilot Wire Monitor

i) Determine overcurrent pickup.

ii) Determine undercurrent pickup.
iii) Determine pilot wire ground pickup level.
x) IEEE 87 Differential
i) Determine operating unit pickup.
ii) Determine operation of each restraint unit.
iii) Determine slope.
iv) Determine harmonic restraint.
v) Determine instantaneous pickup.
vi) Plot operating characteristics for each restraint.

c. Control Verification:
1) Verify each relay contact performs its intended function in control scheme including breaker trip tests, close inhibit tests, 86 lockout tests, and alarm functions.
2) For microprocessor-based relays, verify all inputs, outputs, internal logic, and timing elements used in protection, metering, and control functions.

d. Systems Tests:
1) After the equipment is energized, measure magnitude and phase angle of inputs and compare to expected values.

e. Test Values:
1) When not otherwise specified, use manufacturer's recommendedtolerances.
2) When critical test points are specified, relay should be calibrated to those points even though other test points may be out of tolerance.

11. Instrument Transformers:
a. Visual and Mechanical Inspection:
1) Compare equipment nameplate data with drawings and specifications.
2) Inspect physical and mechanical condition.
3) Verify correct connection of transformers with system requirements.
4) Verify adequate clearance between primary and secondary circuit wiring.
5) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 12.
6) Perform thermographic survey of bolted electrical connections in accordance with paragraph "Thermographic Survey."
7) Verify required grounding and shorting connections provide contact.
8) Verify correct operation of transformer withdrawal mechanism and grounding operation.
9) Verify correct primary and secondary fuse sizes for potential transformers.
10) Confirm correct application of manufacturer's recommended lubricants.

b. Electrical Tests – Current Transformers:
1) Perform insulation-resistance test of current transformer and wiring-to-ground at 1000 VDC. Do not perform this test on wiring connected to units with solid- state components. Follow manufacturer's recommendations.

2) Perform polarity test of each current transformer.
3) Perform ratio-verification test using voltage or current method in accordance with ANSI/IEEE C57.13.1.
4) Perform excitation test on transformers used for relaying applications in accordance with ANSI/IEEE C57.13.1.
5) Measure current circuit burdens at transformer terminal and determine total burden.
6) When applicable, perform insulation-resistance and dielectric withstand tests on primary winding with secondary grounded. Test voltages shall be in accordance with Tables 5 and 9 respectively.
7) Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.

c. Electrical Tests – Voltage Transformers:
1) Perform insulation-resistance tests winding-to-winding and each winding-to- ground. Test voltages shall be applied for one minute in accordance with Table 5. For units with solid-state components, follow manufacturer's recommendation.
2) Perform polarity test on each transformer to verify polarity marks or H1-X1 relationship as applicable.
3) Perform turns ratio test on all tap positions, if applicable.
4) Measure potential circuit burdens at transformer terminals and determine total burden.
5) Perform dielectric withstand test on primary windings with secondary windings connected to ground. Dielectric voltage shall be in accordance with Table 9. Test voltage shall be applied for one minute.

d. Test Values:
1) Insulation-resistance measurement on instrument transformer shall not be less than that shown in Table 5.
2) Bolt-torque levels shall be in accordance with Table 12, unless otherwise specified by the manufacturer.
3) Polarity results shall agree with system drawings.
4) Compare measured burdens to calculated burdens supplied by Owner.
5) Ratio accuracies shall be within 0.5% of nameplate or manufacturer's published data.
6) Insulation shall withstand over-potential test voltage applied.

12. Thermographic Survey:
a. Visual and Mechanical Inspection:
1) Inspect physical, electrical, and mechanical conditions.
2) Remove all necessary covers prior to thermographic inspection.
3) Equipment to be inspected shall include all current-carrying devices. Provide report including the following:
a) Discrepancies.
b) Temperature difference between area of concern and reference area.

c) Cause of temperature difference.
d) Areas inspected. Identify inaccessible and unobservable areas and equipment.
e) Identify load conditions at time of inspection.
f) Provide photographs and thermogram of deficientarea.

b. Test Parameters:
1) Inspect distribution systems with imaging equipment capable of detecting minimum temperature difference of 2°F at 86°F.
2) Equipment shall detect emitted radiation and convert detected radiation to visual signal.
3) Thermographic surveys should be performed during periods of maximum possible loading but not less than 40% of rated load of the electrical equipment being inspected. Refer to NFPA 70B, Section 20.17 (Infrared Inspection).

c. Test Results:
1) Temperature differences of 2°F to 5 °F indicate possible deficiency and warrant investigation.
2) Temperature differences of 7°F to 27°F indicate deficiency; repair as time permits.
3) Temperature differences of 29°F and above indicate major deficiency; repair immediately.
4) Suggested actions based on temperature rise can be found in Table 18.

B. Test Reports:
1. Testing firm shall do the following:
a. Prepare test report, including description of equipment tested, description of test, test results, conclusions and recommendations, retesting results, list of test equipment used and calibration date.
b. Show test results in comparison to industry and manufacturer's values and tolerances.
c. Interpret test results in writing and give recommendations for acceptance or rejection upon consultation with Engineer and prior to energizing equipment.
d. Assure electrical equipment is operational and within industry and manufacturer's tolerances, and is installed in accordance with contract documents.
e. Assure suitability of energization.
f. Report to the Owner and Engineer any system, material, or workmanship that is found defective on the basis of acceptance tests.
g. Retest equipment when required.
h. Maintain written record of tests.
i. Utilize safety practices during the tests in accordance with:
1) Acceptable state and local safety operating procedures
2) Owner's safety practices
3) OSHA

4) NFPA 70E

j. Perform tests with apparatus de-energized and grounded, except where otherwise specifically required ungrounded by test procedures.

k. Assemble and certify final test report.

l. Provide 4 copies of complete test report.

m. Attach label to all tested equipment with indication of date tested and testing firm name.

2. Contractor shall do the following:

a. Investigate, replace, or repair any fault in material or in any part of the installation revealed by the tests.

b. Deliver one copy of each test report directly to Engineer within 30 days after completion of testing, unless directed otherwise. Insert a copy of each test report in the equipment operation and maintenance manuals.

C. Test Equipment:

1. Test Instrument Calibration:

a. Testing firm shall have calibration program that assures test instruments are maintained with rated accuracy.

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

1) Field instruments: Analog, 6 months maximum; Digital, 12 months maximum

2) Laboratory instruments: 12 months

3) Leased specialty equipment: 12 months where accuracy is guaranteed by lessor

c. Dated calibration labels shall be visible on test equipment.

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

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

f. Equipment used for field testing shall be more accurate than instrument being tested.

g. Calibrating standard applied to testing equipment shall be of higher accuracy than instrument tested.

END OF SECTION