Scopes of Work for Electrical Maintenance

Schneider Electric Services: life-cycle solutions for electrical distribution equipment

Make the most of your energy℠
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SECTION 1—INTRODUCTION

The Scopes of Work (SOWs) described in this bulletin are recommended practices that are ordinarily used in the field to determine the condition of an electrical power system. These practices can form the basis for a comprehensive Electrical Preventative Maintenance (EPM) program, however, they are not intended to be a mandatory practice or applicable and all inclusive for each type of equipment found in modern electrical power distribution systems.

The practices in this document describe “What to Do” and not “How To Do It”. These practices should only be performed by persons that are qualified by experience and training in the proper and safe execution of EPM.

In lieu of a customer specification or other written guidelines, this bulletin details the inspection and testing procedures that Schneider Electric Services technicians follow while performing maintenance testing of electrical equipment.

Our qualified field service representatives provide comprehensive maintenance and testing services with a scope of work that includes:

- Equipment inspection
- Protective device testing
- Cleaning and lubrication
- Adjustments
- Electrical testing, including insulation, current path, system function and other services.

Acknowledgement

The standard deliverables to the customer are those services described in the each section of these procedures and titled Visual and Mechanical Inspection and Electrical Tests. Optional Tests will only be performed by Schneider Electric technicians when specified on customer’s purchase order and subsequent field service work order.

For testing of equipment not detailed in this document, Schneider Electric Services will refer to manufacturer's instructions, NFPA 70B, IEEE, ANSI and other relevant standards.

For additional information, contact Schneider Electric Services at 1-888-778-2733.

This document has been prepared based on manufacturer instruction bulletins as well as, NFPA, IEEE, NEMA and ANSI standards

Tables are based on information from Schneider Electric USA, Inc. and the ANSI/NETA Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems
SECTION 2—GENERAL REQUIREMENTS

Schneider Electric Services (SES) considers the safety of our employees, customers and all persons associated or affected by our work to be our highest priority. All work performed by Schneider Electric will adhere to Schneider Electric Safe Work practices, NFPA 70E, Customer Requirements and State and Federal standards. In all cases the most stringent procedures will be adhered to. At any point if the lead Schneider Electric representative determines work cannot proceed safely in accordance with these requirements work will be halted until a mutually agreeable resolution is reached.

OWNER / CUSTOMER shall supply current and accurate one-line and as built drawings for review prior to commencement of work. These will be given to Schneider Electric Personnel for use throughout the testing project.

OWNER / CUSTOMER shall supply OEM (Original Equipment Manufacturer) Operations and Maintenance Manuals for all equipment to be tested. Copies of these should be given to Schneider Electric Personnel for use throughout the testing project.

Schneider Electric Services Employees are NOT AUTHORIZED to work on energized equipment. However, there are occasions in which it may be necessary to take voltage measurements within an energized enclosure. These measurements will be taken using all applicable procedures for energized work.

Schneider Electric Services does not typically perform shutdown and/or switching operations, because these operations may result in damage to property or persons downstream of the equipment as a result of conduct, errors, or omissions made by others. If a customer requests Schneider Electric Company to perform such services, a copy of the Schneider Electric Shutdown/Switching policy must be reviewed and signed by the customer. The onsite technician(s) must also contact their Manager for approval and proper procedures prior to performing any shutdown and/or switching.

Schneider Electric maintains an equipment calibration program to assure that the equipment used to monitor and measure data associated with key characteristics will provide data that is both accurate and repeatable. The calibration cycle is defined by manufacturer and industry guidelines. Equipment included in the program is identified by a calibration sticker or tag affixed to each piece of test equipment. Equipment calibration records are available for review based on project specifications.

Should hazardous materials such as asbestos, PCB contaminated oils or other similar substances be encountered work will be suspended until a mutually agreeable plan can be implemented to safely handle the material.
SECTION 3—AC DRIVES

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report.
2. Check for broken operators, switches, or pilot lights; dented or bent enclosure structures.
3. Check for excessive dirt, dust, or moisture.
4. Verify that a properly sized grounding conductor is connected to the drive grounding lug and terminates on a ground lug in the power distribution panel.
5. Tighten all power wiring connections to proper torque value. Check line and load side connections of all disconnect switches, breakers, contactors, and overloads.
6. Check and tighten all control wiring connections, mounting hardware, drive control terminals and terminal block connections.
7. Check door and disconnect switch alignment and opening/closing operation.
8. Test all mechanical interlocking devices.
9. Manually operate all contactors to verify freedom of movement.
10. Verify that customer supplied fusing agrees with the manufacturer's recommendations.
11. Verify mechanical operation of isolation contactor. Tighten power and control connections.
12. Verify that all control and option boards are securely fastened and plug-in terminals are connected.
13. Check that properly sized thermal overloads are used in ISO/Bypass unit.
14. Document as found/ as left settings.

B. Electrical Tests

1. Verify proper operation of the AFC-Off-Bypass selector switch (if used).
2. Set the AFC-Off-Bypass selector switch (if used) to Bypass and the Hand Off-Auto to Hand. Check the direction of motor rotation. Rotation should be clockwise (ABC) unless indicated differently by the project documentation. Note the as-found and as-left rotation on the start-up documentation.
3. Verify proper operation based on the High Speed (HSP) setting (maximum motor speed setting). Record your results.
4. Verify proper operation based on Check the Low Speed (LSP) setting (minimum motor speed setting). Record your results.
5. Verify that Hand and Auto controls, Start, Stop, and speed input, operate the drive correctly.
6. Check that all indicating lamps illuminate only for their assigned functions. Check all Push to Test lamps.
SECTION 4—AIR SWITCHES: LOW VOLTAGE

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Inspect physical and mechanical condition and clean equipment.
3. Confirm correct application of manufacturer specified lubricants at recommended locations.
4. Verify appropriate anchorage and required area clearances.
5. Verify appropriate equipment grounding.
6. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
7. Verify and record fuse sizes and types are in accordance with record drawings and, if available, coordination studies.
8. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Table 100.12 and 100.23.
9. Check all interlocking systems for correct operation and sequencing, and key distribution, if applicable.
10. Verify correct phase barrier installation.
11. Inspect all indicating and control devices for correct operation.
12. Check the condition of arc contacts and arc chutes.

B. Electrical Tests

NOTE: When performing dielectric tests, you must disconnect (or isolate) all Instrument and Control Transformers, Surge Protection Devices and other sensitive electronic equipment that may cause erroneous results or be damaged by the applied test voltage. Verify no paths to ground exist with an ohmmeter or initially testing insulation resistance at a low voltage.

Record the date of the last calibration for each piece of test equipment used.

1. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute. Test voltage shall be in accordance with manufacturer's published data or Table 100.1.
2. Test all auxiliary devices (solenoid trip, blown main fuse detector, etc.) for proper operation.
3. Perform a Contact Resistance Test across each pole (phase):
   a. With the main power source de-energized, close and open the switch several times using either manual or electrical means.
   b. Apply a minimum current of 10 amperes dc through the closed contacts. If the test current does not conform to the manufacturer's specification, consult the manufacturer.
   c. Measure and record the median (middle) value of three readings (toggling the switch between each reading) compare with the manufacturers published information and adjacent poles.
   d. If the measured resistances are below the manufacturers published data and balanced, the condition of the device contacts is considered suitable for service. If the measured resistances exceed the manufacturers recommendations or are imbalanced, open and close the device several more times and repeat the test. Contact the factory if acceptable values of resistance cannot be achieved.

4. Measure fuse resistance to verify continuity. Take note of any deviations in excess of 15%. Record your results.

5. When ground fault protection is installed on switch, confirm settings are in accordance with the owner supplied coordination study. Verify proper calibration and operation by current injection.
SECTION 5—AIR SWITCHES: MEDIUM VOLTAGE, METAL-ENCLOSED

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Inspect physical and mechanical condition and clean equipment.
3. Confirm correct application of manufacturer specified lubricants at recommended locations.
4. Verify appropriate anchorage and required area clearances.
5. Verify appropriate equipment grounding.
6. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
7. Verify that fuse sizes and types are in accordance with drawings and, if available, coordination studies.
8. Inspect fuse holders for tightness and alignment.
9. Verify that expulsion-limiting devices are in place on all holders having expulsion-type elements. Verify that they are installed to vent in the proper direction.
10. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer’s published data. If no manufacturer’s data is available, use the values in Tables 100.12 and 100.23.
11. Check all interlocking systems for correct operation and sequencing, and key distribution, if applicable.
13. Inspect all indicating and control devices for correct operation.
14. Clean and inspect any connected surge arrestors and verify that they have been properly connected. Verify that they have the appropriate voltage rating per the manufacturer’s drawings and system voltage, where applicable.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance with Switchgear industry standards. Verify no paths to ground exist with an ohmmeter or initially testing insulation resistance at a low voltage

Record the date of the last calibration for each piece of test equipment used.

1. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute. Test voltage shall be in accordance with manufacturer’s published data or Table 100.1.
2. Verify that heaters have been connected and are operating properly.
3. Measure fuse resistance to verify continuity, record your results.
4. Perform a Contact Resistance Test across each pole (phase)
   a. With the main power source de-energized, close and open the switch several times using either manual or electrical means.
   b. Apply a minimum current of 10 amperes dc through the closed contacts.
   c. Measure and record the median (middle) value of three readings (toggling the switch between each reading) compare with the manufacturers published information and adjacent poles.
   d. If the measured resistances are below the manufacturers published data and balanced, the condition of the device contacts is considered suitable for service. If the measured resistances exceed the manufacturers recommendations or are imbalanced, open and close the device several more times and repeat the test. Contact the factory if acceptable values of resistance cannot be achieved.

5. Perform a dielectric test (Hi-Pot) on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 100.2.
SECTION 6—AIR SWITCHES: HIGH AND MEDIUM VOLTAGE, OPEN STYLE

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Inspect physical and mechanical condition and clean equipment.
3. Confirm correct application of manufacturer specified lubricants at recommended locations.
4. Verify that grounding is in accordance with industry standards and project specifications.
5. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no, manufacturer's data is available, use the values in Tables 100.12 and 100.23.
6. Perform mechanical operator tests in accordance with manufacturer’s instructions.
7. Verify correct operation and adjustment of motor operator limit-switches and mechanical interlocks.
8. Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation (over toggle).
9. Inspect fuse holders for tightness and alignment.
10. Check the condition of arc contacts and arc chutes. Verify correct size and type fuses if fuses are presently installed.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance with Switchgear industry standards. Verify no paths to ground exist with an ohmmeter or initially testing insulation resistance at a low voltage

Record the date of the last calibration for each piece of test equipment used.

1. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute. Test voltage should be in accordance with manufacturer’s published data or Table 100.1.
2. Perform a contact-resistance test across each switch blade and fuse holder, record results. Compare with the manufacturer’s published information and adjacent poles. Investigate any values that deviate from the manufactures recommended values.
3. Verify Operator targets and Gas targets, where applicable, are in proper sequence.
4. Perform a dielectric test (Hi-Pot) on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer’s published data or Table 100.2.
A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Inspect physical and mechanical condition and clean equipment.
3. Verify appropriate anchorage and required area clearances.
4. Verify that all power cables are properly terminated and supported.
   *NOTE: When routing shielded cable through window-type current transformers or ground sensor current transformers, the shield-ground connection wire is normally routed back through the current transformer and solidly grounded.*
5. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.

<table>
<thead>
<tr>
<th>Equipment Rating</th>
<th>Field Test Voltages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AC</td>
</tr>
<tr>
<td>4.76kV</td>
<td>14kV</td>
</tr>
<tr>
<td>15kV</td>
<td>27kV</td>
</tr>
<tr>
<td>17.5kV</td>
<td>28.5kV</td>
</tr>
<tr>
<td>27kV</td>
<td>45kV</td>
</tr>
<tr>
<td>38kV</td>
<td>60kV</td>
</tr>
</tbody>
</table>

6. Inspect all control wiring.
7. If FuseLogic™ fuse trip system is installed, verify proper operation.
8. Verify all fuses are properly installed and clips lubricated with Mobil 28.
9. Verify that fuse sizes and types are in accordance with drawings and, if available, coordination studies.
10. Check all interlocking systems for correct operation and sequencing, and key distribution, if applicable.
11. If any isolating switch is not in operation and is left without incoming cables, the corresponding grounding switch must be closed and blocked by means of a padlock to avoid possible unintentional operation.
12. Verify appropriate equipment grounding.
13. Verify that all insulating surfaces are clean and dry.
14. Verify that all barriers and covers are secured.
15. When equipped, verify proper operation of the ground switch and related interlocks.
16. Perform a minimum of 5 open / close operations while verifying smooth operation of the mechanism and all indicators.
17. Inspect all interlocks, indicating and control devices for correct operation.
B. Electrical Tests

NOTE: Prior to performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, Control and Power cables units, and other sensitive electronic equipment that may cause erroneous results or be damaged by the applied test voltage. Capacitive dividers supplied with the equipment must be properly connected or grounded. Verify no paths to ground exist with an ohmmeter or initially testing insulation resistance at a low voltage.

Record the date of the last calibration for each piece of test equipment used.

1. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute. Test voltage shall be in accordance with the above table.
2. Perform Hi-Pot test
   a. Apply voltage to each phase individually for one minute with the other two phases and enclosure grounded. (see table for hi-pot test values gradually increase voltage).
SECTION 8—METERING DEVICES

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Inspect physical and mechanical condition and clean equipment.
3. Confirm case is properly grounded.
4. Verify tightness of electrical connections.
5. For electro-mechanical devices, verify freedom of movement, correct travel, alignment, and tightness of mounting hardware.
6. For microprocessor based meters confirm and record settings for system configuration, CT and PT ratios, multipliers, communications and other specified parameters are in accordance with record drawings or customer supplied specifications.

B. Electrical Tests

Record the date of the last calibration for each piece of test equipment used.

1. Check calibration of meters according to the manufacturer's published data.
2. Electrically confirm that current transformer and voltage transformer secondary circuits are intact.
SECTION 9—BUSWAYS, METAL-ENCLOSED

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Inspect the busway for physical damage and clean equipment.
3. Inspect for appropriate bracing, suspension, alignment, clearances and enclosure grounding and bonding.
4. Verify that the neutral is only grounded at one point in accordance with NEC, CSA or other applicable standards.
5. Verify installation and proper operation of heaters, when applicable.
6. For outdoor busway, confirm removal of “weep-hole” plugs, if applicable, and the correct installation of joint shield(s). Verify that proper gasketing is in place.

B. Electrical Tests

NOTE: Prior to testing, confirm that all tap-off or plug-in devices are in the off position. Isolate the entire busway run by disconnecting any ties to transformers, switchboards, meters or other devices.

Record the date of the last calibration for each piece of test equipment used.

1. Measure insulation resistance of each busway with an insulation resistance tester rated at 1000 volts. Make measurements phase-to-ground, phase-to-neutral and phase-to-phase and for one minute. Compare your results with Table 100.1.
2. Perform a dielectric test (Hi-Pot) on each bus section, phase-to-ground with phases not under test grounded, in accordance with Table 100.2. NOTE: This test is standard on medium voltage busway and optional on low voltage busway.

NOTE: The megohm readings should not be less than the value calculated from the following formula. Megohms = 100 / length of run (in feet) or Megohms = 30.5 / length of run (in meters)

C. Optional Tests

1. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer’s published data. If no manufacturer’s data is available, use the values in Tables 100.12 and 100.23.
SECTION 10 — OUTDOOR / SUBSTATION BUS

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Inspect the bus for physical damage and clean equipment.
3. Inspect for appropriate bracing, suspension, alignment, and proper grounding.
4. Verify that all support insulators are clean and undamaged.

B. Electrical Tests

Record the date of the last calibration for each piece of test equipment used.

1. Perform an insulation resistance test to confirm the system is free of any ground faults. Compare your results with Table 100.1.
2. Perform a dielectric test (Hi-Pot) on each bus, phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. Apply test voltage for one minute. Use test voltage values as shown in Table 100.17.

C. Optional Tests

1. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no, manufacturer's data is available, use the values in Tables 100.12 and 100.23.
SECTION 11—CABLES: LOW VOLTAGE

A. Visual and Mechanical Inspection

1. Document cable sizing and insulation type.
2. Inspect the exposed sections of cables for physical damage and clean equipment.
3. Using a calibrated torque wrench, verify that the tightness of accessible bolted connections is in accordance with the manufacturer’s published data. If no manufacturer’s data is available, use the values in Tables 100.12 and 100.23.
4. Inspect compression-applied connectors for correct cable match and indentation.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance with industry standards.

1. Verify that the opposite end of the cable run being tested is properly isolated from both adjacent equipment and personnel during testing.
2. Record the date of the last calibration date for each piece of test equipment used.
3. Perform an insulation resistance test on each conductor between one conductor and ground with the other conductors grounded. Each conductor shall be tested in the same manner.
   a. The test shall be performed at 1000 volts dc for one minute if the insulation rating of the cable under test is rated at 600V. For cables rated less than 600V, the Vdc test voltage should be a minimum of 1.41 times the Vac rating of the cable.
   b. Each 480V feeder cable shall be tested with the cable connected to the racked-in but open breaker or switch at the equipment. Connection at the other end of each of these cables shall be as follows:
      i. Cables to Motor Control Centers shall be connected to the bus with the switches or breakers in the starters open.
      ii. Cables to motors and other equipment shall be connected to the motors and equipment with feeder switches open.

NOTE: All cables connected to motors and transformers are effectively connected through the windings. To obtain results for individual conductors, isolate the cables from the utilization equipment.
SECTION 12—CABLES: MEDIUM VOLTAGE

A. Visual and Mechanical Inspection

1. Document cable sizing and insulation type.
2. Inspect the exposed sections of cables for physical damage and clean equipment.
3. Using a calibrated torque wrench, verify that the tightness of accessible bolted connections is in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.
4. Inspect compression-applied connectors for correct cable match and indentation.
5. Inspect cable terminations for proper installation in accordance with the termination manufacturer's instructions.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance with industry standards.

1. Verify that the opposite end of the cable run to be tested is disconnected and isolated from personnel.
2. Record the date of the last calibration for each piece of test equipment used.
3. Perform a shield continuity test on each conductor.
4. With cables isolated at both ends, perform an insulation resistance test on each conductor between the conductor and ground with the conductors not under test grounded. Each conductor shall be tested in the same manner. The test shall be performed at 1000 volts dc for one minute.

NOTE: Cable testing technology is an evolving science. DC testing may not be suitable for some cable types (such as XLPE), however, may be best suited for other types (such as EPR). The test method employed should be based on project requirements and discussions with the project engineer.

C. Optional Tests

1. Perform a dielectric test on medium voltage shielded cable per Table 100.6. Refer to the manufacturer's published data, and perform in accordance with IEEE 400, checking leakage current and decay voltage over the specified time period.
2. Very Low Frequency (VLF)
3. Perform power-factor or dissipation-factor tests on each cable.

NOTE: For long cable runs it may be necessary to utilize a resonating inductor due to the large amount of capacitance in the cable.
SECTION 13—CAPACITORS: POWER FACTOR CORRECTION

A. Visual and Mechanical Inspection

**WARNING:** Capacitors are energy storing devices. Care should be exercised and testing performed before physically touching the terminals of any capacitor. Although a voltage detection device might indicate that the capacitor is not electrically energized, the capacitor could be storing a lethal charge. Do NOT falsely assume that the internal discharge resistor is intact and functional. Always assume that a capacitor is charged unless the capacitor has been de-energized from its normal power source and the capacitor has been externally discharged.

1. Document equipment nameplate data on test report.
2. Inspect the physical and mechanical condition of the equipment and clean equipment.
3. Inspect the capacitors for the correct mounting and required clearances, per the manufacturer's recommended procedures.
4. Confirm all ventilation openings are clear and unobstructed.
5. Verify that capacitors are electrically connected in their specified configuration, per the manufacturer's recommended procedures.
6. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.

B. Electrical Tests

Record the date of the last calibration date for each piece of test equipment used.

1. Perform insulation-resistance tests from terminal(s) to case for one minute on capacitors with more than one bushing. The test voltage and minimum resistance shall be in accordance with the manufacturer’s instructions or Table 100.1.
2. Measure and record the input voltage for the capacitor / bank. Voltage should not exceed the capacitor nameplate rating by more then 10%.
3. Measure the capacitance of all terminal combinations.
4. Measure the resistance of the internal discharge resistors.
SECTION 14—CIRCUIT BREAKERS: LOW VOLTAGE INSULATED CASE / MOLDED CASE

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Clean and inspect circuit breaker for damage, correct mounting, alignment and grounding.
3. Open and close the circuit breaker to insure smooth operation.
4. Confirm correct application of manufacturer specified lubricants at recommended locations.
5. Inspect case for cracks or other defects.
6. When applicable, inspect condition and alignment of arc chutes, moving and stationary contacts.
7. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no, manufacturer's data is available, use the values in Tables 100.12 and 100.23.
8. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism.
9. Verify electric open/close and operation of installed accessories, such as Blown Fuse Indicators, Auxiliary Contacts, Cell Switches, Shunt Trip Devices, and Undervoltage Release.
10. Exercise the push to trip button to verify trip and reset.
11. When applicable, activate the Blown Fuse Indicator (BFI) and confirm by attempting to close the breaker without reset.
12. Verify rating plugs, sensors and settings are accordance with the coordination study supplied by the owner, if available.
13. Verify that all maintenance devices are available for servicing and operating the breaker.

B. Electrical Tests

NOTE: When performing dielectric tests, remove rating plugs, disconnects, all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance with molded case circuit breaker industry standards.

Record the date of the last calibration for each piece of test equipment used.

1. Perform a contact-resistance test in accordance with the following procedure.
   a. Open and close circuit breaker manually several times to ensure the mechanism linkages are free and operate properly. Trip the circuit breaker with the push to trip button if so equipped. Close the breaker.
   b. Measure the resistance across each pole with a digital low-resistance ohmmeter.
c. Compare the resistance values with manufacturers published data and between phases.
d. For circuit breakers manufactured by Schneider Electric compare your results to the values in Table 100.24 - 100.26.

2. Perform an insulation-resistance test at 1000 volts dc from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase. Insulation resistance should be greater than 100 Megohms.

3. Verify correct operation of any auxiliary features such as trip and pickup indicators, electrical close and trip operation, trip-free, and anti pump function.

4. Perform the following trip unit / relay tests by secondary injection:
   a. Minimum pickup current.
   b. Long-time delay.
   c. Short-time pickup and delay.
   d. Ground-fault pickup and delay.
   e. Instantaneous pickup.

C. Optional Tests

1. Perform the trip unit / relay tests utilizing primary current injection.
2. Perform a dielectric withstand test.
SECTION 15—CIRCUIT BREAKERS: LOW VOLTAGE POWER (ANSI/IEEE C37.13)

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Clean and inspect circuit breaker for shipping damage, correct mounting, alignment and grounding.
3. Open and close the circuit breaker to insure smooth operation.
4. Confirm correct application of manufacturer specified lubricants at recommended locations.
5. Inspect condition and alignment of arc chutes, moving and stationary contacts.
6. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no, manufacturer's data is available, use the values in Tables 100.12 and 100.23.
7. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism.
8. Verify electrical open/ close operation of installed accessories, such as Blown Fuse Indicators, Auxiliary Contacts, Cell Switches, Shunt Trip Devices, and Undervoltage Release.
9. When applicable, activate the Blown Fuse Indicator (BFI) and confirm by attempting to close the breaker without reset.
10. Verify rating plugs, sensors and settings are accordance with the coordination study supplied by the owner, if available.
11. Verify that all maintenance devices are available for servicing and operating the breaker.

B. Electrical Tests

NOTE: When performing dielectric tests, remove rating plugs and disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance with circuit breaker industry standards.

Record the date of the last calibration for each piece of test equipment used.

1. Perform a contact-resistance test in accordance with the following procedure.
   a. Open and close circuit breaker manually several times to ensure the mechanism linkages are free and operate properly. Trip the circuit breaker with the push to trip button if so equipped. Close the breaker.
   b. Measure the resistance across each pole with a digital low-resistance ohmmeter.
   c. Compare the Resistance values with manufacturers published data and between phases.
   d. For circuit breakers manufactured by Schneider Electric compare your results to the values in Table 100.24.
2. Perform an insulation-resistance test at 1000 volts dc from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase. Insulation resistance should be greater than 100 Megohms.

3. Verify correct operation of any auxiliary features such as trip and pickup indicators, electrical close and trip operation, trip-free, and anti pump function.

4. Perform the following trip unit / relay tests by secondary injection:
   a. Minimum pickup current.
   b. Long-time delay.
   c. Short-time pickup and delay.
   d. Ground-fault pickup and delay.
   e. Instantaneous pickup.

C. Optional Tests

1. Perform the trip unit / relay tests utilizing primary current injection.
2. Perform a dielectric withstand test.
SECTION 16—CIRCUIT BREAKERS: MEDIUM VOLTAGE AIR MAGNETIC

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Clean the circuit breaker and inspect the physical and mechanical condition.
3. Confirm correct application of manufacturer specified lubricants at recommended locations.
4. Inspect anchorage and grounding.
5. Inspect and verify that adjustments of the mechanism are in accordance with the manufacturer’s instructions.
6. Measure critical distances as recommended by manufacturer if indicated by contact resistance test results.
7. If required by the manufacturer, slow close/open breaker and check for binding. (This may not be possible in all cases where special or optionally supplied tooling is required)
8. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer’s published data. If no manufacturer’s data is available, use the values in Table 100.12 and 100.23.
9. Record as-found and as-left counter operations.

B. Electrical Tests

1. Record the date of the last calibration for each piece of test equipment used.
   a. Perform a contact-resistance test in accordance with the following procedure.
   b. Open and close circuit breaker manually several times to ensure the mechanism linkages are free and operate properly.
   c. Measure the resistance across each pole with a digital low-resistance ohmmeter.
   d. Compare the Resistance values with manufacturers published data and between phases.
2. Perform insulation-resistance tests pole-to-pole, pole-to-ground, and across open poles in accordance with Table 100.1.
3. Verify trip, close, trip-free, and antipump functions.
4. Trip the circuit breaker by operating each protective device.
5. Perform a Hi-Pot (dielectric) test in accordance with the manufacturer’s instructions.
C. Optional Tests

1. Perform an insulation-resistance test on all control wiring in accordance with Table 1001. Do not perform this test on wiring connected to solid-state relays.
2. Perform time-travel analysis using a travel distance analyzer.
3. Perform dissipation-factor/power-factor tests on breaker and bushings on each pole with the breaker open, and on each phase with the breaker closed.
4. Perform a minimum pick-up voltage test on trip and close coils.
SECTION 17—CIRCUIT BREAKERS: MEDIUM VOLTAGE SF6

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Clean and inspect the physical and mechanical condition of the breaker.
3. Confirm that lubricants have been correctly applied at the manufacturer's recommended locations.
4. Inspect anchorage and grounding.
5. Inspect and verify that adjustments of the mechanism are in accordance with the manufacturer's instructions.
6. Check indicators for gas leaks in accordance with the manufacturer's instructions.
7. Verify correct operation of all air and SF6 gas pressure switches, alarms and cutouts. *(NOTE: For sealed interrupters, the pressure cannot be varied to change the state of pressure switches.)*
8. If required by the manufacturer, slow close/open breaker and check for binding. *(This may not be possible in all cases where special or optionally supplied tooling is required)*
9. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Table 100.12 and 100.23.
10. Record as-found and as-left counter operations.

B. Electrical Tests

Record the date of the last calibration for each piece of test equipment used.

1. Perform a contact-resistance test in accordance with the following procedure.
   a. Open and close circuit breaker manually several times to ensure the mechanism linkages are free and operate properly.
   b. Measure the resistance across each pole with a digital low-resistance ohmmeter.
   c. Compare the Resistance values with manufacturers published data and between phases.
2. Perform insulation-resistance tests pole-to-pole, pole-to-ground, and across open poles in accordance with Table 100.1.
3. Perform a Hi-Pot (dielectric) test in accordance with the manufacturer's instructions.
4. Verify trip, close, trip-free, and antipump functions.
5. Trip the circuit breaker by operating each protective device.
C. Optional Tests

1. Perform an insulation-resistance test on all control wiring in accordance with Table 100.1. Do not perform this test on wiring connected to solid-state relays.
2. Perform time-travel analysis using a travel distance analyzer.
3. Perform dissipation-factor/power-factor tests on breaker and bushings on each pole with the breaker open, and on each phase with the breaker closed.
4. Perform a minimum pick-up voltage test on trip and close coils.
SECTION 18—CIRCUIT BREAKERS: MEDIUM VOLTAGE VACUUM

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Clean the circuit breaker and inspect physical and mechanical condition.
3. Confirm correct application of manufacturer specified lubricants at recommended locations.
4. Inspect anchorage, alignment, and grounding.
5. Inspect and verify that adjustments of the mechanism are in accordance with the manufacturer's instructions.
6. Measure critical distances, such as contact gap, as specified by the manufacturer's service bulletin.
7. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.
8. Record as-found and as-left operation counter readings.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment. Surge Protection Devices must be completely disconnected from the electrical system (including neutral and ground).

Record the date of the last calibration for each piece of test equipment used.

1. Perform a contact-resistance test in accordance with the following procedure.
   a. Open and close circuit breaker manually several times to ensure the mechanism linkages are free and operate properly.
   b. Measure the resistance across each pole with a digital low-resistance ohmmeter.
   c. Compare the Resistance values with manufacturers published data and between phases.
2. Verify the trip, close, trip-free, and antipump functions.
3. Trip the circuit breaker by operating each protective device.
4. Perform insulation-resistance tests pole-to-pole, pole-to-ground, and across open circuit breaker separable contacts in accordance with Table 100.1.
5. Perform a vacuum bottle integrity test in strict accordance with manufacturer's instructions. Note: Some manufacturers specify either AC or DC voltage for this test. Contact the manufacturer if repeated consistent breakdowns are encountered.
C. Optional Tests

1. Perform an insulation-resistance test on all control wiring in accordance with Table 100.1. Do not perform this test on wiring connected to solid-state relays.
2. Perform breaker travel and velocity analysis, using a travel distance analyzer.
3. Perform minimum pickup voltage tests on trip and close coils.
4. Perform dissipation-factor/power-factor tests on each pole with the breaker open, and on each phase with the breaker closed.
SECTION 19—CIRCUIT BREAKERS: MEDIUM VOLTAGE OIL

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.

A.1. Breaker Mechanism

2. Inspect the breakers physical and mechanical condition, anchorage and grounding.
3. Inspect and verify that adjustments of the mechanism are in accordance with the manufacturer's instructions.
4. Clean and lubricate the mechanism.
5. Check operating mechanism for loose hardware, missing or cotter pins, retaining rings, etc.

NOTE: The step below may be postponed until section A.2 is completed, when an internal inspection is part of the scope.

6. Slow close/open breaker and check for binding. (This may not be possible in all cases where special or optionally supplied tooling is required)
7. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Table 100.12 and 100.23.

A.2. Breaker Internal Inspection

8. Remove a sample of oil from the tank(s) for visual and dielectric testing.

NOTE: As a general guideline oil with a dielectric strength below 22kv should be filtered or replaced. Regardless of the dielectric strength, oil that visually contains an excessive amount of carbon should also be filtered or replaced. Refer to project specifications before proceeding.

9. Remove all oil from the tanks using appropriate removal and storage techniques in accordance with project specifications.
10. Check breaker and tank(s) for loose hardware, missing or cotter pins, retaining rings, etc.
11. Confirm no loose or broken hardware in the bottom of the tank(s)
12. Clean the tank and all components that have been in contact with oil
13. Check condition. Alignment and adjustment of contacts
14. Check condition of all gaskets, seals and valves.

CAUTION: Before performing the next step, consult the manufactures manual before performing any breaker operations without oil in the tank.

15. Operate the breaker to check that there is no friction or binding that might affect proper breaker operation.
16. Record as-found and as-left counter operations.
B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment. Surge Protection Devices must be completely disconnected from the electrical system (including neutral and ground).

Record the date of the last calibration for each piece of test equipment used.

1. Perform a contact-resistance test in accordance with the following procedure.
   a. Open and close circuit breaker manually several times to ensure the mechanism linkages are free and operate properly.
   b. Measure the resistance across each pole with a digital low-resistance ohmmeter.
   c. Compare the Resistance values with manufacturers published data and between phases.
2. Perform insulation-resistance tests pole-to-pole, pole-to-ground, and across open poles in accordance with Table 100.1.
3. Perform a Hi-Pot (dielectric) test in accordance with the manufacturer's instructions. In lieu of manufacturers recommended test voltages, refer to Table 100.19.
4. Verify trip, close, trip-free, and antipump functions.
5. Trip the circuit breaker by operating each protective device.

C. Optional Tests

1. Perform an insulation-resistance test on all control wiring in accordance with Table 100.1. Do not perform this test on wiring connected to solid-state relays.
2. Perform time-travel analysis using a travel distance analyzer.
3. Perform dissipation-factor/power-factor tests on breaker and bushings on each pole with the breaker open, and on each phase with the breaker closed.
4. Perform a minimum pick-up voltage test on trip and close coils.
SECTION 20—DIRECT CURRENT SYSTEMS: BATTERIES AND CHARGERS

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Clean battery and inspect the physical and mechanical condition of the equipment.
3. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.
4. For flooded cells, measure electrolyte specific gravity and temperature, and visually check the fill level.
5. Record the charger float and equalizing voltage levels.
6. When applicable, verify that flame arresters are present.
7. Measure total battery voltage from '+' terminal to ground and form the '-' terminal to ground and record values.
8. Check for proper ventilation of area containing storage batteries.
9. Check for any signs that battery acid has reacted with battery mounting frame or floor.

B. Electrical Tests

Record the date of the last calibration for each piece of test equipment used.

1. Verify that all charger functions and alarms are operating properly.
2. Measure each cell voltage and total battery voltage with the charger energized and in float mode of operation.

C. Optional Tests

1. Adjust the charger float and equalizing voltage levels in accordance with customer specifications.
2. Perform a capacity load test in accordance with the manufacturer's specifications and ANSI/IEEE standards.
3. Perform impedance / internal resistance tests on each cell.
SECTION 21—EMERGENCY SYSTEMS: AUTOMATIC TRANSFER SWITCHES

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Clean the switch and inspect the physical and mechanical condition of the equipment.
3. Confirm correct application of manufacturer specified lubricants at recommended locations.
4. Verify that manual transfer warnings are attached and visible.
5. Verify tightness of all control connections.
6. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.
7. Perform manual transfer operation.
8. Verify positive mechanical interlocking between normal and alternate sources.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment. Surge Protection Devices must be completely disconnected from the electrical system (including neutral and ground).

1. Perform a contact-resistance test in accordance with the following procedure.
   a. Open and close the switch manually several times to ensure the mechanism linkages are free and operate properly.
   b. Measure the resistance across each contact / pole with a digital low-resistance ohmmeter.
   c. Compare the resistance values with manufacturers published data and between phases.
2. Perform insulation-resistance tests, phase-to-phase and phase-to-ground, with the switch in both source positions at the minimum dc test voltage appropriate for the equipment's Maximum Rated Voltage, in accordance with Table 100.1. Record the resistances.
   NOTE: Connection of line / load cable may make performance on an insulation resistance test impractical.
3. Verify the settings and operation of control devices.
4. Perform the following automatic transfer tests:
   a. Simulate loss of normal power.
   b. Return to normal power.
   c. Simulate loss of emergency power.
   d. Simulate all forms of single-phase conditions.

5. Verify that the following functions have correct timing and are operating properly:
   a. Normal source voltage-sensing relays
   b. Engine start sequence
   c. Time delay upon transfer
   d. Alternate source voltage-sensing relays
   e. Automatic transfer operation
SECTION 22—GROUND-FAULT PROTECTION SYSTEMS

A. Visual and Mechanical Inspection

NOTE: Since there are many different types of Ground Fault systems it is not possible to set down one rule of operation. Each system must be evaluated on its own merit, and a logical operation must be determined for each. The procedures below apply to some of the most common systems applied in modern power systems. Any questions concerning the operation of the system should be referred to the system manufacturer and the project engineer.

1. Document equipment nameplate data on test report.
2. Visually inspect the components for damage and errors in polarity or conductor routing.
   a. Verify that the ground connection is made ahead of the neutral disconnect link, and on the line side of any ground fault sensor. **NOTE:** In some cases, Generator neutrals are also bonded to ground in a similar fashion as service entrance bonds are used for commercial power connections. In these cases, neutral sensors are used in the bond connection and differentially connected within the Ground Fault detection system.
   b. Verify that proper polarity exists for both primary and secondary connectors to the neutral sensors.
   c. Verify that all phase conductors and the neutral pass through the sensor in the same direction for zero sequence systems.
   d. Verify that grounding conductors do not pass through zero sequence sensors.
   e. Verify that the grounded conductor (usually Neutral) is bonded to ground in accordance with the power system specifications. Bonding to ground is permitted at the service entrance only with the exception of double ended systems with a single center bond and/or on the secondary of separately derived power systems including generators. Power systems may have multiple service entrances and multiple bonding at the multiple service entrances. Bonding to ground is not permitted downstream of the service and separately derived equipment. **NOTE:** Refer to the operating and testing instructions supplied with the equipment to confirm the system is installed as designed.
3. Verify tightness of all electrical connections, including control circuits.
4. Verify correct operation of all functions of locally or remote mounted test panel(s).
5. Set pickup and time-delay settings in accordance with the settings specified in the system coordination study or provided in writing by the owner.
B. Electrical Tests

Record the date of the last calibration for each piece of test equipment used.

1. Measure the system neutral-to-ground insulation resistance with the neutral disconnect link temporarily removed. Replace the neutral disconnect link after testing. Torque bolts after re-installing the neutral disconnect link after performing this test.

2. For system(s) that involve only one source; using a zero phase sequence sensor that encompasses all phase and neutral conductors; and has a test winding within the zero phase sequence sensor, that is not differentially connected, test by injecting test current in the test winding. The test is a self test that uses a feature integral to the unit. If instructions are not available to perform this test, use current injection and test operation as indicated in step (a) and (b) below.
   a. Verify that the relay does not operate at 90 percent of the pickup setting.
   b. Verify that relay pickup is less than 125 percent of setting, or 1200 amperes, whichever is smaller.

3. For systems involving multiple sources or multiple levels of ground fault protection, refer to the manufacturer's instruction bulletins for testing procedures that would be applicable for the particular system being tested or the testing procedures that accompanied the equipment from the manufacturing plant per NEC 230.95C.

4. For residual sequence sensing type systems utilizing phase and neutral current transformers, verify that polarities are correct by applying current to each phase-neutral current transformer pair. This test also applies to molded-case breakers using an external neutral current transformer.
   a. The relay should operate when the current direction is the same relative to polarity marks in the two current transformers.
   b. The relay should not operate when the current direction is opposite relative to polarity marks in the two current transformers.

5. Verify that zone selective interlock systems are operating correctly. Source breakers to an independent bus should receive a restraint signal when a ground fault is detected by a lower stream device. Complex systems having multiple sources and tie breakers should operate in a logical manner as is determined by the power system involved.

C. Optional Tests

1. Measure the insulation resistance of the control wiring in accordance with Table 100.1. Do not perform tests on wiring connected to solid-state relays.

2. Measure the time delay of the relay at 150 percent or greater of pickup. Verify operability of I^2t function, if being used, of the ground fault trip device.

3. Verify reduced control voltage tripping capability: 55 percent for ac systems.
SECTION 23—GROUNDING RESISTORS

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Clean the equipment and inspect the physical and mechanical condition of the equipment.
3. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer’s published data. If no manufacturer’s data is available, use the values in Tables 100.12 and 100.23.
4. Verify that all frame and enclosure grounds are correct.
5. Record tap connections on service report.
6. Perform a visual and mechanical inspection on all primary and secondary wiring and instrument transformers.

B. Electrical Tests

Record the date of the last calibration for each piece of test equipment used.

1. Perform insulation resistance tests on each instrument transformer, each winding to ground at 500 volts dc. Do not perform this test on solid state devices. Resistance readings should be consistent with Table 100.1 for test voltages of 500 volts dc.
2. Test all electrical controls (relays, lights, switches) to verify that they are operating properly.
3. Use an ohmmeter to measure the ohmic value of the resistor and compare with the nameplate value. Record results.
4. Verify continuity of conductor between resistor and switchgear, transformer or other connected device.
SECTION 24—GROUNDING SYSTEMS

A. Visual and Mechanical Inspection

1. Visually inspect the system to confirm the following;
   a. Type and size of the equipment grounding conductor between
      the grounding electrode or grounding electrode system and the
      service equipment.
   b. Type and size of the equipment grounding electrode(s). NOTE:
      This may be a single ground rod, interconnected ground rods or
      other materials as allowed by the NFPA 70. Additionally, only a
      portion of the electrode may be visible at the time of test.
   c. Confirm system bonding jumper is installed at the service
      entrance.

2. Confirm the tightness of all connections.

B. Electrical Tests

NOTE: Prior to any testing record the date or time (if less than 24 hours)
of the last rainfall and the soil conditions that the grounding electrode is
installed in.

Record the date of the last calibration for each piece of test equipment
used.

1. Perform a fall-of-potential test or alternative in accordance with IEEE
   Standard 81 with the main grounding electrode or the ground bus
   located within the service entrance equipment or substation as the
   designated reference point for the test to remote earth.

2. Perform point-to-point tests to confirm continuity and determine the
   resistance between the main grounding system and all major electrical
   equipment frames, system neutral, and/or derived neutral points.
SECTION 25—ISOLATED POWER SYSTEMS

NOTE: All equipment within the project scope shall be assured to be complete and of acceptable quality. Inspection and testing of all applicable wiring and equipment must conform to Article 517 of the National Electrical Code (NEC) and Article 99 of the National Fire Protection Association (NFPA).

A. Visual and Mechanical Inspection

1. Perform a functional check of all equipment to be evaluated.
2. Inspect all equipment in the area for physical damage such as cracked meters or scratches. Note any physical or electrical defects.
3. Inspect the room ground and the patient reference ground if installed.
4. Examine all connected branch circuit wiring.
5. Verify that the proper breaker identification is on the circuit schedule.
6. Any interconnected equipment (receptacles, ground jacks, lights, switches, and miscellaneous) that is found to not comply with applicable electrical codes should be noted on the inspection records.

B. Electrical Tests

1. Measure line-to-line and line-to-ground voltage with an ac voltmeter and record the voltage on the data sheet.
2. Measure the leakage current with an ac microammeter that is capable of being accurate within 3 percent. Record the value to three significant figures. Measure the current between L1 and ground and L2 and ground.
   NOTE: Before taking current measurements, verify that no phase conductor is at ground potential.
3. Record the individual line impedances based on the criteria below.
   a. Line impedance measurements will include all receptacles, but are not required to include lighting fixtures or components of fixtures. All electrical equipment connected to the isolated power system must be unplugged, and permanently installed equipment must be switched off.
   b. For isolation panels with branch-circuit interlock (x-ray panels), branch circuits must be measured individually. Record the circuit with the lowest calculated impedance as the “system” impedance.
   c. For panels in which a combination of circuits may be energized (PLC laser panels), measure branch circuits individually; energize the combination of circuits that contributes the highest amount of leakage current. This value is used to calculate the system impedance.
   d. If a line impedance is below 200,000 ohms (NFPA-99 1996, 3-3.2.2.2), the probable cause should be determined.
4. Line Isolation Monitor (LIM) Calibration Tests: Determine the exact trip point of the LIM and then measure the total hazard current with an ac milliammeter.

Apply the following test faults between the isolated conductors and ground:

- Single resistive L1 to ground
- Single resistive L2 to ground
- Single resistive L3 to ground (three-phase systems)
- Balanced resistive L1 to ground and L2 to ground (one-phase systems only)
- Single capacitive L1 to ground
- Single capacitive L2 to ground
- Single capacitive L3 to ground (three-phase systems)
- Balanced capacitive L1 to ground and L2 to ground (one-phase systems only)

C. Optional Tests

In patient care areas, determine the effectiveness of the equipment grounding system by using voltage and impedance measurements. Take these measurements with respect to a reference grounding point such as the ground bus in the isolation panel.

Take voltage measurements between the reference point and the exposed conductive surfaces (including ground contacts of receptacles) in the patient care vicinity.

**NOTE:** The voltage limit for new construction is 20mV.

Take impedance measurements between the reference point and the grounding contact of each receptacle in the patient vicinity.

**NOTE:** The impedance limit for new construction is 0.1 ohms.

The grounding terminals of all receptacles and the conductive surfaces of fixed equipment, operating at over 100 volts, must be grounded by a conductor sized in accordance with NEC.

**NOTE:** Conductive surfaces in the patient area that are not likely to become energized (such as windows, door frames, and towel dispensers) need not be intentionally grounded or tested. Ref: NFPA-99, 3-3.3.2.1
SECTION 26—MOTOR CONTROL CENTERS: LOW AND MEDIUM VOLTAGE

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Inspect the physical, electrical, and mechanical condition of structure and all electrical components and clean equipment.
3. Confirm correct application of manufacturer specified lubricants at recommended locations.
4. Verify appropriate anchorage, required area clearances, physical damage, and correct alignment.
5. Inspect all doors, panels, and sections for paint, dents, scratches, fit, and missing hardware.
6. Verify that fuse and/or circuit breaker sizes and types correspond to drawings and coordination study, if available.
7. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.
8. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
   b. Make key exchange with devices operated in off-normal positions.
9. Inspect insulators for evidence of physical damage or contaminated surfaces.
10. Verify correct barrier and shutter installation and operation.
11. Exercise all active components.
12. Verify that filters are in place and/or vents are clear.
13. Test the operation, alignment, and penetration of instrument transformer withdrawal disconnects, current carrying and grounding, in accordance with “Section 35—Transformers, Instrument”
   a. Inspect for physical damage, such as 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, if available.
B. Electrical Tests

**NOTE:** When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment. Surge Protection Devices must be completely disconnected from the electrical system (including neutral and ground).

Record the date of the last calibration for each piece of test equipment used.

1. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground at the minimum dc test voltage appropriate for the equipment Maximum Rated Voltage, in accordance with Table 100.1. Record the resistances.
2. Perform a functional test by applying control voltage and verifying that the equipment operates as intended.
3. Verify that MCC enclosure heaters operate properly.
4. Perform tests on starters in accordance with “Section 27—Motor Starters: Low Voltage” or “Section 28—Motor Starters: Medium Voltage”.
5. For medium voltage MCC’s, perform a dielectric test (Hi-Pot) on each bus section, each phase to ground with phases not under test grounded, in accordance with the manufacturer’s published data. If the manufacturer has no recommendation for this test, it shall be in accordance with Table 100.2. The test voltage shall be applied for one minute.

C. Optional Tests

1. Inspect and Test specified circuit breakers in accordance with “Section 14—Circuit Breakers: Low Voltage Insulated Case/Molded Case”
2. Determine the accuracy of all meters in accordance with “Section 8 Metering Devices”.
3. Perform insulation-resistance tests in accordance with Table 100.1. Do not perform this test on wiring connected to solid-state components.
4. Perform tests on all instrument transformers in accordance with “Section 35—Transformers, Instrument”.
5. Perform the following tests on control power transformers:
   a. Perform insulation-resistance tests. Take measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with Table 100.1 unless otherwise specified by the manufacturer.
   b. Perform a secondary wiring integrity test. Disconnect the transformer at secondary terminals, and connect secondary wiring to the correct secondary voltage. Confirm potential at all devices.
   c. Verify that the secondary voltage is correct by energizing primary winding with system voltage. Measure the secondary voltage with the secondary wiring disconnected.
6. For low voltage MCC’s, perform a dielectric test (Hi-Pot) on each bus section, each phase to ground with phases not under test grounded, in accordance with the manufacturer's published data. If the manufacturer has no recommendation for this test, it shall be in accordance with Table 100.2. The test voltage shall be applied for one minute.

7. Perform ground-resistance tests in accordance with "Section 22, Grounding Systems".

8. Perform a contact resistance test through all bus joints with a low resistance ohmmeter.
SECTION 27—MOTOR STARTERS: LOW VOLTAGE

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report. This will include: contactor, fuses, overloads, circuit breakers, overload relay heaters, power factor correction capacitors, and the control power transformer.
2. Inspect the physical and mechanical condition of the equipment.
3. Inspect starter contacts for signs of arcing, pitting or other deterioration.
4. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, reference the values in Tables 100.12 and 100.23.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment. Surge Protection Devices must be completely disconnected from the electrical system (including neutral and ground).

Record the date of the last calibration for each piece of test equipment used

1. Measure the insulation resistance of each combination starter, phase-to-phase and phase-to-ground, with the starter contacts closed and the protective device open. Test voltage shall be in accordance with Table 100.1. Refer to the manufacturer's instructions for devices with solid-state components.
2. Perform operational tests by initiating control devices.

C. Optional Tests

1. Measure the insulation resistance of each control circuit-to-ground. Test voltage shall be in accordance with Table 100.1. Do not perform tests on wiring connected to solid-state relays.
2. Test the motor overload relay elements by injecting primary current through the overload circuit, and monitoring the trip time of the overload element.
3. Test circuit breakers in accordance with the procedures in the appropriate section of this document based on circuit breaker type.
SECTION 28—MOTOR STARTERS: MEDIUM VOLTAGE

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Clean and inspect the physical, electrical, and mechanical condition of the equipment.
3. Confirm correct application of manufacturer specified lubricants at recommended locations.
4. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.
5. Test all electrical and mechanical interlock systems for correct operation and sequencing.
6. Inspect insulators for evidence of damage or contaminated surfaces.
7. Verify that barriers and shutters are installed and operating correctly.
8. Exercise all active components, and confirm that all indicating devices are operating correctly.
9. Inspect the contactors.
   a. Verify mechanical operation.
   b. Inspect and adjust contact gap, wipe and alignment in accordance with manufacturer's published data.
   c. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.
10. Confirm adjustment of programmable devices are in accordance with the customer supplied protective device coordination study, if available.

B. Electrical Tests

NOTE: When performing dielectric tests, you must disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment. Surge Protection Devices must be completely disconnected from the electrical system (including neutral and ground).

1. Verify that each control feature performs satisfactorily.
2. Perform insulation-resistance tests on contactor, phase-to-ground, phase-to-phase, and across the open contacts for one minute in accordance with Table 100.1.
3. Perform a contact-resistance test in accordance with the following procedure.
   a. Open and close starter several times to ensure the mechanism linkages are free and operate properly.
   b. Measure the resistance across each pole with a digital low resistance ohmmeter.
   c. Compare the Resistance values with manufacturers published data and between phases.
4. Perform a vacuum bottle integrity test using with the breaker in the open position in strict accordance with manufacturer’s instructions. Contact the manufacturer if questionable results are encountered.

5. Energize the contactor using an auxiliary source. Adjust the armature to minimize operating vibration where applicable.

6. Perform a Hi-Pot (dielectric) test in accordance with the manufacturer's instructions. In lieu of manufacturers recommended test voltages, refer to Table 100.19.

C. Optional Tests

1. Perform ratio and polarity tests on all current and voltage transformers in accordance with “Section 37—Transformers, Instrument”.

2. Test control power transformers in accordance with “Section 31—Switchgear and Switchboard Assemblies: Low and Medium Voltage”.

3. Test circuit breakers in accordance with the procedures in the appropriate section of this document based on circuit breaker type.

4. Perform a control wiring performance test. Use the elementary diagrams to identify each remote control and protective device.
SECTION 29—PROTECTIVE RELAYS

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report.
2. Inspect relays and cases for physical damage and clean equipment. Relay inspections and testing shall be performed in strict compliance with the manufacturer's instructions.
3. Tighten case connections. Inspect covers, gasket seals, shorting hardware, connection paddles, and/or knife switches. Remove any foreign material from the case. Verify targets operate and reset.
4. Determine if shorting screws are to be removed or remain in place. If shorting screws are removed they should be stored in or with the current transformer shorting blocks.
   NOTE: Any incorrectly placed shorting screws should be documented and reported to the owner prior to re-energizing the circuit.
5. For electromechanical relays, inspect disk slots of the damping and electromagnets, verify disk clearance, inspect spiral spring convolutions, and inspect disk and contacts for freedom of movement and correct travel, and verify the tightness of mounting hardware and connections. Operate the relay manually.
6. Set relays in accordance with the coordination study supplied by the owner, if available. If a coordination study is not available, the customer will be responsible for setting relays.

B. Electrical Tests

Record the date of the last calibration for each piece of test equipment used

1. Verify operation of all targets and indicators.
2. Verify the operation of all light-emitting diode indicators, if applicable.
3. Set contrast for liquid-crystal display readouts, if applicable.
4. Control Verification:
   a. Verify that each relay trips the appropriate circuit breaker and performs the desired function.
5. Verify all pickup/dropout parameters are on each operating element.
6. Verify timing at three points on the time dial curve.
7. For multifunction relays print the settings / configuration file to document which protective elements and outputs are operational.

C. Optional Tests

1. Perform a complete functional test of the protective system. This may include the following steps.
   a. Development of a system testing plan
   b. End to end testing
   c. Use of multiple input devices and simulation methods
   d. Verification of communications between the various components of the protective system.
SECTION 30—STEP VOLTAGE REGULATORS

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report.
2. Clean and inspect the physical and mechanical condition of the equipment.
3. Verify that auxiliary devices operate correctly.
4. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer’s published data. If no manufacturer’s data is available, use the values in Tables 100.12 and 100.23.
5. Verify that the motor and drive train operate correctly, and automatic motor cut-off at maximum lower and maximum raise.
6. Verify appropriate liquid level in all tanks and bushings.
7. Perform specific inspections and mechanical tests as recommended by the manufacturer.
8. Verify equipment grounding.
9. Record the ‘as found’ upper and lower voltage regulation settings on each regulator.

B. Electrical Tests

**NOTE:** When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment. Surge Protection Devices must be completely disconnected from the electrical system (including neutral and ground).

Record the date of the last calibration for each piece of test equipment used.

1. Perform insulation-resistance tests on each winding-to-ground in the neutral position with the test voltage in accordance with Table 100.1.
2. Perform special tests and adjustments as required by the manufacturer.
3. Perform a turns ratio test on each voltage step position. Verify that the indicator correctly identifies all tap positions.
4. Verify that the voltage range limiter operates accurately.
5. Verify functioning and accuracy of bandwidth, time delay, voltage, and line-drop compensation adjustments.
C. Optional Tests

1. Perform a dielectric breakdown test with a field tester.
2. Remove a sample of insulating liquid in the main tank or common tank in accordance with ASTM D-923. The sample shall be tested for the following:
   a. Dielectric breakdown voltage: ASTM D-877 and/or ASTM D-1816
   d. Interfacial tension: ASTM D-971 or ASTM D-2285.
   e. Color: ASTM D-1500.
3. Remove a sample of insulating liquid in the tap-changer tank in accordance with ASTM D-923. The sample shall be tested for the following:
SECTION 31 — SURGE ARRESTERS: LOW VOLTAGE SURGE PROTECTION DEVICES

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report. Compare Surge Protection Device ( SPD ) operating voltage with connected gear operating voltage insuring compatibility.

2. Inspect the physical and mechanical condition of the equipment.

3. Inspect SPD enclosure for discoloration, deformity, cracks or opening, or evidence of the explosion of any materials or particles from the SPDs.

4. Inspect for correct mounting and adequate clearances.

5. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer’s published data. If no, manufacturer’s data is available, use the values in Tables 100.12 and 100.23.

6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.

7. Reset the surge counter to zero ( if applicable ).

8. When equipped with push to test button(s), verify the proper operation of any visual and audible indicators. Reset all indicators after testing.

9. Verify that conductors between SPD and all phase, neutral, and ground bussing are as short and possible, do not contain any sharp bends, and that leads are twisted.

10. Verify that any indicating lights or LED are functioning as intended.

11. If SPD has a surge counter, record the number of surges registered on the counter.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment. Surge Protection Devices must be completely disconnected from the electrical system ( including neutral and ground ).

1. Perform insulation-resistance tests on each phase terminal-to-ground. The test voltage shall be in accordance with the manufacturers specifications. NOTE: Insulation resistance testing may not be applicable to all types surge arrester / suppression systems.
SECTION 32—SURGE ARRESTERS: MEDIUM AND HIGH VOLTAGE SURGE PROTECTION DEVICES

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report.
2. Clean arrester and inspect the physical and mechanical condition of the equipment.
3. Inspect for correct mounting and adequate clearances.
4. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer’s published data. If no manufacturer’s data is available, use the values in Tables 100.12 and 100.23.
5. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
6. Verify that the stroke counter, if present, is correctly mounted and electrically connected.
7. Where applicable, record the value of any operation or strike counters.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment. Surge Protection Devices must be completely disconnected from the electrical system (including neutral and ground).

1. Perform insulation-resistance tests on each phase terminal-to-ground. The test voltage shall be in accordance with the manufacturers specifications.
   NOTE: Insulation resistance testing may not be applicable to all types surge arrester / suppression systems.

C. Optional Tests

1. Perform a Watts-Loss / Milliwatts-Loss Test on each arrester.
SECTION 33—SWITCHGEAR AND SWITCHBOARD ASSEMBLIES: LOW AND MEDIUM VOLTAGE

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report.
2. Clean and inspect the physical, electrical, and mechanical condition of the equipment and all components in accordance with the applicable section(s) of this document and the manufacturers’ information.
3. Confirm that lubricants have been correctly applied at the manufacturer’s recommended locations.
4. Verify appropriate anchorage, required area clearances, physical damage, and correct alignment and cleanliness.
5. Inspect all doors, panels, and sections for paint, dents, scratches, fit, and missing hardware.
6. Verify that all hardware utilized to secure covers and doors is present and functions as designed.
7. Perform visual and mechanical inspections on instrument transformers in accordance with “Section 37—Transformers, Instrument”.
8. Verify that the tightness of accessible cable connections are in accordance with the manufacturer’s published data. If no manufacturer’s data is available, use the values in Tables 100.12 and 100.23.
9. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
   b. Make key exchange with devices operated in off-normal positions.
10. Inspect insulators for evidence of physical damage or contaminated surfaces.
11. Verify that the barriers and shutters are installed and operating correctly.
12. Exercise all active components.
13. Inspect all mechanical indicating devices for correct operation.
14. Verify that filters are in place and/or vents are clear.
15. For arc resistant switchgear, verify all vent flaps are open and arc flaps are closed.
16. Inspect control power transformers.
   a. Inspect the transformers for physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
17. Verify that drawout disconnecting and grounding contacts and interlocks function correctly.
18. Verify that customer connections to remote power, operators, interlocks, and indicators have been made.
B. Electrical Tests

**NOTE:** When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance with Switchgear or Switchboard industry standards.

1. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground, at the minimum dc test voltage appropriate for the equipment’s Maximum Rated Voltage in accordance with Table 100.1. Record the resistances. **NOTE:** If the resistance is lower than the recommended values in Table 100.1, report it to the owner or project manager. It may be possible to dry the equipment using heat and fans. Any initial and low readings should be documented along with any steps made to correct the deficiency. **If low readings persist, contact the manufacturer.**
2. Verify that the equipment operates as intended.
3. Verify correct function of control power transfer relays located in switchgear with multiple power sources.
4. When applicable, verify proper operation of Automatic Transfer Scheme and verify Sequence of Operation
5. Verify operation of switchgear/switchboard heaters.
6. Perform a dielectric test (Hi-Pot) on each bus section, each phase to ground with phases not under test grounded, in accordance with Table 100.2 or the manufacturer’s published data. **NOTE:** This test is standard on medium voltage switchgear and optional on low voltage switchgear and switchboards.

C. Optional Tests

1. Perform tests on all instrument transformers in accordance with “Section 37—Transformers, Instrument”.
2. Perform insulation-resistance tests in accordance with Table 100.1 on all control wiring. Do not perform this test on wiring connected to solid-state components.
3. Perform ground-resistance tests in accordance with “Section 22—Grounding Systems”.
4. 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 100.1 unless otherwise specified by the manufacturer.
   b. Inspect primary winding tap connections and secondary terminal connections for correct wiring for primary and secondary voltages involved.
   c. Perform a secondary wiring integrity test. Disconnect the transformer at secondary terminals and connect secondary wiring to correct secondary voltage. Confirm potential at all devices.
   d. Verify correct secondary voltage by energizing primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.
5. Perform a contact resistance test through all bus joints, using a low resistance ohmmeter.

6. Perform tests on ground fault protection system in accordance with “Section 22—Ground-Fault Protection Systems”.

7. Perform current tests by primary injection on all metering and relaying circuits, other than ground fault, in each section of switchgear with magnitudes, such that a minimum of 1.0 ampere flows in the secondary circuit. Verify that the secondary current flow at each device is intended in the current circuit.

8. Determine the accuracy of all meters per “Section 8—Metering”.

9. For medium voltage switchgear, perform a dielectric test (Hi-Pot) on each bus section, each phase to ground with phases not under test grounded, in accordance with Table 100.2 or the manufacturer’s published data.
SECTION 34—SWITCHGEAR
DVCAS-38

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on test report.
2. Inspect physical and mechanical condition and clean equipment.
3. Check all control wiring with the wiring diagrams.
4. Verify that all connections are properly made and tightened to the proper torque values.
5. Check all interlocking systems for correct operation and sequencing, and key distribution, if applicable.
6. If any isolating switch is not in operation and is left without incoming cables, the corresponding grounding switch must be closed and blocked by means of a padlock to avoid possible unintentional operation.
7. Verify appropriate anchorage and required area clearances.
8. Verify appropriate equipment grounding.
9. Verify that all surfaces are clean and dry.
10. Verify that all barriers and covers are secured.
11. Operate the grounding switch, isolating switch, circuit breaker and mechanical interlocks a minimum of five times and verify they are functioning properly.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or be damaged by the applied test voltage. Verify no paths to ground exist with an ohmmeter or initially testing insulation resistance at a low voltage.

1. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute. Test voltage shall be in accordance with the below table.
2. Perform Hi-Pot test
   - Disconnect all potential transformer secondary connections or remove all secondary fuses to isolate the transformer
   - Short all current transformer secondary terminals or connections.
   - Apply voltage to each phase individually for one minute with the other two phases and enclosure grounded. (see below table for Hi-Pot test values)
   - Gradually increase voltage.

<table>
<thead>
<tr>
<th>Equipment Rating</th>
<th>Field Test Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>38kV AC</td>
<td>38kV DC</td>
</tr>
<tr>
<td>38kV DC</td>
<td>64kV</td>
</tr>
</tbody>
</table>
SECTION 35—TRANSFORMERS: DRY TYPE: ALL VOLTAGES
- LARGE (GREATER THAN 167 SINGLE-PHASE AND 500KVA THREE-PHASE)

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report.
2. Clean entire transformer and inspect the physical and mechanical condition of the equipment.
3. Verify that the control and alarm settings on temperature indicators are as specified, if the settings are available.
4. Verify that cooling fans operate correctly.
5. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.1 and 100.23.
6. Verify that winding core, frame, and enclosure groundings are correct.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance industry standards.

1. Perform insulation-resistance tests winding-to-winding and each winding- to-ground, with test voltage in accordance with Table 100.5. Test duration shall be for ten minutes with resistances tabulated at 30 seconds, one minute, and ten minutes.
2. Perform a transformer turns-ratio test on as found tap connections.

C. Optional Tests

1. For 5kV and above, perform power-factor or dissipation-factor and excitation- current tests in accordance with the test equipment manufacturer's instructions.
2. Measure the resistance of each winding at each tap connection.
3. Perform a transformer turns-ratio test on all tap connections.
4. Verify that the core is grounded. If the core is insulated and a removable core ground strap is available, perform a core insulation-resistance test at 500 volts dc.
SECTION 36—TRANSFORMERS: DRY TYPE - SMALL (167kVA SINGLE-PHASE, 500kVA THREE-PHASE, AND SMALLER)

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report.
2. Inspect the physical and mechanical condition of the equipment and clean equipment.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Surge Protection Devices, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance industry standards.

1. Perform an insulation-resistance test. Measurements shall be made from winding-to-winding and each winding-to-ground. Test voltages and minimum resistance shall be in accordance with Table 100.5. Results should be temperature corrected in accordance with Table 100.14.
2. Perform a transformer turns-ratio test on as found tap connection.
SECTION 37—TRANSFORMERS, INSTRUMENT

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report.
2. Clean and inspect the physical and mechanical condition of the equipment.
3. Verify that adequate clearances exist between primary and secondary circuit wiring.
4. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer’s published data. If no manufacturer’s data is available, use the values in Tables 100.12 and 100.23.
5. Verify that all required grounding and shorting connections provide contact.
6. Verify that all shorting blocks are in the correct position, either grounding or open, as required.
   NOTE: Any incorrectly placed shorting blocks should be documented and reported to the owner prior to re-energizing the circuit.
7. Verify correct operation of instrument transformer draw-out mechanisms and grounding operation.
8. Record primary and secondary fuse sizes for potential transformers.

B. Electrical Tests - Current Transformers

Record the date of the last calibration for each piece of test equipment used.

1. Perform an insulation-resistance test of the current transformer and wiring-to-ground at 500 volts dc. Do not perform this test on solid-state devices. Resistance readings should be consistent with Table 100.1 for a test voltage of 500 volts dc.
2. Perform a polarity test of each current transformer.
3. Perform a ratio-verification test using the voltage or current method in accordance with ANSI C5XVIII.1 (IEEE Guide for Field Testing of Relaying Current Transformers).

C. Optional Tests - Current Transformers

1. Perform an excitation test on transformers used for relaying applications in accordance with ANSI C5XVIII.1. (IEEE Guide for Field Testing of Relaying Current Transformers).
2. Measure current circuit burdens at transformer terminals and determine the total burden.
3. When applicable, perform insulation-resistance and dielectric withstand tests on the primary winding with secondary grounded. Test voltages shall be in accordance with Table 100.1 saturation voltage test.
D. Electrical Tests - Potential Transformers

Record the date of the last calibration for each piece of test equipment used.

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 100.1. Do not perform this test with solid-state devices connected.

2. Perform a polarity test on each transformer to verify the polarity marks or H1-X1 relationship as applicable.

E. Optional Tests - Potential Transformers

1. Measure potential circuit burdens at transformer terminals and determine the total burden.

2. Perform a dielectric withstand test on the primary windings with the secondary windings connected to ground. The dielectric voltage shall be in accordance with Table 100.9. The test voltage shall be applied for one minute.
SECTION 38—TRANSFORMERS: LIQUID-FILLED: ALL VOLTAGES

A. Visual and Mechanical Inspection

1. Document equipment nameplate data on the test report.
2. Clean and inspect the physical and mechanical condition of the equipment.
3. Record alarm, control, and trip settings.
4. Verify that cooling fans and pumps operate correctly.
5. Verify operation of all alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relay. (Optional second visit if the equipment cannot be energized.)
6. Using a calibrated torque wrench or low resistance ohmmeter, verify that the tightness of accessible bolted connections and/or cable connections are in accordance with the manufacturer's published data. If no manufacturer's data is available, use the values in Tables 100.12 and 100.23.
7. Verify correct liquid level in all tanks and bushings.
8. Verify that positive pressure is maintained on nitrogen-blanketed transformers.
9. Verify correct equipment grounding.
10. Test load tap-changer in accordance with “Section 30—Step Voltage Regulators”, if applicable.

B. Electrical Tests

NOTE: When performing dielectric tests, disconnect all Instrument and Control Transformers, Arresters, TVSS units, and other sensitive electronic equipment that may cause erroneous results or cause damage to equipment that is not rated in accordance industry standards.

1. Perform insulation-resistance tests, winding-to-winding, and each winding-to-ground with the test voltage in accordance with Table 100.5. Test duration shall be for ten minutes with resistances tabulated at 30 seconds, one minute, and ten minutes.
2. Perform a transformer turns-ratio test on as found tap-changer position.

C. Optional Tests

1. Perform insulation power-factor/dissipation-factor tests on all windings and correct to 20° C in accordance with the test equipment manufacturer's instructions.
2. Perform power-factor/dissipation-factor tests (or hot collar watts-loss tests) on bushings and correct for 20° C in accordance with the test equipment manufacturer's instructions.
3. Perform excitation-current tests in accordance with the test equipment manufacturer's instructions.
4. Measure the resistance of each winding at each tap connection.
5. Perform a transformer turns-ratio test on all no-load tap-changer positions and all load tap-changer positions.
6. Remove a sample of insulating liquid in accordance with ASTM D-923.
7. The sample shall be tested for the following:
   a. Dielectric breakdown voltage: ASTM D-877 and/or ASTM D-1816.
   d. Interfacial tension: ASTM D-971 or ASTM D-2285.
   e. Color: ASTM D-1500.
   g. Parts per million water: ASTM D-1533. Required on 25 kV or higher voltages and on all silicone-filled units.
   h. Measure dissipation factor or power factor in accordance with ASTM D-924.
8. Remove a sample of insulating liquid in accordance with ASTM D3613 and perform dissolved gas analysis (DGA) in accordance with ANSI/IEEE C5XVI4 or ASTM D-3612.
9. If a core ground strap is accessible, measure the core insulation resistance at 500 Vdc.
10. Measure the insulation resistance of each high-voltage winding in each no-load tap-changer position. Measure the resistance of each low-voltage winding in each load tap-changer position, if applicable.
NOTE: Proper infrared scanning of electrical power systems requires that the system be energized and under normal load.

WARNING: Infrared scanning of energized electrical systems poses potential safety hazards for the person performing the scan, the person(s) opening/removing covers and any other persons working within the limited approach boundary (often 10 feet or further) of the work area. A proper job briefing, safety review and job hazard analysis are required prior to commencing work. All relevant safe work practices must be strictly adhered to.

A. Visual and Mechanical Inspection

1. Document all equipment to be scanned on test report.
2. Visually inspect equipment prior to removal of covers or opening doors to determine if any obvious signs of impending mechanical failure or deterioration indicate it may not be safe to proceed. Document any deficiencies.

B. Infrared Scan

1. Gain access to equipment to be scanned by opening hinged covers or removal of bolted covers. This is to be performed by customer or facility electricians.
2. Perform infrared scan in accordance with operating procedures for the specific scanning equipment utilized.
3. For equipment indicating abnormal temperatures, attempt to determine equipment loading or take current measurements when it is safe to do so, document findings
4. Record a thermal and visual light picture for all of out of tolerance conditions.
5. Note: For equipment operating within normal limits infrared images and visible light pictures will not be taken
6. Prepare a final report including list of scanned equipment, out of tolerance conditions and recommendations for any required corrective actions.

c. Optional Tests

1. Open hinged doors or remove covers to gain access to equipment to be scanned. This aspect of infrared scanning is normally provided by customer staff or electricians. This service can be provided by Schneider Electric Services as an optional service.
### TABLE 100.1
Insulation Test Voltages and Analysis of Test Results

<table>
<thead>
<tr>
<th>Rated Voltage of Equipment</th>
<th>Recommended Test Voltage*</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>500</td>
</tr>
<tr>
<td>600</td>
<td>1,000</td>
</tr>
<tr>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>2,500</td>
<td>1,000</td>
</tr>
<tr>
<td>5,000</td>
<td>2,500</td>
</tr>
<tr>
<td>8,000</td>
<td>2,500</td>
</tr>
<tr>
<td>15,000</td>
<td>2,500</td>
</tr>
<tr>
<td>25,000</td>
<td>5,000</td>
</tr>
<tr>
<td>34,500 and above</td>
<td>5,000</td>
</tr>
</tbody>
</table>

* These values should only be utilized in the absence of manufacturer guidelines or other standards that are specific to the equipment type being tested.

Evaluation of Results:

The main value of insulation resistance testing lies in the charting of data recorded from periodic tests. For the data to be useful the tests should be conducted in a similar manner each time. All test data should be corrected for temperature using Table 100.14.

Trends observed based on charted results may be useful to indicate deteriorating conditions or an increase in contamination.

A single insulation resistance test may be used to establish a baseline or detect a possible short circuit. A single test should not be considered a definitive indication of insulation weakness or overall dielectric strength.

Any test results that are considered questionable or possibly indicative of a significant problem should be reviewed with the equipment manufacturer prior to re-energization or taking other corrective measures.
**TABLE 100.2**  
Switchgear Withstand Test Voltages

<table>
<thead>
<tr>
<th>Type of Switchgear</th>
<th>Rated Maximum Voltage (kV) (rms)</th>
<th>Maximum Test Voltage (kV)</th>
<th>AC</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Voltage Power Circuit Breaker Switchgear</td>
<td>.254/.508/.635</td>
<td>1.6</td>
<td>1.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Metal-Clad Switchgear</td>
<td>4.76</td>
<td>14</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.25</td>
<td>27</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15.0</td>
<td>27</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>27.0</td>
<td>45</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>38.0</td>
<td>60</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td>Station-Type Cubicle Switchgear</td>
<td>15.5</td>
<td>37</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>38.0</td>
<td>60</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>72.5</td>
<td>120</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td>Metal-Enclosed Interrupter Switchgear</td>
<td>4.76</td>
<td>14</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.25</td>
<td>19</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15.0</td>
<td>27</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>27.0</td>
<td>45</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>38.0</td>
<td>60</td>
<td>a</td>
<td></td>
</tr>
</tbody>
</table>


The column headed “DC” is given as a reference only for those using dc tests to verify the integrity of connected cable installations without disconnecting the cables from the switchgear. It represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for voltage rating of switchgear. The presence of this column in no way implies any requirement for a dc withstand test on ac equipment or that a dc withstand test represents an acceptable alternative to the low-frequency withstand tests specified in these specifications, either for design tests, production tests, conformance tests, or field tests. When making dc tests, the voltage should be raised to the test value in discrete steps and held for a period of one minute.

a. Because of the variable voltage distribution encountered when making dc withstand tests, the manufacturer should be contacted for recommendations before applying dc withstand tests to the switchgear. Voltage transformers above 34.5 kV should be disconnected when testing with dc. Refer to ANSI/IEEE C57.13-1993 (*IEEE Standard Requirements for Instrument Transformers*) paragraph 8.8.2.
### TABLE 100.3

**Maintenance Test Values**

**Recommended Dissipation Factor/Power Factor at 20° C**

**Liquid-Filled Transformers, Regulators, and Reactors**

<table>
<thead>
<tr>
<th></th>
<th>Oil Maximum</th>
<th>Silicone Maximum</th>
<th>Tetrachloroethylene Maximum</th>
<th>High Fire Point Hydrocarbon Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Transformers</strong></td>
<td>1.0%</td>
<td>0.5%</td>
<td>3.0%</td>
<td>2.0%</td>
</tr>
<tr>
<td><strong>Distribution Transformers</strong></td>
<td>2.0%</td>
<td>0.5%</td>
<td>3.0%</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

In the absence of consensus standards dealing with transformer dissipation/power factor values, the NETA Standards Review Council suggests the above representative values. Maximum values for oil are based on data from Doble Engineering Company.
# TABLE 100.4.1

Suggested Limits for Class I Insulating Oil

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Method</th>
<th>Acceptable Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>69 kV and Below</td>
</tr>
<tr>
<td>Dielectric breakdown, kV minimum b</td>
<td>D 877</td>
<td>26</td>
</tr>
<tr>
<td>Dielectric breakdown, kV minimum @ 1 mm (0.04 inch) gap</td>
<td>D 1816</td>
<td>23</td>
</tr>
<tr>
<td>Dielectric breakdown, kV minimum @ 2 mm (0.08 inch) gap</td>
<td>D 1816</td>
<td>40</td>
</tr>
<tr>
<td>Interfacial tension mN/m minimum</td>
<td>D 971 or D 2285</td>
<td>25</td>
</tr>
<tr>
<td>Neutralization number, mg KOH/g maximum</td>
<td>D 974</td>
<td>0.20</td>
</tr>
<tr>
<td>Water content, ppm maximum @ 60° C c</td>
<td>D 1533</td>
<td>35</td>
</tr>
<tr>
<td>Power factor at 25° C, %</td>
<td>D 924</td>
<td>0.5</td>
</tr>
<tr>
<td>Power factor at 100° C, %</td>
<td>D 924</td>
<td>5.0</td>
</tr>
<tr>
<td>Color d</td>
<td>D 1500</td>
<td>3.5</td>
</tr>
<tr>
<td>Visual Condition</td>
<td>D 1524</td>
<td>Bright, clear and free of particles</td>
</tr>
<tr>
<td>Specific Gravity (Relative Density)</td>
<td>D 1298</td>
<td>0.91</td>
</tr>
</tbody>
</table>

b. IEEE STD 637-1985 Guide for Reclamation of Insulating Oil and Criteria for Its Use, Table 1.
d. In the absence of consensus standards, NETA’s Standard Review Council suggests these values.
e. ANSI/IEEE C57.106 Guide for Acceptance and Maintenance of Insulating Oil in Equipment, Table 1.
TABLE 100.4.2
Suggested Limits for Less-Flammable Hydrocarbon Insulating Liquid

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Method</th>
<th>Acceptable Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric breakdown voltage, kV minimum</td>
<td>D 877</td>
<td>24</td>
</tr>
<tr>
<td>Dielectric breakdown voltage for 1 mm (0.04 inch) gap, kV minimum</td>
<td>D 1816</td>
<td>34</td>
</tr>
<tr>
<td>Dielectric breakdown voltage for 2 mm (0.08 inch) gap, kV minimum</td>
<td>D 1816</td>
<td>24</td>
</tr>
<tr>
<td>Water content, ppm maximum</td>
<td>D 1533 B</td>
<td>35</td>
</tr>
<tr>
<td>Dissipation/power factor, 60 hertz, % max. @ 25° C</td>
<td>D 924</td>
<td>1.0</td>
</tr>
<tr>
<td>Fire point, °C, minimum</td>
<td>D 92</td>
<td>300</td>
</tr>
<tr>
<td>Interfacial tension, mN/m, 25° C</td>
<td>D 971</td>
<td>24</td>
</tr>
<tr>
<td>Neutralization number, mg KOH/g</td>
<td>D 664</td>
<td>0.20</td>
</tr>
</tbody>
</table>


The values in this table are considered typical for acceptable service-aged LFH fluids as a general class. If actual test analysis approaches the values shown, consult the fluid manufacturer for specific recommendations.

If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.
TABLE 100.4.3
Suggested Limits for Service-Aged Silicone Insulating Liquid

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Method</th>
<th>Acceptable Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric breakdown, kV minimum</td>
<td>D 877</td>
<td>25</td>
</tr>
<tr>
<td>Visual</td>
<td>D 2129</td>
<td>Colorless, clear, free of particles</td>
</tr>
<tr>
<td>Water content, ppm maximum</td>
<td>D 1533</td>
<td>100</td>
</tr>
<tr>
<td>Dissipation/power factor, 60 hertz, maximum @ 25°C</td>
<td>D 924</td>
<td>0.2</td>
</tr>
<tr>
<td>Viscosity, cSt @ 25°C</td>
<td>D 445</td>
<td>47.5 – 52.5</td>
</tr>
<tr>
<td>Fire point, °C, minimum</td>
<td>D 92</td>
<td>340</td>
</tr>
<tr>
<td>Neutralization number, mg KOH/g max.</td>
<td>D 974</td>
<td>0.2</td>
</tr>
</tbody>
</table>


TABLE 100.4.4
Suggested Limits for Service-Aged Tetrachloroethylene Insulating Fluid

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Method</th>
<th>Acceptable Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric breakdown, kV minimum</td>
<td>D 877</td>
<td>26</td>
</tr>
<tr>
<td>Visual</td>
<td>D 2129</td>
<td>Clear with purple iridescence</td>
</tr>
<tr>
<td>Water content, ppm maximum</td>
<td>D 1533</td>
<td>35</td>
</tr>
<tr>
<td>Dissipation/power factor, % maximum @ 25°C</td>
<td>D 924</td>
<td>12.0</td>
</tr>
<tr>
<td>Viscosity, cSt @ 25°C</td>
<td>D 445</td>
<td>0</td>
</tr>
<tr>
<td>Fire point, °C, minimum</td>
<td>D 92</td>
<td>-</td>
</tr>
<tr>
<td>Neutralization number, mg KOH/g maximum</td>
<td>D 974</td>
<td>0.25</td>
</tr>
<tr>
<td>Neutralization number, mg KOH/g maximum</td>
<td>D 664</td>
<td>-</td>
</tr>
<tr>
<td>Interfacial tension, mN/m minimum @ 25°C</td>
<td>D 971</td>
<td>-</td>
</tr>
</tbody>
</table>

Instruction Book PC-2000 for Wecosol™ Fluid-Filled Primary and Secondary Unit Substation Transformers, ABB Power T&D.
## TABLE 100.5
Transformer Insulation Resistance
Maintenance Testing

<table>
<thead>
<tr>
<th>Transformer Coil Rating Type (Volts)</th>
<th>Minimum DC Test Voltage</th>
<th>Recommended Minimum Insulation Resistance (Megohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Liquid Filled</td>
</tr>
<tr>
<td>0 – 600</td>
<td>1000</td>
<td>100</td>
</tr>
<tr>
<td>601 – 5000</td>
<td>2500</td>
<td>1000</td>
</tr>
<tr>
<td>Greater than 5000</td>
<td>5000</td>
<td>5000</td>
</tr>
</tbody>
</table>

In the absence of consensus standards, the NETA Standards Review Council suggests the above representative values.

See Table 100.14 for temperature correction factors.

NOTE: Since insulation resistance depends on insulation rating (kV) and winding capacity (kVA), values obtained should be compared to manufacturer’s published data.
## TABLE 100.6.1

Medium-Voltage Cables
Maintenance Test Values
DC Test Voltages

<table>
<thead>
<tr>
<th>Rated Voltage Phase-to-Phase (kV)</th>
<th>Conductor Size AWG or kcmil (mm)</th>
<th>Nominal Insulation Thickness mils (mm)</th>
<th>Maximum DC Field Test Voltages (kV) First 5 Years After Installation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100% Insulation Level</td>
<td>133% Insulation Level</td>
</tr>
<tr>
<td>5</td>
<td>8-1000 (8.4-507) Above 1000 (507)</td>
<td>90 (2.29)</td>
<td>115 (2.92)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>140 (3.56)</td>
<td>140 (3.56)</td>
</tr>
<tr>
<td>8</td>
<td>6-1000 (13.3-507) Above 1000 (507)</td>
<td>115 (2.92)</td>
<td>140 (3.56)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>175 (4.45)</td>
<td>175 (4.45)</td>
</tr>
<tr>
<td>15</td>
<td>2-1000 (33.6-507) Above 1000 (507)</td>
<td>175 (4.45)</td>
<td>220 (5.59)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>220 (5.59)</td>
<td>220 (5.59)</td>
</tr>
<tr>
<td>25</td>
<td>1-2000 (42.4-1013)</td>
<td>260 (6.60)</td>
<td>320 (8.13)</td>
</tr>
<tr>
<td>28</td>
<td>1-2000 (42.4-1013)</td>
<td>280 (7.11)</td>
<td>345 (8.76)</td>
</tr>
<tr>
<td>35</td>
<td>1/0-2000 (53.5-1013)</td>
<td>345 (8.76)</td>
<td>420 (10.7)</td>
</tr>
<tr>
<td>46</td>
<td>4/0-2000 (107.2-1013)</td>
<td>445 (11.3)</td>
<td>580 (14.7)</td>
</tr>
</tbody>
</table>

### TABLE 100.6.2

Field Test Voltages for Laminated Dielectric, Shielded Power Cable Systems Rated 5,000 Volts and Above with High DC Voltage

<table>
<thead>
<tr>
<th>System voltage, kV rms, phase-to-phase</th>
<th>System BIL, kV crest</th>
<th>Maintenance test, kV dc, phase-to-ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>75</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>95</td>
<td>29</td>
</tr>
<tr>
<td>15</td>
<td>110</td>
<td>46</td>
</tr>
<tr>
<td>25</td>
<td>150</td>
<td>61</td>
</tr>
<tr>
<td>28</td>
<td>170</td>
<td>68</td>
</tr>
<tr>
<td>35</td>
<td>200</td>
<td>75</td>
</tr>
<tr>
<td>46</td>
<td>250</td>
<td>95</td>
</tr>
<tr>
<td>69</td>
<td>350</td>
<td>130</td>
</tr>
<tr>
<td>115</td>
<td>450</td>
<td>170</td>
</tr>
<tr>
<td>115</td>
<td>550</td>
<td>205</td>
</tr>
<tr>
<td>138</td>
<td>650</td>
<td>245</td>
</tr>
<tr>
<td>161</td>
<td>750</td>
<td>280</td>
</tr>
<tr>
<td>230</td>
<td>1050</td>
<td>395</td>
</tr>
<tr>
<td>345</td>
<td>1175</td>
<td>440</td>
</tr>
<tr>
<td>345</td>
<td>1300</td>
<td>488</td>
</tr>
<tr>
<td>500</td>
<td>1425</td>
<td>535</td>
</tr>
<tr>
<td>500</td>
<td>1550</td>
<td>580</td>
</tr>
<tr>
<td>500</td>
<td>1675</td>
<td>629</td>
</tr>
</tbody>
</table>

**NOTE 1** – Voltages higher than those listed, up to 80% of system BIL, may be considered, but the age and operating environment of the system should be taken into account. The user is urged to consult the suppliers of the cable and any/all accessories before applying the high voltage.

**NOTE 2** – When older cables or other types/classes of cables or other equipment, such as transformers, switchgear, motors, etc. are connected to the cable to be tested, voltages lower than those shown in this table may be necessary to comply with the limitations imposed by such interconnected cables and equipment. See IEEE Std 95 [B5] and Table 1 of IEEE Std C37.20.2 [B7].

**NOTE 3** – If the test voltage exceeds 50% of system BIL, surge protection against excessive overvoltages induced by flashovers at the termination should be provided.

**NOTE 4** – It is strongly recommended that the user consult with the manufacturer(s) of all components that will be subjected to such testing before performing any tests on cables and cable accessories rated 115 kV and higher.

**NOTE 5** – It should be noted that this table and the test procedures suggested in this guide do not necessarily agree with the recommendations of other organizations, such as those of the Association of Edison Illuminating Companies [B1], [B2], [B3], [B4]. Where there is concern, a user should consult the supplier of the cable and accessories to ascertain that the components will withstand the test.

TABLE 100.6.3

Very Low Frequency Testing Levels for Medium-Voltage Cable
0.1 Hz Test Voltage (rms)

<table>
<thead>
<tr>
<th>System Voltage Phase-to-Phase (kV) (rms)</th>
<th>Maintenance Phase-to-Ground (kV) (rms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>35</td>
<td>33</td>
</tr>
</tbody>
</table>

Adaptation of table from IEEE Std 400.2-2004 *Guide for field testing of shielded power cable systems using very low frequency (VLF).*
# TABLE 100.7

Molded-Case Circuit Breakers

Inverse Time Trip Test

(At 300% of Rated Continuous Current of Circuit Breaker)

<table>
<thead>
<tr>
<th>Range of Rated Continuous Current (Amperes)</th>
<th>Maximum Trip Time in Seconds for Each Maximum Frame Rating&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 250 V</td>
</tr>
<tr>
<td>0-30</td>
<td>50</td>
</tr>
<tr>
<td>31-50</td>
<td>80</td>
</tr>
<tr>
<td>51-100</td>
<td>140</td>
</tr>
<tr>
<td>101-150</td>
<td>200</td>
</tr>
<tr>
<td>151-225</td>
<td>230</td>
</tr>
<tr>
<td>226-400</td>
<td>300</td>
</tr>
<tr>
<td>401-600</td>
<td>- - - -</td>
</tr>
<tr>
<td>601-800</td>
<td>- - - -</td>
</tr>
<tr>
<td>801-1000</td>
<td>- - - -</td>
</tr>
<tr>
<td>1001 – 1200</td>
<td>- - - -</td>
</tr>
<tr>
<td>1201-1600</td>
<td>- - - -</td>
</tr>
<tr>
<td>1601-2000</td>
<td>- - - -</td>
</tr>
<tr>
<td>2001-2500</td>
<td>- - - -</td>
</tr>
<tr>
<td>2501-5000</td>
<td>- - - -</td>
</tr>
<tr>
<td>6000</td>
<td>- - - -</td>
</tr>
</tbody>
</table>

Derived from Table 5-3, NEMA Standard AB 4-2000, Guidelines for Inspection and Preventative Maintenance of Molded-Case Circuit Breaker Used in Commercial and Industrial Applications.

<sup>a</sup> Trip times may be substantially longer for integrally-fused circuit breakers if tested with the fuses replaced by solid links (shorting bars).
## TABLE 100.8

### Instantaneous Trip Tolerances for Field Testing of Circuit Breakers

<table>
<thead>
<tr>
<th>Breaker Type</th>
<th>Tolerance of Settings</th>
<th>High Side</th>
<th>Low Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Trip Units (1)</td>
<td>+30%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Adjustable (1)</td>
<td>+40%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-30%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nonadjustable (2)</td>
<td>-</td>
<td>+25%</td>
<td>-25%</td>
</tr>
</tbody>
</table>

NEMA AB4-2009 Guidelines for Inspection and Preventative Maintenance of Molded-Case Circuit Breaker Used in Commercial and Industrial Applications, Table 4.

1. Tolerances are based on variations from the nominal settings.
2. Tolerances are based on variations from the manufacturer’s published trip band (i.e., -25% below the low side of the band; +25% above the high side of the band.)
TABLE 100.9

Instrument Transformer Dielectric Tests
Field Maintenance

<table>
<thead>
<tr>
<th>Nominal System (kV)</th>
<th>BIL (kV)</th>
<th>Periodic Dielectric Withstand Test Field Test Voltage (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AC</td>
</tr>
<tr>
<td>0.6</td>
<td>10</td>
<td>2.6</td>
</tr>
<tr>
<td>1.1</td>
<td>30</td>
<td>6.5</td>
</tr>
<tr>
<td>2.4</td>
<td>45</td>
<td>9.7</td>
</tr>
<tr>
<td>4.8</td>
<td>60</td>
<td>12.3</td>
</tr>
<tr>
<td>8.32</td>
<td>75</td>
<td>16.9</td>
</tr>
<tr>
<td>13.8</td>
<td>95</td>
<td>22.1</td>
</tr>
<tr>
<td>13.8</td>
<td>110</td>
<td>22.1</td>
</tr>
<tr>
<td>25</td>
<td>125</td>
<td>26.0</td>
</tr>
<tr>
<td>25</td>
<td>150</td>
<td>32.5</td>
</tr>
<tr>
<td>34.5</td>
<td>150</td>
<td>32.5</td>
</tr>
<tr>
<td>34.5</td>
<td>200</td>
<td>45.5</td>
</tr>
<tr>
<td>46</td>
<td>250</td>
<td>61.7</td>
</tr>
<tr>
<td>69</td>
<td>350</td>
<td>91.0</td>
</tr>
<tr>
<td>115</td>
<td>450</td>
<td>120.0</td>
</tr>
<tr>
<td>115</td>
<td>550</td>
<td>149.0</td>
</tr>
<tr>
<td>138</td>
<td>550</td>
<td>149.0</td>
</tr>
<tr>
<td>138</td>
<td>650</td>
<td>178.0</td>
</tr>
<tr>
<td>161</td>
<td>650</td>
<td>178.0</td>
</tr>
<tr>
<td>161</td>
<td>750</td>
<td>211.0</td>
</tr>
<tr>
<td>230</td>
<td>900</td>
<td>256.0</td>
</tr>
<tr>
<td>230</td>
<td>1050</td>
<td>299.0</td>
</tr>
</tbody>
</table>

Table is derived from Paragraph 8.8.2 and Tables 2 and 7 of ANSI/IEEE C57.13-1993, Standard Requirements for Instrument Transformers.

a. Periodic dc potential tests are not recommended for transformers rated higher than 34.5 kV.

b. Under some conditions transformers may be subjected to periodic insulation test using direct voltage. In such cases the test direct voltage should not exceed the original factory test rms alternating voltage. Periodic direct-voltage tests should not be applied to (instrument) transformers of higher than 34.5 kV voltage rating.
TABLE 100.10

Maximum Allowable Vibration Amplitude

<table>
<thead>
<tr>
<th>RPM (at 60 Hz)</th>
<th>Velocity (in/s peak)</th>
<th>Velocity (mm/s)</th>
<th>RPM (at 50 Hz)</th>
<th>Velocity (in/s peak)</th>
<th>Velocity (mm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3600</td>
<td>0.15</td>
<td>3.8</td>
<td>3000</td>
<td>0.15</td>
<td>3.8</td>
</tr>
<tr>
<td>1800</td>
<td>0.15</td>
<td>3.8</td>
<td>1500</td>
<td>0.15</td>
<td>3.8</td>
</tr>
<tr>
<td>1200</td>
<td>0.15</td>
<td>3.8</td>
<td>1000</td>
<td>0.13</td>
<td>3.3</td>
</tr>
<tr>
<td>900</td>
<td>0.12</td>
<td>3.0</td>
<td>750</td>
<td>0.10</td>
<td>2.5</td>
</tr>
<tr>
<td>720</td>
<td>0.09</td>
<td>2.3</td>
<td>600</td>
<td>0.08</td>
<td>2.0</td>
</tr>
<tr>
<td>600</td>
<td>0.08</td>
<td>2.0</td>
<td>500</td>
<td>0.07</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Derived from NEMA MG 1-7.08, Table 7-1.

Table is unfiltered vibration limits for resiliently mounted machines. For machines with rigid mounting multiply the limiting values by 0.8.
TABLE 100.11

– WITHDRAWN –
**TABLE 100.12.1**

Bolt-Torque Values for Electrical Connections

**US Standard Fasteners**

*Heat-Treated Steel – Cadmium or Zinc Plated*

<table>
<thead>
<tr>
<th>Grade</th>
<th>SAE 1&amp;2</th>
<th>SAE 5</th>
<th>SAE 7</th>
<th>SAE 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Marking</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
</tr>
<tr>
<td>Minimum Tensile (Strength) (lbf/in²)</td>
<td>64K</td>
<td>105K</td>
<td>133K</td>
<td>150K</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bolt Diameter (Inches)</th>
<th>Torque (Pound-Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>4</td>
</tr>
<tr>
<td>5/16</td>
<td>7</td>
</tr>
<tr>
<td>3/8</td>
<td>12</td>
</tr>
<tr>
<td>7/16</td>
<td>19</td>
</tr>
<tr>
<td>1/2</td>
<td>30</td>
</tr>
<tr>
<td>9/16</td>
<td>42</td>
</tr>
<tr>
<td>5/8</td>
<td>59</td>
</tr>
<tr>
<td>3/4</td>
<td>96</td>
</tr>
<tr>
<td>7/8</td>
<td>150</td>
</tr>
<tr>
<td>1.0</td>
<td>225</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bolt Diameter (Inches)</th>
<th>Nonlubricated</th>
<th>Lubricated</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>3/8</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>1/2</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>5/8</td>
<td>55</td>
<td>40</td>
</tr>
<tr>
<td>3/4</td>
<td>70</td>
<td>60</td>
</tr>
</tbody>
</table>

- a. Consult manufacturer for equipment supplied with metric fasteners.
- b. Table is based on national coarse thread pitch.

---

**Table 100.12.2**

**US Standard Fasteners**

*Silicon Bronze Fasteners*

<table>
<thead>
<tr>
<th>Bolt Diameter (Inches)</th>
<th>Nonlubricated</th>
<th>Lubricated</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>3/8</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>1/2</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>5/8</td>
<td>55</td>
<td>40</td>
</tr>
<tr>
<td>3/4</td>
<td>70</td>
<td>60</td>
</tr>
</tbody>
</table>

- a. Consult manufacturer for equipment supplied with metric fasteners.
- b. Table is based on national coarse thread pitch.
- c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.
### TABLE 100.12.3

**US Standard Fasteners**

**Aluminum Alloy Fasteners**

**Torque (Pound-Feet)**

<table>
<thead>
<tr>
<th>Bolt Diameter (Inches)</th>
<th>Lubricated</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>10</td>
</tr>
<tr>
<td>3/8</td>
<td>14</td>
</tr>
<tr>
<td>1/2</td>
<td>25</td>
</tr>
<tr>
<td>5/8</td>
<td>40</td>
</tr>
<tr>
<td>3/4</td>
<td>60</td>
</tr>
</tbody>
</table>

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

### TABLE 100.12.4

**US Standard Fasteners**

**Stainless Steel Fasteners**

**Torque (Pound-Feet)**

<table>
<thead>
<tr>
<th>Bolt Diameter (Inches)</th>
<th>Uncoated</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>15</td>
</tr>
<tr>
<td>3/8</td>
<td>20</td>
</tr>
<tr>
<td>1/2</td>
<td>40</td>
</tr>
<tr>
<td>5/8</td>
<td>55</td>
</tr>
<tr>
<td>3/4</td>
<td>70</td>
</tr>
</tbody>
</table>

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
   - Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
   - Belleville washers (302 alloy).

Tables in 100.12 are compiled from Penn-Union Catalogue and Square D Company, Anderson Products Division, General Catalog: Class 3910 Distribution Technical Data, Class 3930 Reference Data Substation Connector Products.
### TABLE 100.13

**SF₆ Gas Tests**

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Serviceability Limits a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>Hygrometer</td>
<td>Per manufacturer or ≥ 200 ppm b</td>
</tr>
<tr>
<td>SF₆ decomposition byproducts</td>
<td>ASTM D 2685</td>
<td>≥ 500 ppm</td>
</tr>
<tr>
<td>Air</td>
<td>ASTM D 2685</td>
<td>≥ 5000 ppm c</td>
</tr>
<tr>
<td>Dielectric breakdown hemispherical contacts</td>
<td>2.54 mm (0.10 inch) gap at atmospheric pressure</td>
<td>11.5 – 13.5 kV d</td>
</tr>
</tbody>
</table>

a. In the absence of consensus standards dealing with SF₆ circuit breaker gas tests, the NETA Standards Review Council suggests the above representative values.

b. According to some manufacturers.


Reference: IEC 61634 High-Voltage Switchgear and Controlgear – *Use and Handling of Sulfur Hexafluoride (SF₆) in High-Voltage Switchgear and Controlgear.*
**TABLE 100.14.1**

**Insulation Resistance Conversion Factors (20°C)**

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Temperature °F</th>
<th>Apparatus Containing Oil Immersed Insulation</th>
<th>Multiplier</th>
<th>Apparatus Containing Solid Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td>14</td>
<td>0.125</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td>23</td>
<td>0.180</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>32</td>
<td>0.25</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>41</td>
<td>0.36</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>0.50</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>59</td>
<td>0.75</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>68</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>77</td>
<td>1.40</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>86</td>
<td>1.98</td>
<td>1.58</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>95</td>
<td>2.80</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>104</td>
<td>3.95</td>
<td>2.50</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>113</td>
<td>5.60</td>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>122</td>
<td>7.85</td>
<td>3.98</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>131</td>
<td>11.20</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>140</td>
<td>15.85</td>
<td>6.30</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>149</td>
<td>22.40</td>
<td>7.90</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>158</td>
<td>31.75</td>
<td>10.00</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>167</td>
<td>44.70</td>
<td>12.60</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>176</td>
<td>63.50</td>
<td>15.80</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>185</td>
<td>89.789</td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>194</td>
<td>127.00</td>
<td>25.20</td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>203</td>
<td>180.00</td>
<td>31.60</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>212</td>
<td>254.00</td>
<td>40.00</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>221</td>
<td>359.15</td>
<td>50.40</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>230</td>
<td>509.00</td>
<td>63.20</td>
<td></td>
</tr>
</tbody>
</table>

Derived from Megger, *Stitch in Time...The Complete Guide to Electrical Insulation Testing.*

**Formula:**

R<sub>c</sub> = R<sub>a</sub> x K

Where:

- R<sub>c</sub> is resistance corrected to 20°C
- R<sub>a</sub> is measured resistance at test temperature
- K is applicable multiplier

**Example:** Resistance test on oil-immersion insulation at 104°F

R<sub>a</sub> = 2 megohms @ 104°F

K = 3.95

R<sub>c</sub> = R<sub>a</sub> x K

R<sub>c</sub> = 2.0 x 3.95

R<sub>c</sub> = 7.90 megohms @ 20°C

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### TABLE 100.14.2

**Insulation Resistance Conversion Factors (40° C)**

<table>
<thead>
<tr>
<th>° C</th>
<th>° F</th>
<th>Apparatus Containing Oil Immersed Insulation</th>
<th>Apparatus Containing Solid Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td>14</td>
<td>0.03</td>
<td>0.10</td>
</tr>
<tr>
<td>-5</td>
<td>23</td>
<td>0.04</td>
<td>0.13</td>
</tr>
<tr>
<td>0</td>
<td>32</td>
<td>0.06</td>
<td>0.16</td>
</tr>
<tr>
<td>5</td>
<td>41</td>
<td>0.09</td>
<td>0.20</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>0.13</td>
<td>0.25</td>
</tr>
<tr>
<td>15</td>
<td>59</td>
<td>0.18</td>
<td>0.31</td>
</tr>
<tr>
<td>20</td>
<td>68</td>
<td>0.25</td>
<td>0.40</td>
</tr>
<tr>
<td>25</td>
<td>77</td>
<td>0.35</td>
<td>0.50</td>
</tr>
<tr>
<td>30</td>
<td>86</td>
<td>0.50</td>
<td>0.63</td>
</tr>
<tr>
<td>35</td>
<td>95</td>
<td>0.71</td>
<td>0.79</td>
</tr>
<tr>
<td>40</td>
<td>104</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>45</td>
<td>113</td>
<td>1.41</td>
<td>1.26</td>
</tr>
<tr>
<td>50</td>
<td>122</td>
<td>2.00</td>
<td>1.59</td>
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<tr>
<td>55</td>
<td>131</td>
<td>2.83</td>
<td>2.00</td>
</tr>
<tr>
<td>60</td>
<td>140</td>
<td>4.00</td>
<td>2.52</td>
</tr>
<tr>
<td>65</td>
<td>149</td>
<td>5.66</td>
<td>3.17</td>
</tr>
<tr>
<td>70</td>
<td>158</td>
<td>8.00</td>
<td>4.00</td>
</tr>
<tr>
<td>75</td>
<td>167</td>
<td>11.31</td>
<td>5.04</td>
</tr>
<tr>
<td>80</td>
<td>176</td>
<td>16.00</td>
<td>6.35</td>
</tr>
<tr>
<td>85</td>
<td>185</td>
<td>22.63</td>
<td>8.00</td>
</tr>
<tr>
<td>90</td>
<td>194</td>
<td>32.00</td>
<td>10.08</td>
</tr>
<tr>
<td>95</td>
<td>203</td>
<td>45.25</td>
<td>12.70</td>
</tr>
<tr>
<td>100</td>
<td>212</td>
<td>64.00</td>
<td>16.00</td>
</tr>
<tr>
<td>105</td>
<td>221</td>
<td>90.51</td>
<td>20.16</td>
</tr>
<tr>
<td>110</td>
<td>230</td>
<td>128.00</td>
<td>25.40</td>
</tr>
</tbody>
</table>


Notes: The insulation resistance coefficient is based on the halving of the insulation resistance to the change in temperature. *Apparatus Containing Immersed Oil Insulation Table* uses 10° C change with temperature halving. *Apparatus Containing Solid Insulation Table* uses 15° C change with temperature halving.

**Formula:**

\[ R_c = R_a \times K \]

Where:  
- \( R_c \) is resistance corrected to 40° C  
- \( R_a \) is measured resistance at test temperature  
- \( K \) is applicable multiplier

**Example:** Resistance test on oil-immersion insulation at 68° F/20° C

\[ R_a = 2 \text{ megohms @ 68° F/20° C} \]
\[ K = 0.40 \]
\[ R_c = R_a \times K \]
\[ R_c = 2.0 \times 0.40 = 0.8 \text{ megohms @ 40° C} \]
### TABLE 100.15

High-Potential Test Voltage for Automatic Circuit Reclosers

#### Maintenance Testing

<table>
<thead>
<tr>
<th>Nominal Voltage Class (kV)</th>
<th>Maximum Voltage (kV)</th>
<th>Rated Impulse Withstand Voltage (kV)</th>
<th>Maximum AC (^a) Field Test Voltage (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.4 (1 ø and 3 ø)</td>
<td>15.0</td>
<td>95</td>
<td>26.2</td>
</tr>
<tr>
<td>14.4 (1 ø and 3 ø)</td>
<td>15.5</td>
<td>110</td>
<td>37.5</td>
</tr>
<tr>
<td>24.9 (1 ø and 3 ø)</td>
<td>27.0</td>
<td>150</td>
<td>45.0</td>
</tr>
<tr>
<td>34.5 (1 ø and 3 ø)</td>
<td>38.0</td>
<td>150</td>
<td>52.5</td>
</tr>
<tr>
<td>46.0 (3 ø)</td>
<td>48.3</td>
<td>250</td>
<td>78.7</td>
</tr>
<tr>
<td>69.0 (3 ø)</td>
<td>72.5</td>
<td>350</td>
<td>120.0</td>
</tr>
</tbody>
</table>


\(^a\) Derived from ANSI/IEEE C37.60-1981(R1992), Table 2, Column 5. In accordance with ANSI/IEEE C37.61, Section 6.2.2 (Servicing), a .75 multiplier has been applied to the values.
**TABLE 100.16**

**High-Potential Test Voltage for Periodic Test of Line Sectionalizers**

<table>
<thead>
<tr>
<th>Nominal Voltage Class (kV)</th>
<th>Maximum Voltage (kV)</th>
<th>Rated Impulse Withstand Voltage (kV)</th>
<th>Maximum AC Field Test Voltage (kV)</th>
<th>15 Minute DC Withstand (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.4 (1 ø)</td>
<td>15.0</td>
<td>95</td>
<td>26.2</td>
<td>39</td>
</tr>
<tr>
<td>14.4 (1 ø)</td>
<td>15.0</td>
<td>125</td>
<td>31.5</td>
<td>39</td>
</tr>
<tr>
<td>14.4 (3 ø)</td>
<td>15.5</td>
<td>110</td>
<td>37.5</td>
<td>39</td>
</tr>
<tr>
<td>24.9 (1 ø)</td>
<td>27.0</td>
<td>125</td>
<td>45.0</td>
<td>58</td>
</tr>
<tr>
<td>34.5 (3 ø)</td>
<td>38.0</td>
<td>150</td>
<td>52.5</td>
<td>77</td>
</tr>
</tbody>
</table>


The table includes a 0.75 multiplier with fractions rounded down.

In the absence of consensus standards, the NETA Standards Review Council suggests the above representative values.

**NOTE:** Values of ac voltage given are dry test, one-minute, factory test values.
# TABLE 100.17

## Metal-Enclosed Bus Dielectric Withstand Test Voltages

<table>
<thead>
<tr>
<th>Type of Bus</th>
<th>Rated kV</th>
<th>Maximum Test Voltage (kV)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AC</td>
<td>DC</td>
<td>AC</td>
</tr>
<tr>
<td>Isolated Phase for Generator Leads</td>
<td>24.5</td>
<td>37.0</td>
<td>52.0</td>
<td>29.5</td>
</tr>
<tr>
<td>Isolated Phase for Other than Generator Leads</td>
<td>15.5</td>
<td>37.0</td>
<td>52.0</td>
<td>25.8</td>
</tr>
<tr>
<td>Nonsegregated Phase</td>
<td>0.635</td>
<td>1.6</td>
<td>2.3</td>
<td>4.76</td>
</tr>
<tr>
<td></td>
<td>15.0</td>
<td>27.0</td>
<td>37.0</td>
<td>25.8</td>
</tr>
<tr>
<td></td>
<td>38.0</td>
<td>60.0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Segregated Phase</td>
<td>15.5</td>
<td>37.0</td>
<td>52.0</td>
<td>25.8</td>
</tr>
<tr>
<td></td>
<td>38.0</td>
<td>60.0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>DC Bus Duct a</td>
<td>0.3</td>
<td>1.6</td>
<td>2.3</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>3.4</td>
<td>4.8</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>3.2</td>
<td>6.6</td>
<td>9.3</td>
<td></td>
</tr>
</tbody>
</table>

Derived from ANSI-IEEE C37.23-1987 *Standard for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus*, Tables 3A, 3B, 3C, 3D and paragraph 6.4.2. The table includes a 0.75 multiplier with fractions rounded down.

**Note:**

a. The presence of the column headed “DC” does not imply any requirement for a dc withstand test on ac equipment. This column is given as a reference only for those using dc tests and represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for each class of bus.

Direct current withstand tests are recommended for flexible bus to avoid the loss of insulation life that may result from the dielectric heating that occurs with rated frequency withstand testing.

Because of the variable voltage distribution encountered when making dc withstand tests and variances in leakage currents associated with various insulation systems, the manufacturer should be consulted for recommendations before applying dc withstand tests to this equipment.
## TABLE 100.18

Thermographic Survey
Suggested Actions Based on Temperature Rise

<table>
<thead>
<tr>
<th>Temperature difference ((\Delta T)) based on comparisons between similar components under similar loading</th>
<th>Temperature difference ((\Delta T)) based upon comparisons between component and ambient air temperatures</th>
<th>Recommended Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1º C – 3º C</td>
<td>1º C – 10º C</td>
<td>Possible deficiency; warrants investigation</td>
</tr>
<tr>
<td>4º C – 15º C</td>
<td>11º C – 20º C</td>
<td>Indicates probable deficiency; repair as time permits</td>
</tr>
<tr>
<td>- - - - -</td>
<td>21º C – 40º C</td>
<td>Monitor until corrective measures can be accomplished</td>
</tr>
<tr>
<td>&gt;15º C</td>
<td>&gt;40º C</td>
<td>Major discrepancy; repair immediately</td>
</tr>
</tbody>
</table>

Temperature specifications vary depending on the exact type of equipment. Even in the same class of equipment (i.e., cables) there are various temperature ratings. Heating is generally related to the square of the current; therefore, the load current will have a major impact on \(\Delta T\). In the absence of consensus standards for \(\Delta T\), the values in this table will provide reasonable guidelines.


It is a necessary and valid requirement that the person performing the electrical inspection be thoroughly trained and experienced concerning the apparatus and systems being evaluated as well as knowledgeable of thermographic methodology.
TABLE 100.19

Dielectric Withstand Test Voltages for Electrical Apparatus Other than Inductive Equipment

<table>
<thead>
<tr>
<th>Nominal System (Line) Voltage (^a) (kV)</th>
<th>Insulation Class (kV)</th>
<th>AC Factory Test (kV)</th>
<th>Maximum Field Applied AC Test (kV)</th>
<th>Maximum Field Applied DC Test (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>1.2</td>
<td>10</td>
<td>6.0</td>
<td>8.5</td>
</tr>
<tr>
<td>2.4</td>
<td>2.5</td>
<td>15</td>
<td>9.0</td>
<td>12.7</td>
</tr>
<tr>
<td>4.8</td>
<td>5.0</td>
<td>19</td>
<td>11.4</td>
<td>16.1</td>
</tr>
<tr>
<td>8.3</td>
<td>8.7</td>
<td>26</td>
<td>15.6</td>
<td>22.1</td>
</tr>
<tr>
<td>14.4</td>
<td>15.0</td>
<td>34</td>
<td>20.4</td>
<td>28.8</td>
</tr>
<tr>
<td>18.0</td>
<td>18.0</td>
<td>40</td>
<td>24.0</td>
<td>33.9</td>
</tr>
<tr>
<td>25.0</td>
<td>25.0</td>
<td>50</td>
<td>30.0</td>
<td>42.4</td>
</tr>
<tr>
<td>34.5</td>
<td>35.0</td>
<td>70</td>
<td>42.0</td>
<td>59.4</td>
</tr>
<tr>
<td>46.0</td>
<td>46.0</td>
<td>95</td>
<td>57.0</td>
<td>80.6</td>
</tr>
<tr>
<td>69.0</td>
<td>69.0</td>
<td>140</td>
<td>84.0</td>
<td>118.8</td>
</tr>
</tbody>
</table>

In the absence of consensus standards, the NETA Standards Review Council suggests the above representative values.

a. Intermediate voltage ratings are placed in the next higher insulation class.
**TABLE 100.20.1**

**Rated Control Voltages and Their Ranges for Circuit Breakers**

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Circuit Breakers</td>
<td>Outdoor Circuit Breakers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 (6)</td>
<td>--</td>
<td>14–28</td>
<td>120 (104–127 (7))</td>
</tr>
<tr>
<td>48 (6)</td>
<td>38–56</td>
<td>28–56</td>
<td>240 (208–254 (7))</td>
</tr>
<tr>
<td>125</td>
<td>100–140</td>
<td>70–140</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>200–280</td>
<td>140–280</td>
<td>Polyphase</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Polyphase</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>208Y/120 (180Y/104–220Y/127)</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>240 (208–254)</td>
</tr>
</tbody>
</table>

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities.*
### TABLE 100.20.1

**Rated Control Voltages and Their Ranges for Circuit Breakers**

**Notes**

1. Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

2. Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

3. Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

4. Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

5. It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

6. 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

7. Includes heater circuits

8. Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

9. Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges.

10. This table also applies to circuit breakers in gas-insulated substation installations.

11. In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the “Rated Control Voltage.” In these cases, tests shall be performed at the levels in this column.

12. For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user’s control circuit wiring.

13. For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.
TABLE 100.20.2

Rated Control Voltages and Their Ranges for Circuit Breakers
Solenoid-Operated Devices

<table>
<thead>
<tr>
<th>Rated Voltage</th>
<th>Closing Voltage Ranges for Power Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 dc</td>
<td>90 – 115 or 105 – 130</td>
</tr>
<tr>
<td>250 dc</td>
<td>180 – 230 or 210 – 260</td>
</tr>
<tr>
<td>230 ac</td>
<td>190 – 230 or 210 – 260</td>
</tr>
</tbody>
</table>

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.
TABLE 100.21

Accuracy of IEC Class TP Current Transformers

Error Limit

<table>
<thead>
<tr>
<th>Class</th>
<th>At Rated Current</th>
<th>At Accuracy Limit Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ratio Error (%)</td>
<td>Phase Displacement Minimum</td>
</tr>
<tr>
<td>TPX</td>
<td>± 0.5</td>
<td>± 30</td>
</tr>
<tr>
<td>TPY</td>
<td>± 1.0</td>
<td>± 60</td>
</tr>
<tr>
<td>TPZ</td>
<td>± 1.0</td>
<td>180 ± 18</td>
</tr>
</tbody>
</table>

NOTE – Alternating current component error.

There are four different TP classifications to meet different functional requirements as follows:

1. Class TPS low leakage flux design ct.
2. Class TPX closed core ct for specified transient duty cycle.
3. Class TPY gapped (low remanance) ct for specified transient duty cycle
4. Class TPZ linear ct (no remanence).

The error limit for TPS ct in terms of turn ratio error is ± .25% and the excitation voltage under limiting conditions should not be less than the specified value; furthermore, this value is such that an increase of 10 percent in magnitude does not result in an increase in the corresponding peak instantaneous exciting current exceeding 100 percent. In other words, the ct should not be in saturated state at the specified maximum operating voltage.

The accuracy limit conditions are specified on the rating plate. The required rating plate information is shown in the table below. (The obvious information such as rated primary and secondary currents is not shown.)

<table>
<thead>
<tr>
<th>CT Class</th>
<th>TPS</th>
<th>TPX</th>
<th>TPY</th>
<th>TPZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symmetrical short-circuit current factor</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Rated resistive burden (R_s)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Secondary winding resistance (°C)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Rated Transient dimensioning factor</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Steady-state error limit factor</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Excitation limiting secondary voltage</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Accuracy limiting secondary exciting current</td>
<td>x</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Factor of construction*</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Rated secondary loop time constant</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
</tr>
<tr>
<td>Specified primary time constant (T_p)</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>-</td>
</tr>
</tbody>
</table>

x = applicable, – = not applicable

*The factor construction is determined from the following ratio:

Equivalent secondary accuracy limiting voltage \( V_{cal} \)

Equivalent secondary accuracy limiting e.m.f \( E_{cal} \)

where

\( V_{cal} \) is the rms value of sinusoidal voltage of rated frequency, with, if applied to the secondary winding of a ct, would result in an exciting current corresponding to the maximum permissible error current appropriate to ct class

\( E_{cal} \) is the equivalent rms emf of rated frequency determined during test observed error current corresponds to the appropriate limit for the class

Derived from C37.110

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### TABLE 100.22

**Minimum Radii for Power Cable**

*Single and Multiple Conductor Cables with Interlocked Armor, Smooth or Corrugated Aluminum Sheath or Lead Sheath*

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Overall Diameter of Cable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>and less</td>
</tr>
<tr>
<td>Smooth Aluminum Sheath Single Conductor Nonshielded, Multiple Conductor or Multiplexed, with Individually Shielded Conductors</td>
<td>10</td>
</tr>
<tr>
<td>Single Conductor Shielded</td>
<td>12</td>
</tr>
<tr>
<td>Multiple Conductor or Multiplexed, with Overall Shield</td>
<td>12</td>
</tr>
<tr>
<td>Interlocked Armor or Corrugated Aluminum Sheath Nonshielded</td>
<td>7</td>
</tr>
<tr>
<td>Multiple Conductor with Individually Shielded Conductor</td>
<td>12/7 a</td>
</tr>
<tr>
<td>Multiple Conductor with Overall Shield</td>
<td>12</td>
</tr>
<tr>
<td>Lead Sheath</td>
<td>12</td>
</tr>
</tbody>
</table>

1. 12 x individual shielded conductor diameter, or 7 x overall cable diameter, whichever is greater.

TABLE 100.22

Minimum Radii for Power Cable
Single and Multiple Conductor Cables with Interlocked Armor,
Smooth or Corrugated Aluminum Sheath or Lead Sheath

Notes

Specific references from Appendix I:

1. Interlocked-Armor and Metallic-Sheathed Cables

1.1 The minimum bending radius for interlocked-armored cables, smooth or corrugated aluminum sheath or lead sheath, shall be in accordance with Table 100.22.

2. Flat-Tape Armored or Wire-Armored Cables

2.1 The minimum bending radius for all flat-tape armored and all wire- armored cables is twelve times the overall diameter of cable.

3. Tape-Shielded Cables

3.1 The minimum bending radius for tape-shielded cables given above applies to helically applied flat or corrugated tape or longitudinally applied corrugated tape-shielded cables.

3.2 The minimum bending radius for a single-conductor cable is twelve times the overall diameter.

3.3 For multiple-conductor or multiplexed single-conductor cables having individually taped shielded conductors, the minimum bending radius is twelve times the diameter of the individual conductors or seven times the overall diameter, whichever is greater.

3.4 For multiple-conductor cables having an overall tape shield over the assembly, the minimum bending radius is twelve times the overall diameter of the cable.

4. Wire-Shielded Cables

4.1 The minimum bending radius for a single-conductor cable is eight times the overall diameter.

4.2 For multiple-conductor or multiplexed single-conductor cables having wire-shielded individual conductors, the minimum bending radius is eight times the diameter of the individual conductors or five times the overall diameter, whichever is greater.

4.3 For multiple-conductor cables having a wire shield over the assembly, the minimum bending radius is eight times the overall diameter of the cable.
### TABLE: 100.23
Recommended Torque Values for Field Installed Wiring, Bus and Cable Connections

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Socket Size Across Flats (inches)</th>
<th>Torque (lb-in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incoming lugs</td>
<td>1/4</td>
<td>180</td>
</tr>
<tr>
<td>Branch lugs</td>
<td>5/16</td>
<td>250</td>
</tr>
<tr>
<td>Neutral lugs</td>
<td>3/8</td>
<td>340</td>
</tr>
<tr>
<td>Ground lugs</td>
<td>1/2 (see exception on next line)</td>
<td>450</td>
</tr>
<tr>
<td></td>
<td>1/2 (3/0–750 kcmil)</td>
<td>620</td>
</tr>
<tr>
<td><strong>Multiple Conductor Neutral and/or Ground Bar</strong></td>
<td><strong>Conductor Size</strong></td>
<td><strong>Torque (lb-in.)</strong></td>
</tr>
<tr>
<td>Screw Type</td>
<td>Lug Wire Range</td>
<td></td>
</tr>
<tr>
<td>Slotted head</td>
<td>#14-4</td>
<td>#14-10CU, #12-10AL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#8 CU-AL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#6-4 CU-AL</td>
</tr>
<tr>
<td></td>
<td>#14-1/0</td>
<td>#14-8 CU-AL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#6-1/0 CU-AL</td>
</tr>
<tr>
<td>Socket head</td>
<td></td>
<td>ALL</td>
</tr>
<tr>
<td></td>
<td>#6-300 kcmil</td>
<td>ALL</td>
</tr>
</tbody>
</table>

Aluminum lugs are suitable for use with copper or aluminum conductors. Copper lugs are suitable for use with copper conductors only.

Use 75 °C copper or aluminum conductors except as marked on or near installed circuit breakers or switches.

Hardware that secures electrical joints must be torqued to the values shown in the following table:
### TABLE: 100.23 (cont.)

**Recommended Torque Values for Electrical Bus Joints**

<table>
<thead>
<tr>
<th>Description of Hardware</th>
<th>Carriage Bolt Grade 5, Standard or Heavy Hex Nut, One Conical Washer</th>
<th>Carriage Bolt Grade 5, Nut and Conical Washer Assy</th>
<th>Square Head Bolt Grade 5</th>
<th>Hex Head Bolt Grade 5, Standard or Heavy Hex Nut, 2 Conical Washers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bolt Diameter (inches)</strong></td>
<td><strong>Washer O.D. (inches)</strong></td>
<td><strong>lbs-inch</strong></td>
<td><strong>lbs-inch</strong></td>
<td><strong>Nut and conical washer assy. lbs-inch</strong></td>
</tr>
<tr>
<td>0.25 (1/4)</td>
<td>****</td>
<td>****</td>
<td>50–75</td>
<td>****</td>
</tr>
<tr>
<td>0.31 (5/16)</td>
<td>****</td>
<td>****</td>
<td>80–125</td>
<td>****</td>
</tr>
<tr>
<td>0.38 (3/8)</td>
<td>****</td>
<td>****</td>
<td>175-255</td>
<td>175-225</td>
</tr>
<tr>
<td>0.50(1/2)</td>
<td>1.25</td>
<td>780–900</td>
<td>250–350</td>
<td>250–350</td>
</tr>
<tr>
<td></td>
<td>2.25</td>
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**Maximum Micro-Ohms Per Pole**

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Remove Test Connections

Upon completing testing:
- Remove test connections from circuit breaker.
- Inspect connections for damage caused by testing.

Additional Information

For more information concerning Square D Circuit breakers, refer to the appropriate instruction manual. These manuals contain installation instructions, mounting information, safety features, wiring diagrams, and troubleshooting charts for specific circuit breakers.
### TABLE: 100.25
Maximum Micro-Ohms Per Pole

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### TABLE: 100.26
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### TABLE: 100.27

**Type DS, DSII, DSL, and DSLII Circuit Breaker**

Contact Resistance Maximum Contact Resistance

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Comments or Suggestions?

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Please complete the information below and mail or e-mail it to the indicated address.

☐ Omission  ☐ Error  ☐ Suggestion  ☐ Other Comment

Reference Page Number and/or Paragraph: __________________________

Comment/Suggestion Notes:

____________________________________________________________________
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____________________________________________________________________

Name: _____________________________________________________________
Company: ___________________________________________________________
Address: ___________________________________________________________ 
City / State / Zip: ______________________________________________________
E-mail: ______________________________________________________________
Phone: ______________________________________________________________

Do you wish to be contacted regarding your comment: ☐ Yes ☐ No

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Nashville, TN 37217

Email: sibs@us.schneider-electric.com
Include subject title: MTP Bulletin - Comments/Suggestions
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