NECA 430

Standard for Installing and Maintaining Medium-Voltage Switchgear

ANSI Recirculation Draft
September~~July~~ 2024

Table of Contents

(This Foreword is not a part of the Standard)

Foreword

National Electrical Installation Standards™ *(NEIS™)* are designed to improve communication among specifiers, purchasers, and suppliers of electrical construction services. They define a minimum baseline of quality and workmanship for installing electrical products and systems. *NEIS*® are intended to be referenced in contract documents for electrical construction projects. The following language is recommended:

> Medium-voltage switchgear shall be installed and maintained in accordance with NECA 430, *Standard for Installing and Maintaining Medium-Voltage Switchgear* (ANSI).

Use of *NEIS*® is voluntary, and the National Electrical Contractors Association (NECA) assumes no obligation or liability to users of this publication. Existence of a Standard shall not preclude any member or non-member of NECA from specifying or using alternate construction methods permitted by applicable regulations.

This publication is intended to comply with the National Electrical Code (NEC). Because they are quality Standards, NEIS may in some instances go beyond the minimum safety requirements of the NEC. It is the responsibility of users of this publication to comply with State and local electrical Codes and National and State OSHA safety regulations as well as follow manufacturer installation instructions when installing electrical products and systems.

Suggestions for revisions and improvements to this standard are welcome. They should be addressed to:

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1. Scope

This standard describes site preparation and installation of new medium-voltage switchgear and maintenance procedures for existing medium-voltage switchgear nominally rated up to a maximum operating voltage of 38 kV AC. For the purpose of this standard, medium-voltage switchgear may be classified as either metal-clad switchgear or metal-enclosed switchgear. Medium-voltage switchgear may also be arc-resistant or non-arc-resistant construction.

1.1 Products and Applications Included

1. Metal-clad switchgear
2. Metal-enclosed switchgear
3. Vacuum circuit breakers
4. Interrupter switches
5. Indoor and outdoor locations
6. Testing, energizing, and commissioning
7. Maintenance procedures
8. Dead front equipment

1.2 Equipment and Applications Excluded

1. Pad-mounted, compartmentalized switchgear
2. Sulfur-Hexafluoride (SF_6) circuit breakers
3. Underground installations
4. Transformers or unit substations
5. Station-type switchgear
6. Gas Insulated Switchgear (GIS)
7. Reconditioned switchgear
8. Live front equipment

1.3 Regulatory and Other Requirements

All information in this publication is intended to conform to the National Electrical Safety Code or NESC (ANSI/IEEE C2) and National Electrical Code or NEC (ANSI/NFPA 70). Installers shall follow the NESC, NEC, applicable National, State and local Codes and Standards, manufacturer instructions, and contract documents when installing medium-voltage switchgear.

Only qualified persons as defined in the NEC familiar with the construction, installation, and operation of high voltage circuits and electrical power distribution and control systems and equipment shall perform the technical work described in this publication. Administrative functions and other tasks shall be performed under the supervision of a qualified person. All work shall be performed in accordance with NFPA 70E, Standard for Electrical Safety in the Workplace.

General requirements for installing electrical products and systems are described in the latest version of NECA 1, Standard Practices for Good Workmanship in Electrical Contracting (ANSI). Other NEIS provide additional guidance for installing particular types of electrical products and systems. A complete list of NEIS is provided in Annex A.

1.4 Mandatory Requirements, Permissive Requirements, Quality and Performance Recommendations, Explanatory Material, and Informative Annexes

Mandatory requirements in manufacturer instructions, Codes, or other mandatory Standards that may or may not be adopted into law are those that identify actions that are specifically required or prohibited and are characterized in this StandardRecommended Practice by the use of the terms "must" or "must not," "shall" or "shall not," or "may not," or "are not permitted," or "are required," or by the use of positive phrasing of mandatory requirements. Examples of mandatory requirements may equally take the form of, "equipment must be protected…," "equipment shall be protected…," or "protect equipment…," with the latter interpreted (understood) as "(it is necessary to) protect equipment…"

Permissive requirements of manufacturer instructions, Codes, or other mandatory Standards that may or may not be adopted into law are those that identify actions that are allowed but not required or are normally used to describe options or alternative means and methods and are characterized in this StandardRecommended Practice by the use of the terms "may," or "are permitted," or "are not required."

Quality and performance instructions identify actions that are recommended or not recommended to improve the overall quality or performance of the installation and are characterized in this StandardRecommended Practice by the use of the terms "should" or "should not."

Explanatory material, such as references to other Codes, Standards, documents, references to related sections of this StandardRecommended Practice, information related to another Code, Standard, or document, and supplemental application and design information and data, is included throughout this StandardRecommended Practice to expand the understanding of mandatory requirements, permissive requirements, and quality and performance instructions. Such explanatory material is included for information only and is identified by the use of the term "NOTE," or by the use of italicized text.

Non-mandatory information and other reference Standards or documents relative to the application and use of materials, equipment, and systems covered by this StandardRecommended Practice are provided in informative annexes. Informative annexes are not part of the enforceable requirements of this StandardRecommended Practice but are included for information purposes only.

1.5 Manufacturer Instructions

The information in this document is generic and intended to describe the general nature of the activities required for preparation, installation, and maintenance of medium-voltage switchgear. Manufacturer instructions, including drawings and instruction manuals, must be adhered to in the preparation, installation, and maintenance of medium-voltage switchgear.

2. Definitions

NOTE. These definitions come from various standards and are presented here as a reference only. In all cases, the controlling standard will be the controlling document when the definition here is different than the definition in the controlling standard.

Ampacity. The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

Approved. Acceptable to the authority having jurisdiction.

Arc-Resistant Switchgear. Equipment designed to withstand the effects of an internal arcing fault as indicated by successfully meeting the test requirements of IEEE Std C37.20.7.

Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Bonding. Connected to establish electrical continuity and conductivity.

Circuit Breaker. A device designed to open and close a circuit by nonautomatic means and to open the circuit ~~automatically~~ on a predetermined overcurrent without damage to itself when properly applied within its rating.

Continuous Load. A load where the maximum current is expected to continue for 3 hours or more.

Control Power Transformer (CPT). A transformer, typically connected to the switchgear bus, used to provide control power for ancillary functions.

Current Transformer. An instrument transformer that is intended to have its primary winding connected in series with the conductor carrying the current to be measured or controlled.

Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection.

Grounding Conductor, Equipment (EGC). A conductive path(s) that is part of an effective ground-fault current path and connects normally non–current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.

Grounding Electrode Conductor (GEC). A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.

Load Interrupter Switch. An interrupter switch designed to interrupt currents not in excess of the continuous-current rating of the switch, although it may be designated to close and carry short-circuit currents as specified.

Metal-Clad (MC) Switchgear. Metal-enclosed power switchgear characterized by the following necessary features:

a) The main switching and interrupting device is of the removable (drawout) type arranged with a mechanism for moving it physically between connected and disconnected positions and equipped with self-aligning and self-coupling primary disconnecting devices and disconnectable control wiring connections.
b) Major parts of the primary circuit, that is, the circuit switching or interrupting devices, buses, voltage transformers, and control power transformers, are completely enclosed by grounded metal barriers that have no intentional openings between compartments except for small openings for

wires, wire bundles, mechanical linkages, or items of similar nature. Specifically included is a metal barrier in front of, or a part of, the circuit interrupting device so that, when in the connected position, no primary circuit components are exposed by the opening of a door.

c) All live parts are enclosed within grounded metal compartments.
d) Automatic shutters that cover primary circuit elements when the removable element is in the disconnected, test, or removed position.
e) Primary bus conductors and connections are covered with insulating material throughout.
f) Mechanical interlocks are provided for proper operating sequence under normal operating conditions.
g) Instruments, meters, relays, secondary control devices, and their wiring are isolated by grounded metal barriers from all primary circuit elements with the exception of short lengths of wire such as at instrument transformer terminals.
h) The door through which the circuit-interrupting device is inserted into the housing may serve as an instrument or relay panel and also may provide access to a secondary or control compartment within the housing.

NOTE 1. Auxiliary vertical sections may be required for mounting devices or for use as a bus transition.
NOTE 2. The term metal-clad (as applied to switchgear assemblies) is correctly used only in connection with switchgear conforming fully to the definition for Metal-Clad (MC) Switchgear. Metal-clad switchgear is metal-enclosed, but not all metal-enclosed switchgear can be correctly designated as metal-clad.

Metal-Enclosed Interrupter Switchgear. Metal-enclosed power switchgear including the following equipment as required:

a) Interrupter (interrupter switches and/or circuit breakers)
b) Power fuses (current-limiting or noncurrent-limiting)
c) Bare bus and connections
d) Instrument transformers
e) Control wiring and accessories
f) An isolating switch with visible break contacts for stationary circuit breakers (non-drawout)

Metal-Enclosed (ME) Power Switchgear. A switchgear assembly completely enclosed on all sides and the top with sheet metal (except for ventilating openings and inspection windows, viewing panes, or similar items) containing primary power circuit switching or interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors or removable covers or both. *NOTE. Metal-clad switchgear, metal-enclosed interrupter switchgear, and low-voltage power circuit-breaker switchgear are specific types of metal-enclosed power switchgear.*

Personal Protective Grounds. A portable device designed to connect (bond) a de-energized conductor or piece of equipment, or both, to an electrical ground at a work site when work is to be performed on a conductor or piece of equipment that could accidentally become energized.

Outdoor Walk-in Switchgear. An enclosed assembly containing switchgear and an aisle or working space which is accessible through a personnel door.

Pad-Mounted, Compartmentalized Switchgear*. Low-profile switchgear that is positioned on a surface-mounted pad outdoors, typically at ground level. Pad-mounted switchgear, with enclosed compartments for cable entry from below and with all exposed surfaces at ground potential, is used as a part of an underground distribution system.

Plenum (Arc-Resistant Switchgear): A specified area attached to, or located within switchgear, intended to collect the gas and associated pressure caused by an internal arcing fault, and redirect these, through the use of baffles, vents, or duct systems.

Potential Transformer (PT). Voltage transformer used for metering and controls. PTs may be drawout-mounted or dump out style with primary fuses included, or may be fixed-mounted with drawout or stationary primary fuses.

Qualified Person. One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved.

Sulfur-Hexafluoride (SF_6) Circuit Breaker*. A mechanical switching device capable of making, carrying, and breaking currents under normal circuit conditions and also, making and carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of a short circuit or ground fault, that uses sulfur-hexafluoride (SF_6) under pressure as the interrupting medium.

Switchgear. An assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings and inspection windows) and containing primary power circuit switching, interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors, removable covers, or both.

Switchgear Assembly. An assembled equipment (indoor or outdoor) including, but not limited to, one or more of switching, interrupting, control, instrumentation, metering, protective, and regulating devices, together with their supporting structures, enclosures, conductors, electric interconnections, and accessories.

Vacuum Circuit Breaker. A mechanical switching device capable of making, carrying, and breaking currents under normal circuit conditions and also, making and carrying for a specified time and breaking currents under specifies abnormal circuit conditions such as those of a short circuit or ground fault, that uses vacuum as the interrupting medium. Vacuum circuit breakers can be of the fixed-mounted or drawout type.

Voltage Transformer. *See Potential Transformer (PT).*

* Included for informational purposes only. This product is excluded from this Standard.

3. High Voltage and Electrical Safety

For switchgear to work properly, it must be handled carefully and installed, operated, and maintained correctly. Read and understand the manufacturer instructions and safety messages before attempting assembly, operation, or maintenance of medium-voltage switchgear.

Neglecting fundamental installation and maintenance requirements may lead to personal injury or death and damage to electrical equipment or other property. Personnel working on energized switchgear should follow the safe work practices described in NFPA 70E, including the use of PPE appropriate for the task being performed. Consider having a second knowledgeable person inspect the equipment before

energizing.

Ensure that doors to switchgear that would provide unqualified persons access to energized parts are lockable and are locked.

Verify that circuit breakers and switches are open. Verify by testing that the desired cables and equipment are de-energized. Use electrical testing equipment rated for the operating voltage of the system. Test voltage testing equipment on a known, energized source immediately before and after testing the equipment to ensure that voltage testing equipment is operating properly.

If there is any evidence of or suspected deterioration of circuit breaker dielectric capability, immediately evacuate areas and spaces adjacent to the circuit breaker. De-energize the circuit breaker by opening an up-stream disconnect device before operating the circuit breaker and removing it from service.

3.1 General

Consider all ungrounded and grounded metal parts of equipment and devices to be energized at the highest voltage to which they are exposed unless they are de-energized, tested, grounded, locked out, and tagged out in accordance with OSHA requirements. Use appropriate PPE and established safety procedures when working on or near energized electrical equipment.

Ensure the equipment is in an electrically safe work condition in accordance with NFPA 70E.

Considering the increased possibility of arc blast, wear appropriate personal protective equipment (PPE), and exercise extreme caution when tripping, closing, installing, or removing medium-voltage circuit breakers from energized switchgear.

Do not work on energized conductors or equipment. Using established safety procedures, guard energized conductors and equipment in close proximity to the work.

Follow lockout/tag-out procedures. Use out-of-service tags and padlocks when working on equipment. Leave locks and tags in place until the work is completed and the equipment is ready to be put into service.

Disconnect all sources of power to switchgear before accessing the bus compartment and any high voltage conductors. Verify that all sources of control power are de-energized. Sources of control power include those inside the switchgear as well as those coming from external sources.

Secure circuit breakers and switches with locks and tags. Install personal protective grounds on cables and equipment that are sufficient for the available short circuit current from the supplier. Guidelines for protective grounding equipment are contained in ASTM F855, ASTM Standard Specifications for Temporary Grounding Systems to be Used on De-energized Electric Power Lines and Equipment.

Do not make any modifications to the equipment or operate the system with any interlocks defeated or safety barriers removed.

Exercise caution around CT circuits. A CT carrying primary current can develop high secondary terminal voltages if the secondary terminals are open-circuited.

Protect against accidental energization of automatic or remotely controlled equipment by identifying,

opening, locking, and tagging starting devices. Remove locks, tags, and personal protective grounds only after work is complete and tested, and all personnel are clear of the area.

Carefully inspect the work area and remove any tools and objects left inside equipment before energizing switchgear. All circuit breaker doors, cable compartment doors, voltage transformer compartment doors, and control power compartment doors must be closed, latched, or bolted before energizing switchgear.

3.2 Existing Facilities

Perform preliminary inspections and tests prior to beginning work to determine existing conditions. Check existing conditions against available record documents.

Verify all cable connections to equipment. Confirm that supply cables and load cables are properly connected to equipment. Keep in mind that transposed cables may be connected to different terminals than expected.

Resolve discrepancies between as-built conditions and electrical drawings, if available. Determine if the as-built condition is appropriate or if the installation should be corrected to match the electrical drawings. If the as-built condition is appropriate, recommend revisions to the drawings that accurately reflect the as-built condition. Provide appropriate hazard labels, following ANSI Z535, Safety Alerting Standards, on equipment where necessary to indicate unexpected and potentially hazardous conditions. Do not modify manufacturer applied labels.

Maintain as much distance as practical from equipment and devices that may arc during operation or handling, but not less than the arc flash protection boundary specified in NFPA 70E.

3.3 Interrupter Switches

Interrupter switch doors cannot be opened with the switch in the CLOSED position. Similarly, interrupter switches cannot be closed with the door open. Manually open the switch as defined by the manufacturer. In general, manually rotate the operating handle in a smooth swift motion in the open direction while standing clear of the front of the switch cubicle. Follow electric safe work practices especially with respect to arc flash. Opening the switch releases the door safety interlock, and the door may be opened.

Do not defeat or disengage any safety interlocks when switchgear is in service. Defeating or disengaging safety interlocks on a medium-voltage interrupter switch that is connected to a power source may result in death, bodily injury, or property damage.

Before opening interrupter switch doors, use the viewing window on the door to visually verify that all three main contacts and secondary arc breaking contacts are open. If necessary, use an additional suitable light source to visually inspect the blades.

Ensure that interrupter switches are in the position recommended by the manufacturer when moving switchgear. Only operate interrupter switches when switchgear is mounted on a flat, level surface. Do not operate interrupter switches if the switchgear is unsupported or is mounted on an uneven surface.

4. Delivery, Handling, and Storage

4.1 Delivery

Coordinate the arrival of switchgear so that the installation of equipment pads and foundations is complete and ready to receive the equipment upon delivery.

Upon delivery of equipment and accessories, visually inspect packaging for physical damage. Carefully unpack protective crates and packing sufficiently to inspect for concealed damage resulting from shipping and handling. Inspect equipment for condensation and water damage. If damage has occurred, notify the shipper and the manufacturer in writing immediately.

Compare equipment and accessories received with the bill of materials to verify that the shipment is complete. Verify that equipment and accessories received conform to approved submittals and manufacturer quotations. If the shipment is not complete, notify the manufacturer in writing immediately.

Uncrate station control power batteries and place on trickle chargers immediately upon receipt.

Circuit breakers are typically shipped in the CLOSED position. After removing packing material, open the circuit breaker by pushing the manual trip button located on the front of the circuit breaker. Check the indicator flags on the front of the circuit breaker to ensure that the circuit breaker is OPEN and the springs are DISCHARGED.

If equipment and accessories are to be stored prior to installation, restore original packing materials and protect switchgear internal components from exposure to environmental conditions. When conditions permit, leave the packing materials intact until equipment and accessories are ready for installation. Follow the manufacturer instructions for proper protection and storage of the equipment, including the use of heaters and other methods to prevent condensation.

4.2 Handling

Switchgear is typically shipped to the customer as completely assembled as possible, although several shipping splits may be necessary to facilitate handling larger switchgear line-ups. Switchgear sections may be bolted to wooden skids or pallets, or may be permanently bolted to a structural steel base. Drawout type circuit breakers are typically shipped in individual containers, but fixed-mounted circuit breakers are shipped installed in switchgear. Follow the manufacturer instructions for proper handling.

Switchgear is typically large, bulky equipment weighing several thousand pounds or more. The packing list will provide the actual weight of each item. Handle equipment and accessories in accordance with the manufacturer instructions in order to avoid personal injury or death and damage to the equipment. Heed all manufacturer warnings and instructions, including hazard messages. If the instructions are unclear, consult the manufacturer.

Verify that the lifting capacity of the handling equipment is more than the weight to be moved. Obtain the shipping weight prior to receiving the shipment. Provide suitable protection against the weather, in accordance with the manufacturer instructions.

Handle switchgear carefully, especially considering that instrument panels on the front of the switchgear

may contain delicate instruments, relays, meters, switches, and controls that are easily damaged. Avoid impact, jolting, jarring, and rough handling.

Indoor switchgear shipping sections are typically equipped with lifting lugs or provisions at the top of the sections, while outdoor switchgear shipping sections typically have lifting provisions at the bottom of the section. Switchgear is typically intended to be handled using a crane. Do not handle switchgear that is not mounted and secured to the shipping pallet or circuit breakers using a forklift unless the manufacturer instructions provide specific guidance for the use of a forklift.

Unload switchgear shipping sections from the delivery truck using a crane *(See Figure 1)* or forklift in accordance with the switchgear manufacturer handling instructions. Attach a lifting cable at each of the four (4) lifting points to lift and move sections, and use load-rated slings or cables with safety hooks or shackles. Use spreader bars to maintain proper angles for lifting and to prevent slings or cables from rubbing against equipment. Rig the lifting slings or cables so that the minimum angle between lifting slings or cables and the top of the equipment is 45°, and the maximum interior angle is 90°. Interior angles greater than 90° apply greater inward pressure to lifting lugs which can damage or dislodge lifting lugs from switchgear. Remove and discard lifting lugs after the equipment has been placed in position. Screw bolts back into place to cover the mounting holes.

If crane facilities are unavailable, use rollers under the shipping skids or consult the manufacturer for recommendations. Maintain shipping skids to protect switchgear from being distorted or damaged during handling. Do not handle switchgear directly on rollers.

Preferably, install switchgear in the final installation location upon delivery. When switchgear is stored in other than the final installation location, coordinate staging to minimize handling. *NOTE: Do not install the plenum or exhaust duct(s) on arc-resistant switchgear so equipped (when shipped uninstalled) until the switchgear is installed in its permanent location.*

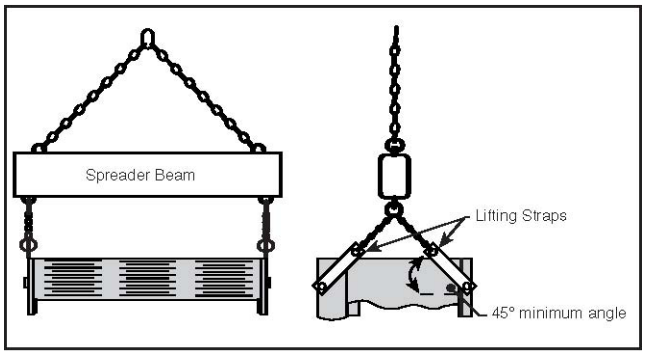

Figure 1

When handling circuit breakers on a smooth, flat surface, roll and maneuver circuit breakers by grasping only those points specified by the circuit breaker manufacturer. Do not use the main contacts of circuit breakers or primary lead assemblies as lifting handles.

Use the lifting truck or other equipment designed for lifting that is recommended by the manufacturer for elevating and transporting circuit breakers. If it is necessary to lift circuit breakers with a hoist or crane, follow the circuit breaker manufacturer instructions for lifting the circuit breaker. Always verify that the lifting device is capable of supporting more than the weight of the circuit breaker, and use four appropriately sized and rated hooks. Use the manufacturer-provided structural lifting points when hoisting or lifting circuit breakers. Attach lifting hooks to the circuit breaker lifting provisions (typically located on the side frame members of the circuit breaker). Use a spreader bar or beam that is wider that

the circuit breaker to prevent the slings from contacting the vacuum interrupter supports. Do not lift circuit breakers by placing forklift forks beneath the circuit breaker frame.

4.3 Storage

Failure to properly store and protect switchgear in accordance with the manufacturer instructions may cause damage to the equipment and components that could result in property damage and personal injury or death when switchgear is energized. Unsatisfactory storage conditions can cause damage to the insulation and sensitive electrical and electronic components. Inspect switchgear regularly during storage for signs of damage or deterioration.

Switchgear bus connections that are completed in the field are vulnerable to contamination during storage. Protect switchgear open bus connections from the environment during storage.

Store switchgear indoors in a clean, warm, dry, well-ventilated room with a moderate temperature ranging between 40°F and 100°F, with a smooth, level floor to prevent strain and distortion of equipment. Ensure that the storage location has suitable drainage to prevent standing water in close proximity to the switchgear. Keep in mind that outdoor switchgear is not considered weatherproof until the installation is complete.

Store switchgear in its permanently installed location whenever possible.

Protect switchgear from rain, snow, dirt, and dust, until final assembly is completed, especially considering switchgear bus runs and openings in shipping splits.

Protect switchgear and circuit breakers from corrosive gases or fumes, dust, foreign objects, and rodents. Moisture in combination with cement dust is very corrosive.

Store switchgear in a monitored area to discourage vandalism and theft, and out of the way of construction traffic.

Lubricate important parts such as jack-screws, gears and chains of racking mechanisms, linkages, and moving parts with manufacturer-recommended heavy oil or grease to prevent corrosion or rust.

Maintain switchgear internal temperature approximately 10°F above ambient temperature during storage to prevent condensation. Temporarily energize switchgear space heaters from an outside source. Open the control power transformer secondary disconnecting means, remove the primary fuses, and install an out-of-service tag before energizing space heaters from an outside source to prevent backfeeding the main bus through the control power transformer. Alternatively, use a temporary heating source for switchgear that is not equipped with space heaters. Maintain a minimum of 200 Watts of heat per circuit breaker and primary cable compartment. Remove all cartons and other miscellaneous materials packed inside units before energizing heaters. Do not use sources of heat that generate smoke, grease, or other products of combustion that can deposit carbon on insulation, resulting in tracking, corona, and eventual insulation failure.

Spot check insulation resistance of such parts as operating coils every six weeks during storage. If any readings are low, perform high potential testing. If switchgear shows evidence of moisture contamination, follow the guidelines found in the NEMA publication, “Evaluating Water-Damaged Electrical Equipment.” Consult the manufacturer for additional recommendations.

Support the switchgear frame during storage. The foundation must be level and flat. If the base is made of a material other than concrete, elevate switchgear above ground level to minimize the effects of ground moisture. If pier mounting is required, consult the manufacturer for recommendations.

Provide ventilation during storage. If extended storage is required, ensure that switchgear ventilation openings are unobstructed and provide free circulation of air.

4.3.1 Storing vacuum circuit breakers

Store vacuum circuit breakers in a clean, dry area protected from damage, corrosion, and construction debris. Store drawout-type circuit breakers separately from switchgear, unless recommended to be stored in the switchgear by the circuit breaker manufacturer.

Inspect circuit breakers regularly for rust and overall condition when stored for prolonged periods. Manually operate circuit breakers periodically when stored for any length of time, and lubricate in accordance with manufacturer instructions when necessary.

Complete the manufacturer recommended inspections and tests before energization. If vacuum circuit breakers show evidence of water contamination, follow the guidelines found in the NEMA publication, "Evaluating Water-Damaged Electrical Equipment." Consult the manufacturer for additional recommendations,

4.3.2 Storing batteries

Store batteries indoors, in a dry location.

Batteries that have been shipped dry and charged should have the seals inspected when they are received at the site. Renew seals that are damaged in accordance with manufacturer instructions.

Batteries that have been shipped wet should be handled carefully and inspected periodically. As storage and float charge recommendations may vary by battery technology type and storage temperature, follow manufacturer instructions. Inspect electrolyte levels when batteries are received at the site. Add electrolyte as needed to maintain proper levels.

Charging batteries can result in the generation of explosive gases. Provide proper ventilation during charging operations. Do not exceed the manufacturer recommended charging rate. Do not overcharge batteries.

Other types of batteries that have been shipped wet should be handled in accordance with the manufacturer instructions.

4.3.3 Storing maintenance and test equipment

Store maintenance and test equipment, such as charging tools, racking tools, and Ground and Test devices, in a clean, dry area protected from damage, corrosion, and construction debris. Store maintenance and test equipment separately from switchgear, unless recommended to be stored in the switchgear by the circuit breaker manufacturer.

Inspect maintenance and test equipment regularly for rust and overall condition when stored for prolonged periods. Manually operate maintenance and test equipment periodically when stored for any length of time, and lubricate in accordance with manufacturer instructions when necessary.

Complete the manufacturer recommended inspections and tests before energization. If maintenance and test equipment shows evidence of water contamination, follow the guidelines found in the NEMA publication, "Evaluating Water-Damaged Electrical Equipment." Consult the manufacturer for additional recommendations,

5. Site Preparation

5.1 General Requirements

Install switchgear in accordance with contract documents, drawings and specifications, approved shop drawings, and manufacturer instructions. Follow local codes and standards, especially the NEC. Consult qualified individuals for the evaluation and recommendations related to the site.

Install switchgear in damp or wet locations in accordance with NEC Section 495.3(B).

Locate switchgear to reduce to a minimum the probability of igniting adjacent combustible materials. Provide suitable protection when installing switchgear over a combustible floor.

Maintain a minimum overhead clearance of 900 mm (3 feet). For arc-resistant switchgear, maintain a minimum overhead clearance that is no less than that specified by the switchgear manufacturer, NEC, and applicable building codes. Do not install switchgear underneath catwalks or other elevated personnel access routes.

Install arc-resistant switchgear in accordance with manufacturer instructions.

5.2 Site Selection

Check that the switchgear location has adequate ventilation and/or suitable environmental controls that limit the ambient temperature around the switchgear to 40°C (104°F) or less. If the switchgear is intended to be installed in an environment with an ambient temperature that exceeds 40°C (104°F), de-rate the switchgear in accordance with manufacturer instructions. Check that supply air around the switchgear is clean, dry, and filtered.

Check that adequate lighting is provided for all working spaces about switchgear, including both the front and back aisle spaces around the switchgear.

Provide clearances in accordance with applicable Codes, such as NEC 110.32, 110.33, and 110.34, in accordance with manufacturer instructions, and as needed for access and maneuvering lifting trucks, whichever is greater. Check that sufficient clear aisle and working space is available around the switchgear to fully open doors for removing circuit breakers and transformers, considering equipment and components that may be recessed-mounted on the cubicle door. Provide working space at the rear of the switchgear to install conductors and to perform inspections and maintenance as needed. The working space must allow all doors to open at least 90 degrees, and shall, at a minimum, comply with the working

space requirements of the NEC.

Check that switchgear is protected against water damage. Check that water, sewer, and steam lines do not pass directly over or in close proximity (within 2 m (6 feet)) to switchgear. When possible, have water, sewer, and steam lines re-routed. Otherwise, provide drain pans, rain guards, or water shields as needed to protect switchgear from overhead sources of liquids. Check that adequate floor drainage exists in switchgear rooms. Ensure compliance with NEC and local building codes with respect to locating water lines and other foreign systems in the vicinity of switchgear.

Check that the site can structurally support the installed switchgear and the equipment necessary to move the switchgear into position.

Check that switchgear seismic withstand capabilities are compatible with the installed location and comply with contract requirements. Check the proposed installation pathways before ordering shipping splits to ensure that switchgear sections or lengths can be moved past obstructions in the pathways.

5.3 Raceways

Install raceways in accordance with drawings, specifications, and manufacturer shop drawings. Carefully coordinate raceway locations to prevent mechanical interferences. Raceways must enter from either the top or the bottom of the cable compartment in accordance with the switchgear manufacturer instructions.

Install raceways stubbed up prior to pouring concrete. Stub up raceways, including end fittings, a maximum of 75 mm (3 inches) above the bottom of the switchgear enclosure. Ensure that there is no mechanical interference with raceways and switchgear floor steel. Protect existing raceways and conductors when existing switchgear is replaced with new.

Install top entrance raceways after switchgear is set in place.

5.4 Switchgear Foundation

Install concrete equipment pads in accordance with contract documents, drawings and specifications, and manufacturer instructions. Coordinate the installation of grounding electrodes, such as ground rods, ground rings, and concrete-encased electrodes, with the foundation installation. Coordinate underground raceway stub-ups with the foundation installation.

Switchgear may be designed to be installed on manufacturer-supplied base channels. When provided, install base channels and grout in concrete in accordance with manufacturer instructions. Locate base channels where detailed in the manufacturer shop drawings. When existing switchgear is replaced with new, coordinate base channel requirements of new switchgear with the existing base channel, and ensure that the base channels lie in a flat, level plane in accordance with the manufacturer instructions to ensure proper alignment and to prevent distortion of the switchgear cubicles and structure. Ensure that non-supporting areas of the foundation are lower than the tops of the base channels.

When base channels are not provided, ensure that the switchgear foundation is smooth, hard, and level. Ensure that the aisle in front of the switchgear foundation is smooth, hard, and level to accommodate the lifting truck and to facilitate the installation and removal of circuit breakers.

Do not install continuous loops of reinforcing rods, structural steel, or circular cut-outs of steel sheets or plates where such a loop will surround a single conductor of a three-phase circuit, such as for an isolated phase arrangement. All conductors of a three-phase circuit shall pass through the same opening in any steel plate, sheet, structure, or the like to avoid inducing circulating currents in the steel.

6. Installing Medium-Voltage Switchgear

6.1 General Requirements

Switchgear and accessories vary with the manufacturer. Install switchgear sections in accordance with approved shop drawings and manufacturer instructions. Review the manufacturer assembly drawings prior to installation. Ensure that switchgear sections are assembled in the correct order.

Coordinate the installation of utility service entrance rated switchgear with the local electric utility company.

Verify that the switchgear foundation is properly sized and located with sufficient clearances in accordance with approved shop drawings. Provide sufficient clearance in front of the switchgear to remove and install drawout type circuit breakers and potential transformers, and at the back of the switchgear to install cables and to perform maintenance and inspections. The working space must allow all doors to open at least 90 degrees, and shall, at a minimum, comply with the working space requirements of the NEC.

Verify that raceway placement on the foundation is accurate according to the approved shop drawings. Errors in raceway placement may prohibit proper installation of the switchgear.

Sweep the concrete pad clean and remove debris before installing any switchgear sections.

Inspect switchgear for physical damage prior to installation. Do not install switchgear that is damaged. Complete all manufacturer recommended repairs prior to installing switchgear.

If there is evidence of moisture contamination, follow the guidelines found in the NEMA publication, “Evaluating Water-Damaged Electrical Equipment” and consult the switchgear manufacturer for additional recommendations. Test primary circuits using high potential testing in accordance with the switchgear manufacturer instructions. Consult the manufacturer for recommendations for any suspect test results.

Use an aligning tool such as a punch as needed to move cubicle sections into alignment. Ensure that switchgear is properly aligned and that cubicle doors open and close without binding. Binding doors indicate that the cubicle is not level. Level cubicles in accordance with the manufacturer instructions as needed.

Protect relay cases, instrument cases, and control panels of outdoor walk-in switchgear from environmental conditions during installation until the enclosure is fully assembled, tested, and energized. Relay and instrument cases are not weatherproof.

Upon completion of the installation, seal any gaps between the concrete pad and switchgear steel structure to prevent the entry of contaminants, such as rodents, rain, or snow.

6.2 Setting Switchgear in Place

When installing switchgear consisting of two or more shipping sections, carefully select which switchgear section to install first. When more than two shipping sections are involved, any error in raceway stub-up location can cause a cumulative error significant enough to prohibit proper installation of the switchgear. To lessen the cumulative error, install the center shipping section first and work toward each end.

If the switchgear lineup is to be installed where it will be close-coupled to a transformer, install the switchgear section that connects to the transformer first before installing subsequent sections.

Carefully align the openings on the bottom of switchgear sections with raceways on the foundation before lowering switchgear into place.

Unbolt and remove the switchgear shipping skids. Set the switchgear section into position. Use a level to make sure the section is level both across its width and along its length. Use a plumb line to make sure the section is plumb. If necessary, level the section using steel shims at the points where the vertical sections will be bolted to the foundation.

Line up the bolt holes in the base of the vertical sections with the bolt holes in the base channels in the foundation. Loosely install but do not tighten anchor bolts. Verify that the back of the section is square with the concrete pad and has proper clearance. Draw a base line along the length of the intended location of the switchgear in the front of the line-up to keep the shipping sections parallel when installing subsequent sections.

After the installation of the switchgear, remove the door supports, if provided, so that the upper and lower compartment doors on the front of the switchgear can be opened. Discard the door supports after removal. It is not necessary to retain or replace these supports after the switchgear installation is complete.

For outdoor switchgear, verify that the factory-installed gasket attached to one side of the shipping section is in place before installing subsequent sections. If gasket material is damaged or missing, repair it using manufacturer-supplied gasket repair materials. Ensure that there is no gap between splices if repairs are made. Outdoor walk-in switchgear with an aisle may have separate aisle sections. See Sections 6.4 and 6.5 for further installation instructions.

Position subsequent sections of switchgear as close as the lifting members will permit with the front in alignment with the previous section. Carefully align the openings on the bottom of switchgear sections with raceways on the foundation before lowering switchgear into place.

Remove the lifting members and maneuver the section until it is flush with the previous section. Distribute forces over the side frame using appropriate timbers or materials so as not to deform or damage the surface of the structure. If necessary, level the section using steel shims at the points where the vertical sections will be bolted to the floor.

Verify that the switchgear sections are level, aligned, and fit snugly together. If the sections do not fit properly, lift the most recently placed section by crane, remove any obstructions, and re-install.

Align the shipping sections side by side on the tie bolt side and bolt switchgear shipping sections together using manufacturer-supplied bolts and recommended methods. For outdoor switchgear, secure the two sections together using bolts at the front and rear of the switchgear, and across the roof of the assembly in

accordance with manufacturer instructions. Tighten bolts sequentially. Do not tighten bolts to manufacturer recommended torque values until all bolts are installed to maintain flexibility while installing sections.

Repeat this installation sequence for additional sections of switchgear.

After indoor switchgear sections are in place, bolt or weld the base members of the front and rear vertical section frames to the foundation channel. Do not bolt or weld the base members of outdoor switchgear until all components are assembled as detailed in Section 6.4.

Remove shipping covers. Be careful not to damage instrumentation on front doors of switchgear when removing shipping covers.

Remove all shipping braces. *NOTE: Failure to remove shipping braces in accordance with manufacturer instructions in arc-resistant switchgear may prevent automatic operation of ventilation flaps.* Do not remove shipping bracing, sheet metal angles, bars, or channels for outdoor walk-in switchgear until the aisle space section is in place and bolted to the switchgear section. See Sections 6.4 and 6.5.

6.3 Arc-Resistant Switchgear

Install arc-resistant switchgear in accordance with manufacturer instructions and installation drawings.

Ensure that switchgear foundation conforms to design documents and manufacturer instructions.

These conditions are considered normal operating conditions for proper application of arc resistant switchgear designs and are as follows.

- All doors and covers providing access to high-voltage (primary) components are properly closed and latched. All bolts, fasteners, and hardware must be installed and tightened. All latches must be in the latched position.
- Plenum and exhaust ducts, as required by the switchgear manufacturer, are properly field-installed on top of the switchgear when the switchgear is of the ducted design. *NOTE: The exhaust plenum must be routed to an area where personnel will not be present when the equipment is energized. When the exhaust duct provided by the switchgear manufacturer is modified or extended, the switchgear manufacturer must be consulted to determine that such modification or extension will not affect the performance of the switchgear.*
- Pressure relief devices are free to operate as designed.
- The fault energy available to the equipment does not exceed the rating of the equipment (short-circuit current and duration).
- There are no obstructions around the equipment that could direct the arc fault products into an area intended to be protected.
- The equipment is properly grounded.

Maintain the manufacturer recommended or NEC required minimum clearances from arc-resistant indoor switchgear to walls or overhead obstructions, whichever is greater. Ensure that no one is in the areas above the switchgear or adjacent to the top of the switchgear when switchgear is energized. Ensure that no one walks on or stands on top of the switchgear when the switchgear is energized. Maintain horizontal clearances in accordance with the manufacturer recommendations for the specific switchgear application.

Arc-resistant switchgear is provided in either a ducted or non-ducted configuration. The ducted configuration directs the pressure, hot gases, and debris through a duct to an area outside of the room in which the switchgear is located. The non-ducted configuration uses pressure relief flaps to relieve the internal pressures generated by an internal arc and directs the resultant hot gases and debris into the room, but away from areas normally occupied by personnel in the room. The non-ducted design may have additional arc shields that serve to direct the gases and debris away from personnel.

Some arc-resistant switchgear plenum or arc shield assemblies are factory-installed. Handle such switchgear in accordance with manufacturer instructions. Use manufacturer recommended lifting points. Do not lift switchgear cubicles using the plenum, exhaust, or arc shield assemblies.

When the switchgear is shipped with the plenum, duct, or arc shield assemblies separate from the switchgear, these must be installed in accordance with the manufacturer instructions. For arc-resistant switchgear with plenum or arc shield assemblies that must be field-installed, lift and move field-installed plenum assemblies by following the manufacturer instructions. Cranes or fork lifts shall only be used to handle these parts as recommended by the switchgear manufacturer.

If equipment or space restrictions prevent the use of power equipment to lift the plenum assemblies, they must be installed manually. To do this, select a single plenum assembly and disassemble it into component pieces, saving all parts and hardware. Then install the plenum on top of the equipment one piece at a time, reassembling with the same hardware. It is strongly recommended that only one assembly is disassembled at a time, so the others may be used as a reference during reassembly, and parts are not mixed.

NOTE: Plenums, ducts, and arc shield assemblies for arc-resistive switchgear that are shipped separately are designed for installation after the equipment is positioned in its final installation location.

Do not over-tighten self-tapping screws. If any self-tapping screws strip during installation, screw the self-tapping screw into a nut. Ensure that the nut is installed to the same torque value as the self-tapping screw.

Ensure all shipping splits of the switchgear are installed, properly aligned and flush, and all bolts (including foundation anchor bolts) are properly torqued prior to installing field-installed plenum, exhaust, or arc shield assemblies.

6.3.1 Field-Installed Plenum and Exhaust Duct Assemblies

Follow manufacturer instructions for transporting, moving, and installing plenum and exhaust assemblies.

Improper installation of plenums, exhaust duct, and associated collars and fittings may adversely affect the ability of the equipment to protect against the hazards associated with internal arcing faults. Installation shall be made strictly in accordance with the instructions provided by the switchgear manufacturer. If any collars, fittings, or hardware are missing or damaged, replacements should be obtained from the original switchgear manufacturer.

6.3.2 Field-Installed Arc Shield Assemblies

Follow manufacturer instructions for transporting, moving, and installing arc shield assemblies.

NOTE: Some arc-resistant switchgear designs incorporate arc shield assemblies that help to redirect exhaust gases away from the switchgear. The arc shield is designed to raise the switchgear exhaust height, should an arc event occur, thereby increasing the likelihood of protection at the front, rear, and sides of the equipment. Arc shields must be installed when (and only when) they are specified in the switchgear manufacturer installation instructions.

6.4 Single-Aisle Outdoor Walk-In Switchgear

Follow specific manufacturer installation instructions and shop drawings when installing equipment. The description which follows is generic.

For some outdoor walk-in switchgear designs, it may be necessary to disassemble channel caps, cap bushings, roof caps, end trim, corner caps, and similar components to attach aisle sections to switchgear sections. Retain hardware, washers, and bolts for reassembly.

Some outdoor walk-in switchgear aisle sections are field-assembled from separate components, such as aisle floors, walls, and extensions, and require sequenced assembly in addition to the setting of the aisle shipping sections. Follow the manufacturer instructions for the sequenced installation of components.

Take care in aligning joints between aisle sections and between aisle and switchgear sections. Ensure that gaskets are properly placed.

Verify that bases and roof lines are level using a level and a straight-edge. The front floor aisle will only be level if the switchgear is level.

Install aisle space sections. Aisle space is shipped in sections for multiple bays, typically four or more bays. Equipment and corridor space sections are typically designed similar to switchgear sections and can be unloaded and installed in a similar manner.

Do not remove shipping bracing, sheet metal angles, bars, or channels until the aisle space section is in place and bolted to the switchgear section.

Verify that vertical sections, bases, and roofs are aligned with switchgear sections. If necessary, level and align sections using steel shims at the points where vertical sections will be bolted to the floor. *NOTE: Check the manufacturer instructions for the number of shims that can be used. Some manufacturers limit the number of shims permitted.* Ensure that the bolt holes of the aisle roof support brackets align with the corresponding holes on the front of the switchgear sections.

Attach the aisle section to the switchgear section by bolting each bay's aisle roof support bracket to the front of the switchgear and the aisle roof to the switchgear roof. Verify continuity of gasket material or apply gasket material. Repair damaged or missing gasket material. Ensure that spliced gasket material overlaps. Install connecting bolts loosely until all are in place.

Bolt the aisle base to the switchgear base. If required, pry the aisle base in place with an alignment bar using care to avoid damaging the equipment.

After the aisle section is in place and attached to the switchgear section, remove the end shipping braces. Do not remove the braces from in front of the switchgear as it may be necessary to lift the aisle section again if it does not align properly.

Using a crane, set the second aisle section onto the concrete pad or foundation approximately 300 mm (12 inches) from the section in place.

Remove the end braces from the new section and lift it carefully by crane into place. Do not remove the end braces before it is setting on the pad to prevent distorting the assembly.

Attach the second aisle section to the switchgear by bolting each bay's aisle roof support bracket to the front of the switchgear and the aisle roof to the switchgear roof. Insert the connecting bolts loosely and tighten after all of the bolts are in place.

Attach the second aisle section to the first aisle section by bolting the aisle roof supports together.

Bolt the aisle base to the switchgear base. If required, pry the aisle base in place with an alignment bar using care to avoid damaging the equipment.

After all aisle sections are bolted in place, remove the aisle shipping braces in front of the switchgear.

Mount the aisle roof caps to the roof at each shipping split and at each end, using manufacturer-supplied hardware and any supplemental sealant, caulk, or gasket material.

Mount the switchgear roof cap to the roof at each shipping split and at each end, then to the aisle roof support using bolts, seal washers, and locknuts.

Inspect for cracks which could be directly exposed to rain. Enter the walk-in enclosure, close the doors, and look for any light coming through joints, mainly in the corners and other locations that could be directly exposed to rain. Make note of cracks and seal them using the manufacturer recommended materials and methods.

Remove lifting lugs located on the roof of switchgear (if applicable) and plug holes with factory supplied bolts and seal washers.

Install all skirts around the bottom of the switchgear.

6.5 Common-Aisle Outdoor Walk-In Switchgear

Follow specific manufacturer installation instructions and shop drawings when installing equipment. The description which follows is generic.

Refer to the single aisle installation procedures (Section 6.4) for similar general assembly procedures for common aisle switchgear. Common aisle switchgear may be shipped with "low side" switchgear sections (that have a lower height where the roof sub-assembly connects to the sections) and "high side" switchgear sections (that have a higher height where the roof sub-assembly connects to the sections) fully assembled and ready to set on a concrete pad or foundation. The aisle may be shipped in separate sub-assemblies (base or floor sub-assembly, roof sub-assembly, and end-panel sub-assemblies).

Install the "high side" switchgear section first.

Line up and bolt the aisle bases to the "high side" switchgear.

Install the "low side" switchgear section and bolt it to the aisle base. The line-up of all switchgear sections and bases must be accurate and square, and the floor must be level. Use shims as needed to level the aisle base.

Install the roof sub-assemblies by attaching them to the switchgear sections starting at the first cubicle. Ensure that roof sub-assemblies with equipment such as fans and heaters are installed at the correct location in accordance with the manufacturer shop drawings. Secure the roof panels with the manufacturer-supplied hardware.

Attach the end panel sub-assemblies to the sheet side and to the roof.

Make sure the gaskets attached to one side of the roof and around all bolted flanges are in place. If damaged, repair gaskets using the factory-supplied gasket material. Ensure that there is no gap between splices when making repairs.

Attach the roof caps to the aisle and switchgear roof.

If applicable, remove the lifting lugs and seal the holes with factory-supplied bolts and seal washers. Ensure that all bolts and seal washers are in place. These bolts not only seal but hold the roof to the switchgear.

Install all skirts around the bottom of the switchgear.

6.6 Installing New Sections to Existing Switchgear

Consult the manufacturer for recommendations and instructions for modifying existing switchgear and to maintain the Nationally Recognized Testing Laboratory (NRTL) listing, if applicable. Ensure all existing equipment is in an electrically safe work condition for workers. Follow proper electrical/mechanical safety procedures to de-energize, test, ground, lockout, and tag out all sources of energy prior to removing any covers or doors of switchgear.

Circuit breakers and switches in switchgear have mechanical energy in charged springs used to operate mechanisms. Switchgear may contain uninterruptible power supplies (UPSs) or station batteries that provide control power during utility power interruptions. Switchgear also contains control power wiring within the switchgear enclosure to power spring charging mechanisms, operate controls, provide heating and illumination, indicate control position, and measure energy. Control power sources should be identified and placed in an electrically safe work condition for workers. Personnel working on energized switchgear should follow the safe work practices described in NFPA 70E, including the use of PPE appropriate for the task being performed.

6.6.1 Installing new sections

Carefully coordinate the installation of additional switchgear to extend existing switchgear with the manufacturer. Follow the manufacturer instructions, along with any special requirements for the specific installation.

Consult the manufacturer approved shop drawings prior to adding new sections of switchgear to existing line-ups, noting any specially prepared drawings detailing complicated or special assembly requirements.

Ensure that all required parts, tools, materials, and equipment are on-site prior to the start of work, to minimize the required power outage.

6.7 Final Assembly Checks

Tighten bolts sequentially to the manufacturer-recommended values using a calibrated torque wrench. Mark all torqued joints.

For outdoor walk-in or non-walk-in switchgear, verify that all joints are resistant to water leaks. Use a source of outside light with the aisle darkened to help identify areas subject to water leaks.

Anchor the base of the switchgear assembly to the foundation using materials and methods conforming to the manufacturer instructions. Install seismic restraints in accordance with the manufacturer instructions and anchoring details.

7. Electrical Connections

Circuit breakers and drawout components can be installed at any time after switchgear has been permanently installed. See Section 9, Checking and Installing Drawout Components. The installer typically makes the external control, ground, and power connections at the terminals provided, and reconnects the factory wiring and bus bars at the shipping splits.

Exercise caution around current transformer (CT) circuits. A CT carrying primary current can develop high secondary terminal voltages if the secondary terminals are open-circuited.

Medium-voltage cables supplied by the switchgear manufacturer for making field connections are typically not cut to length at the factory and must be cut to length in the field. Some switchgear manufacturer-supplied medium-voltage cables may be unshielded. In such a case, ensure that manufacturer-supplied unshielded cables are properly separated from all grounded metal components, from all other phases, and from bushings or terminations of other phases. Install and terminate medium-voltage cable in accordance with the NEC, and NECA/MACSCB 600, Standard for Installing and Maintaining Medium-Voltage Cables (ANSI). Protect cables from damage from sharp edges.

7.1 Bus Bar Connections

Carefully observe the phasing of buses and conductors. Bus is typically phased A-B-C from left to right, top to bottom, and front to back, when viewing the assembly from the front, but most terminations and connections are made in the back of the equipment.

For three-phase four-wire delta-connected systems, connect the phase having the higher voltage to ground to the B phase. *Note: Equipment within the same single section or multi-section switchgear as the meter on three-phase four-wire delta-connected systems are permitted to have the same phase configuration as the metering equipment.*

Confirm that the bus phase sequence is as designed and intended for the typical phasing arrangement, and that any different bus phasing is properly identified and labeled. Ensure that phase rotation and phase angles match for paralleled systems. Instruments, meters, and relays will not work properly on out-of-

phase or reverse-phase systems.

Follow the manufacturer instructions when making bus bar connections.

Ensure that all sources of power are disconnected in accordance with Section 3 prior to making bus bar connections.

For metal-clad switchgear, install the primary bus between switchgear sections by removing the main bus covers to expose the vertical bus bar risers. Install one phase at a time by sliding the horizontal bus bars through the divided insulating barrier.

For metal-enclosed switchgear, install the primary bus between open switchgear sections by removing access covers to expose the bare main bus bars. Where working space is restricted, install one phase at a time, installing the most restrictive components first.

Wipe contact surfaces with a clean, soft, dry, lint-free cloth to remove dirt and grease from silver-plated or tin-plated surface areas. Do not use any chemicals, abrasive agents or wire brushes on plated surfaces. Avoid handling contact surfaces after cleaning.

Most medium-voltage connections are made with plated conductors and are dry connections. Protect plating from damage. Apply manufacturer recommended grease covering all contact surfaces only when recommended by the manufacturer. Apply grease evenly such that excess grease will be squeezed out along the edges of the bus bars as bolts are tightened. Wipe off excess grease.

Loosely bolt the horizontal bus to the vertical bus. Do not bend or force the bus bars to make this connection. For metal-clad switchgear, loosen the through-bushings and the divided insulating barrier, if necessary, to allow for minor field misalignment of shipping sections.

Tighten bolts connecting the bus joints only after bus bars are in place and properly aligned. Tighten bus bar connection bolts sequentially using a calibrated torque wrench in accordance with the manufacturer instructions. Ensure that Belleville washers, where installed, are properly flattened. Check all connections that do not have torque marks.

For uninsulated or boot-insulated joints and connections of silver-plated or tin-plated materials, apply a thin coat of manufacturer recommended grease to all external joint surfaces, if applicable, including the edge of bus bars and all hardware. Tape-insulated and non-silvered connections do not require grease on external surfaces, but may require grease on internal contact surfaces.

For metal-clad switchgear, insulate the bus and bus connections using insulation boots, heat-shrink or cold-shrink insulation products, or high voltage tape in accordance with the switchgear manufacturer instructions. Bus bar insulation and boots form an integral insulating system for the switchgear to meet its dielectric ratings. Do not damage or modify bus bar insulation.

Re-install metal barriers and any other parts that may have been removed to give access to bus compartments.

7.1.1 Ground bus

Assemble ground bus joints using manufacturer-furnished splice bus in accordance with manufacturer instructions. Refer to shop drawings for the locations of shipping splits and splice plates and associated

mounting hardware.

Bond the switchgear ground bus to the grounding electrode system or station ground bus using a grounding electrode conductor sized in accordance with the NEC or NESC as applicable, and sized to carry the available fault current of the installation. Install the grounding electrode conductor in as direct a path as possible.

Install the grounding electrode conductor in a non-metallic raceway. Do not use metal raceways to protect the grounding electrode conductor unless the raceway is bonded to the grounding electrode conductor at each end.

7.2 Bus Insulation

Insulate bus connections in accordance with the manufacturer instructions. All connections in metal-clad switchgear must be insulated to comply with ANSI/IEEE C37.20.2, Standard for Metal-Clad Switchgear.

Install heat-shrink and cold-shrink insulation products in accordance with the switchgear and installation kit manufacturer instructions. Select and install insulating tape in accordance with the manufacturer instructions.

Clean the area to be insulated of dirt and foreign matter using a clean, dry cloth. Do not use solvents or abrasives.

Insulated bus coverings made from thermoplastic can be damaged if cleaned with petroleum-based chemicals such as solvents, oils, greases, and electrical joint compounds. Use only manufacturer approved tapes and fillers for insulating bus bar joints. If recommended by the termination kit manufacturer, use electrical grade putty or filler to grade voids and to smooth out sharp edges of joints, potheads, terminators, entrance bushing connections, hardware, and similar materials.

If recommended by the manufacturer, deburr any bus bars with any burrs or sharp edges and make smooth prior to installing tape.

Apply three layers of high voltage tape, mastic side down, at medium tension to bus bars and over all bolt heads, nuts, bars, and splice plates, to form a smooth surface for taping.

Apply two layers of one-half lap of high voltage tape, mastic side down, maintaining a medium tension on the tape while wrapping. Begin the wrap away from connections, overlapping the adjacent insulation, whether epoxy fluid dip, thermoplastic sleeves, cable, or tape, by a minimum of three inches.

Extend insulation beyond bus insulation for voltage rating of equipment in accordance with the switchgear manufacturer instructions. Where potheads or porcelain bushings are to be taped, overlap the first porcelain skirt with tape.

When completing the wrapping of the connection, do not keep tension on the last 50 to 75 mm (2 to 3 inches) of tape. Carefully place the last few inches of tape in place, mastic side down, without tension to prevent the tape from unraveling.

Apply insulation when assembling the connection bar end of roof entrance bushing inside outdoor switchgear and at other terminations where porcelain insulators are used.

7.3 Control Conductors

Reconnect internal switchgear control wiring between terminal blocks at the shipping splits in accordance with manufacturer instructions. Torque control wiring terminations to the manufacturer recommended tightness.

Install external control conductors after switchgear is set in place. Segregate conductor and cable routing by conductor insulation rating and purpose, such as routing control circuits away from high voltage conductors and connections, where possible. Control conductors must be routed away from all high voltage cables and components, whether insulated or uninsulated.

Route control conductors entering switchgear from raceways toward the sides of the switchgear enclosure to protect from moving components and damage. Properly secure all field installed wiring and verify no interference with components of the switchgear, including drawout elements.

Connect conductors to terminal blocks in accordance with manufacturer wiring diagrams.

7.4 Medium-Voltage Cable Terminations

Install conductors in accordance with drawings, specifications, and manufacturer instructions. Confirm the voltage and phase configuration prior to making terminations.

Install medium-voltage cable in accordance with NECA/MACSCB 600, *Standard for Installing and Maintaining Medium-Voltage Cables.* Avoid sharp bends or kinking cables when training cables in switchgear cable compartments. Ensure that cables do not rest on sharp corners or edges that could damage insulation. Ensure that cables comply with minimum bending radii.

Ensure that cables are supported independently of terminations. Failure to independently support cables may result in damage to switchgear terminals that can result in personal injury or death and equipment damage. Where required, secure, brace, and otherwise restrain cables to limit cable movement during a short circuit.

Remove rear bolted covers, cable trough cover, and cable trough.

For bottom-fed cables, terminate cables in the bottom cubicle first. For top-fed cables, terminate cables in the top cubicle first. Avoid sharp turns, edges, or corners to prevent damage to cable insulation.

Terminate cables in the remaining cubicle, if applicable. Maintain adequate dielectric clearances between bus bars and cable shields.

Insulate cable connections in accordance with switchgear and cable manufacturer instructions. After cables are installed, use insulating putty and tape or heat-shrink or cold-shrink insulating means to insulate power cable lug connections in accordance with the switchgear manufacturer instructions.

For insulating tapes:

- Place insulating putty around lugs and bolts to reduce the concentrated electric field created by their irregular shapes.
- Apply a layer of semi-conducting tape over the insulating putty. Apply semi-conducting tape in

half-lap layers and extend onto the conductors. Do not extend the tape over the bus epoxy insulation. Ensure that semi-conducting tape touches the bus or terminals in at least one place, and does not overlap bus or cable insulation.

- Apply high voltage insulating tape over the semi-conducting tape. Apply half-lap layers in accordance with the manufacturer instructions for the nominal system voltage. Insulate terminations for the voltage rating of equipment in accordance with the manufacturer instructions.
- Apply two additional layers of insulating tape for moisture-tight electrical and mechanical protection of the connection. Extend tape completely over the high voltage insulating tape in all directions.

Install heat-shrink and cold-shrink insulation products in accordance with the switchgear manufacturer recommendations and installation kit instructions.

Provide suitable, permanent identification for primary conductors.

Replace the switchgear cable trough and cover, and rear access covers.

7.4.1 Window-type (zero-sequence) ground-fault current transformers

Window-type current transformers are furnished where specified for sensitive protection against ground faults and are typically installed in a horizontal position directly above or below the primary cable terminations so that the primary cable or cables can pass through them easily. One transformer is required for each three-phase circuit.

Terminate and ground the armor of armored cable before primary cables pass through current transformers. Use manufacturer-approved armor clamps for this purpose. Maintain adequate dielectric clearance between cables and CTs.

Solidly ground conducting cable sheathes to the switchgear ground bus before primary cables pass through current transformers.

Where the ground cannot be applied before the primary cable passes through the transformer, bond the lead to the sheath or shield between the transformer and the primary terminals. Route the ground conductor back along the cable path through the current transformer before connecting to the ground bus.

Insulate pothead mountings from ground where pothead terminations are used with current transformers.

7.5 Metal-Enclosed Bus

Install metal-enclosed bus, or medium-voltage busway, in accordance with the manufacturer instructions.

Provide supports and seismic bracing for metal-enclosed bus in accordance with approved shop drawings.

Loosen metal-enclosed bus expansion joints, if equipped, prior to installation.

Start the installation of metal-enclosed bus from the most restrictive end of the run.

Install gasket material in outdoor metal-enclosed bus in accordance with the manufacturer instructions.

Torque connections in accordance with the manufacturer instructions.

Connect heaters for outdoor metal-enclosed bus in accordance with approved shop drawings.

7.6 Surge Arresters

Install surge arresters in accordance with the manufacturer instructions and in accordance with contract documents, drawings and specifications.

Mount surge arresters in the location recommended by the switchgear manufacturer. Typically, this is at the base of the switchgear in the event of an arrester failure. *Note: The addition of surge arresters to previously listed or labeled equipment may require further investigation by the certifying organization.*

Install surge arresters using short lengths of conductors. Do not install surge arresters using bus or other permanent installation methods.

Insulate the primary cable terminations of surge arresters. Surge arrester primary cable terminations are typically insulated at the factory unless they must be disconnected for shipment. When this connection is completed in the field, the primary connection must be insulated before the switchgear is energized.

7.7 Grounding and Bonding

Ground switchgear in accordance with the NEC and the NESC as applicable.

Size grounding electrode conductors in accordance with NEC 250.66.

7.7.1 Service Equipment

Switchgear installed as service equipment must include a ground bus for the connection of service cable shields and to facilitate the attachment of safety grounds for personnel protection. The ground bus must be extended into the compartment where the service conductors are terminated.

Where switchgear is used as service equipment, provide a main bonding jumper sized in accordance with NEC 250.28(D). Bond all sections of switchgear together using an equipment bonding jumper or supply-side bonding jumper sized in accordance with NEC 250.122 or 250.102(C)(1) as applicable.

Where the service disconnecting means does not disconnect the grounded conductor from the premises wiring, other means must be provided for this purpose in the service equipment. *NOTE: In switchgear, the disconnecting means provided for the grounded conductor is typically identified as a neutral disconnect link and is typically located in the bus to which the service grounded conductor is connected.* The disconnecting means for the grounded conductor is permitted to be located in any section of a multi-section switchgear provided that the switchgear section is marked to indicate that the grounded conductor disconnect is located within that section.

7.8 Outdoor Walk-In Switchgear Ancillary Equipment Connections

Switchgear accessories and optional equipment may be supplied power from external branch circuits, from a panelboard located inside an outdoor enclosure, from a panelboard mounted within the switchgear, or directly from the switchgear.

Connect accessories and optional equipment of outdoor walk-in switchgear in accordance with the manufacturer instructions. Refer to the wiring diagrams furnished with the switchgear for the locations of circuit breakers and the electrical connections of the shipping sections. In general, ancillary equipment is supplied power from one or more control power transformers connected to the switchgear main bus. Where control power is not derived within the switchgear, provide branch circuits for ancillary equipment as required.

Connect lights. Connect exhaust fans with thermostats. Consult the owner, Engineer of Record, or switchgear manufacturer for recommended exhaust fan thermostat settings. In the absence of other guidance, set exhaust fan thermostat temperatures for 27°C (80°F).

Connect service and maintenance receptacles, typically a minimum of one at each end of the enclosure.

Connect heaters with thermostats. Consult the switchgear manufacturer for recommended heater thermostat settings. In the absence of other guidance, set heater thermostat temperatures for 10°C (50°F), except for thermostats located inside the switchgear used to control space heaters within the switchgear. Keep in mind that the use of thermostatically controlled heaters must not cause the internal switchgear ambient temperature to exceed the maximum temperature specified by the manufacturer.

8. Closing Equipment

Carefully coordinate recommended and required internal inspections and electrical testing of switchgear before closing equipment. See Section 10, Testing and Commissioning Switchgear.

Carefully inspect cubicles, compartments, and work areas for debris, tools, conductor strands, and similar contaminants. Remove tools and debris, and clean equipment before replacing covers and closing doors. Use a vacuum with a cartridge filter to clean every compartment.

Seal cracks in outdoor switchgear found after final inspections using manufacturer-approved materials and methods.

Adjust switchgear doors as needed in accordance with the manufacturer instructions. Incremental adjustments are recommended to avoid springing a door hinge.

Replace all main bus covers, and any other barriers or covers that were removed during installation. Verify that all insulating boots are installed, if applicable. Secure insulating boots with wire ties or plastic fasteners in accordance with switchgear manufacturer instructions.

Install cable compartment covers and access doors.

Verify that control power transformers have current limiting fuses in place. Pull the drawer out to the withdrawn position.

Check that the pressure relief flaps are in the correct position and free of obstructions.

Ensure that all shipping braces are removed. Shipping braces may be applied to devices such as meters and relays as well as current-carrying conductors and bus. *NOTE: Failure to remove shipping braces in accordance with manufacturer instructions in arc-resistant switchgear may prevent the proper operation of ventilation flaps*.

8.1 Signs and Warning Labels

Install the manufacturer required signs and warning labels. Install arc flash warning labels in accordance with OSHA/NFPA 70E requirements. *NOTE: Arc flash warning labels are based on the results of short circuit, overcurrent device coordination, and arc flash studies and are required to warn installation and commissioning personnel of the actual arc flash hazard level and the type of PPE, such as a flash/blast suit, to be utilized after the switchgear is energized.*

Identify each circuit as to its clear, evident, and specific purpose or use at each switch or circuit breaker. Identify spare positions that contain unused overcurrent protective devices or switches. Provide a permanent label suitable for the installed environment and permanently affixed to identify each source of supply to the switchgear. Handwritten markings are not permitted.

Provide field markings and caution signs and warning labels that comply with NEC 110.21(B).

For three-phase four-wire delta-connected systems, provide a legible and permanent field marking of switchgear with the following or equivalent verbiage:

CAUTION: _____ PHASE HAS _____ VOLTS TO GROUND

For ungrounded switchgear as permitted in NEC 250.21, provide a legible and permanent field marking with the following or equivalent verbiage:

CAUTION: UNGROUNDED SYSTEM
OPERATING – _____ VOLTS
BETWEEN CONDUCTORS

For high-impedance-grounded neutral switchgear in accordance with NEC 250.36, provide a legible and permanent field marking with the following or equivalent verbiage:

CAUTION: HIGH-IMPEDANCE GROUNDED NEUTRAL AC SYSTEM
OPERATING - _____ VOLTS BETWEEN CONDUCTORS AND
MAY OPERATE - _____ VOLTS TO GROUND FOR INDEFINITE
PERIODS UNDER FAULT CONDITIONS

Obtain the available fault current for each source of supply and the date the calculations were performed from the Engineer of Record, and legibly and permanently field mark the enclosure at each source of supply. The marking must comply with NEC 110.21(B)(3).

For multi-section switchgear used as service equipment, provide a field marking to identify the section with the location of the grounded conductor disconnecting means or neutral disconnect link.

For equipment where the possibility of backfeed exists, provide a permanent sign in accordance with NEC 110.21(B) on the disconnecting means or immediately adjacent to open disconnecting means with

the following verbiage or the equivalent:

DANGER – CONTACTS ON EITHER
SIDE OF THIS DEVICE MAY BE ENERGIZED BY BACKFEED.

Additionally, provide a permanent and legible single-line diagram of the local switching arrangement that clearly identifies each point of connection to the high-voltage section within sight of each point of connection.

Provide permanent signs in accordance with NEC 110.21(B) on switchgear doors and panels that provide access to live parts over 1000 volts that state:

DANGER – HIGH VOLTAGE –KEEP OUT

Additionally, where the compartment door or panel provides access to parts that can only be de-energized and visibly isolated by the serving utility, include a notice that access is limited to the serving utility or is permitted only following authorization by the serving utility.

9. Checking and Installing Drawout Components

9.1 General

Considering the increased possibility of arc blast at medium-voltage, exercise extreme caution when tripping, closing, installing, or removing medium-voltage circuit breakers from energized switchgear. *NOTE: Personnel working on energized switchgear should follow the safe work practices described in NFPA 70E, including the use of PPE appropriate for the task being performed. See Section 3.*

Drawout components, such as circuit breakers, potential transformer (PT) drawers, and grounding or testing components, typically have a series of interlocks to prevent unsafe conditions during the attempted removal or installation of equipment. Do not operate safety interlocks manually. Refer to the manufacturer instructions regarding interlocks and safety features unique to the switchgear before attempting any operation.

The circuit breaker compartment may require ventilation for normal operation in arc-resistant switchgear. In this case, the equipment may be provided with a flap that closes to cover the ventilation opening during an internal arcing event. For arc-resistant switchgear, do not place a circuit breaker into service with the cubicle safety ventilation flap closed.

9.2 Initial Vacuum Circuit Breaker Checks

Handle, test, operate, and install circuit breakers in accordance with the manufacturer instructions. Examine the entire circuit breaker for damage, dirt, and moisture. See Section 11 for additional information.

Perform a manual OPEN/CLOSE operation check of circuit breakers prior to installing in switchgear. Circuit breakers are typically shipped in the CLOSED position. Press the OPEN pushbutton, the CLOSE pushbutton, and then the OPEN pushbutton on the circuit breaker.

Check indicators to verify that the circuit breaker is in the OPEN position with all springs discharged. If it is not in the OPEN position, press the OPEN pushbutton, the CLOSE pushbutton, and then the OPEN pushbutton.

Cycle the circuit breaker manually several times, checking for proper operation. Manually charge the circuit breaker springs by using the manual spring charging handle in accordance with the manufacturer instructions. The closing spring assembly is fully charged when the charging handle resists any further motion and the CHARGED/DISCHARGED indicator indicates that it is CHARGED.

After charging the closing spring assembly, close the circuit breaker by pressing the CLOSE pushbutton or by energizing the closing coil. *NOTE: Follow safe electrical work practices in accordance with NFPA 70E and remove all items that could cause unintentional operation. Exercise extreme caution when making temporary control power connections for the purpose of checking circuit breakers for proper operation*. The CLOSE push button releases the closing latch, allowing the closing spring assembly to discharge.

Push the OPEN pushbutton or energize the opening coil to open the circuit breaker. *NOTE: Follow safe electrical work practices in accordance with NFPA 70E and remove all items that could cause unintentional operation. Exercise extreme caution when making temporary control power connections for the purpose of checking circuit breakers for proper operation*. If the circuit breaker is in the CLOSED position, the opening springs will automatically be charged or compressed. The mechanism releases the opening latch and allows the opening spring assembly to discharge.

Ensure that the circuit breaker is in the OPEN position with all springs DISCHARGED prior to installing in switchgear. Ensure that control power is turned off to the switchgear cubicle prior to installing circuit breakers. Install circuit breakers in cubicles in accordance with Section 9.3.

9.3 Vacuum Circuit Breaker Installation and Removal

NOTE: Different manufacturers provide different labels and different meanings for circuit breaker racking positions, such as CONNECTED, TEST, TEST/DISCONNECTED, and DISCONNECTED. Become familiar with the specific racking positions and their meanings before attempting to rack circuit breakers into switchgear.

Do not test safety interlocks by hand. Test interlocks by moving the circuit breaker over the compartment-mounted operating cams. Operate interlocks in the correct sequence to prevent injury or equipment damage.

When connected to a source of control power, vacuum circuit breaker spring charging motors will automatically charge the closing spring assembly. Ensure that control power is turned off to the switchgear cubicle prior to installing circuit breakers.

Remove all tools, the lifting assembly, and any miscellaneous items left on the circuit breaker or in the switchgear cubicle before installing the circuit breaker into the circuit breaker compartment.

Circuit breakers typically have a “key” that will only permit their installation in a switchgear cubicle with identical ratings as the circuit breaker. Do not force the installation of drawout components if they do not operate easily. When meeting resistance, return drawout components to their last position and clear any foreign objects or debris and ensure that the cubicle is rated for the circuit breaker. Consult the manufacturer for recommendations as needed.

Clean and grease the various sliding contact surfaces in accordance with manufacturer instructions.

Always install circuit breakers fully connected or fully withdrawn in its compartment. Do not leave a circuit breaker in the TEST/DISCONNECTED position unless performing testing.

9.3.1 Lifting Truck

A lifting truck or other equipment designed for lifting that is recommended by the manufacturer is generally required to install or to remove vacuum circuit breakers when switchgear is installed on a raised equipment pad. The description which follows is generic. Follow the manufacturer instructions for the equipment.

General lifting truck operating instructions include:

- Push the lifting truck toward the circuit breaker compartment so the lifting truck pan is square with the front of the circuit breaker cell.
- Raise the platform of the lifting truck until it is at the same level as the circuit breaker compartment floor. Rotating the handle clockwise raises the lifting truck pan. Rotating the handle counterclockwise lowers the lifting truck pan.
- Line up the lifting truck platform to mate with the switchgear cubicle locking method. Typically, the switchgear manufacturer provides some means for latching or locking the lifting truck platform in place, such as catch pins on the circuit breaker compartment floor.
- Latch or lock the lifting truck platform to the circuit breaker compartment if possible. Engage the lifting truck wheel brakes, if provided.
- Roll the circuit breaker onto or off of the lifting truck pan. Circuit breakers are typically secured to the lifting truck using a safety cable and captive latch. Verify that the breaker is properly secured to the lifting truck.
- When ready to move, raise the lifting truck pan until it clears the catch pins.
- Release the brake on the lifting truck and remove the lifting truck from the cell. As soon as the lifting truck is clear of obstructions, lower the breaker to the lowest travel position possible. Keep the lifting truck at the lower most position when moving the breaker.
- To remove the circuit breaker from the lifting truck platform, either to install the circuit breaker into a compartment or to transfer the circuit breaker to the floor, push the circuit breaker slightly toward the back of the lifting truck pan and pull the lever on the back of the lifting truck pan while rolling the circuit breaker off the lifting truck pan.

9.3.2 Racking Circuit Breakers into the TEST/DISCONNECTED Position

The description which follows is generic. Follow the manufacturer instructions for the equipment.

Inspect the circuit breaker cubicle for foreign objects and debris. Remove any foreign objects and debris from the cell before performing this procedure.

Use only manufacturer approved tools and devices to rack circuit breakers and other components into and out of switchgear cubicles. Do not remove keyways, alignment tabs or other safety or locking features of switchgear-specific tools and devices, such as the racking tool. Use a remote racking mechanism, if available, in accordance with the manufacturer instructions. Unless using a remote racking mechanism, install circuit breakers in switchgear manually. Do not force the circuit breaker into the cell or into the

CONNECTED position. Consult the manufacturer for recommendations if unable to rack the circuit breaker. Do not use power tools such as a power drill or impact driver to install or remove circuit breakers. Power tools can damage the circuit breaker and the switchgear cubicle racking system. Do not use remote racking mechanisms that are not identified as suitable for the circuit breaker that is being inserted. Use of incorrect racking mechanisms may damage the circuit breaker, the racking system, or the switchgear assembly.

Ensure that circuit breakers are installed in the appropriate switchgear cubicles. Ensure that the rating of the circuit breaker matches the rating of the cubicle or cell.

Ensure that the circuit breaker is in the OPEN position with the closing springs DISCHARGED prior to racking circuit breakers into switchgear.

Verify that the racking position indicator reads TEST/DISCONNECTED.

Remove the padlock from the door handle, if installed, and open the door.

Install the circuit breaker using the lifting truck, if required. A lifting truck is required to install circuit breakers into top cubicles, and into lower cubicles for switchgear mounted on a housekeeping pad.

Roll the circuit breaker onto the lifting truck and secure in accordance with the manufacturer provisions.

Elevate and align the lifting truck and circuit breaker compartment rails. Carefully align the lifting truck when installing and removing circuit breakers to prevent damage to components inside of circuit breaker cubicles.

Align the rollers on each side of the circuit breaker with the compartment positioning rails mounted on the side walls of the circuit breaker compartment, and roll the circuit breaker into the cubicle until the front of the circuit breaker lines up with the test position indicator(s).

A mechanical latch or interlock should engage to prevent the circuit breaker from rolling back out of the cubicle once the circuit breaker is in the TEST/DISCONNECTED position.

If the circuit breaker does not easily roll into the compartment, remove the circuit breaker from the cubicle. If necessary, operate the mechanical latch or interlock to release the circuit breaker from the TEST/DISCONNECTED position in order to remove the circuit breaker from the cubicle. Repeat the above steps as needed to rack in the circuit breaker. If satisfactory results are not achieved, consult the manufacturer for recommendations.

For some vacuum circuit breakers, the secondary disconnect control block can be manually connected to the circuit breaker compartment secondary disconnect, which provides a convenient method for electrically testing the operation of the circuit breaker mechanism with the circuit breaker disconnected from the switchgear main bus. Keep in mind that the circuit breaker closing springs will charge automatically upon connection to control power.

9.3.3 Racking Circuit Breakers into the CONNECTED Position

Use only manufacturer approved tools and devices to rack circuit breakers and other components into and out of switchgear cubicles. Do not remove keyways, alignment tabs or other safety or locking features of switchgear-specific tools and devices, such as the racking tool. Use a remote racking mechanism, if

available, in accordance with the manufacturer instructions. Unless using a remote racking mechanism, install circuit breakers in switchgear manually. Do not use power tools such as a power drill or impact driver to install or remove circuit breakers. Power tools can damage the circuit breaker and the switchgear cubicle racking system. Do not use remote racking mechanisms that are not identified as suitable for the circuit breaker that is being inserted. Use of incorrect racking mechanisms may damage the circuit breaker, the racking system, or the switchgear assembly.

Ensure that the circuit breaker is in the OPEN position. Circuit breakers must be in the OPEN position when racked into or out of the cubicle. Interlock mechanisms allow the racking shaft to rotate only when the circuit breaker is in the OPEN position.

Close the circuit breaker compartment door and remove the padlock from the racking port, if installed. Always keep the circuit breaker compartment door closed when racking the circuit breaker from one position to another while the switchgear is energized. *NOTE: For some non-arc-resistant switchgear, circuit breakers can only be racked in or racked out with the cell door open (only if switchgear is not energized) or closed. For arc-resistant switchgear, the circuit breaker should only be racked in or racked out with the compartment door closed and latched. Arc resistant switchgear that requires the door to be open to perform the racking operation must be tested and shown to meet the arc-resistant requirements with the door open.*

Open the racking port, insert the racking crank or handle into the port, and engage the handle onto the racking shaft. Keep the racking handle as straight as possible during the racking procedure.

Rotate the racking handle clockwise. If the circuit breaker does not easily rack into the compartment, remove the circuit breaker and repeat the above steps as needed.

If satisfactory results are not achieved, consult the manufacturer for recommendations. Never force the circuit breaker into or out of the circuit breaker compartment. If a mechanism is not operating easily, inspect the equipment and remove any foreign objects or debris.

If control power is available, the circuit breaker spring winding motor will operate as soon as the circuit breaker control secondary disconnects makes contact with control power, typically as the circuit breaker passes the TEST/DISCONNECTED position.

Continue rotating the racking handle clockwise until the racking position indicator reads CONNECTED, keeping in mind that there will be resistance to rotating the racking handle as the circuit breaker contact assemblies make contact with both the switchgear main or primary bus and the feeder or secondary bus, open further, and fully slide onto the respective buses.

Do not over-torque the racking shaft.

When the racking position indicator reads CONNECTED, the circuit breaker is fully racked into the circuit breaker compartment and the circuit breaker's primary and secondary contacts are fully connected to their respective bus.

9.3.4 Racking Out Circuit Breakers

Use only manufacturer approved tools and devices to rack circuit breakers and other components out of switchgear cubicles. Do not remove keyways, alignment tabs or other safety or locking features of switchgear-specific tools and devices, such as the racking tool. Use a remote racking mechanism, if

available, in accordance with the manufacturer instructions. Unless using a remote racking mechanism, remove circuit breakers from switchgear manually. Do not use power tools such as a power drill or impact driver to remove circuit breakers. Power tools can damage the circuit breaker and the switchgear cubicle racking system. Do not use remote racking mechanisms that are not identified as suitable for the circuit breaker that is being removed. Use of incorrect racking mechanisms may damage the circuit breaker, the racking system, or the switchgear assembly.

Always keep the circuit breaker compartment door closed when racking the circuit breaker from one position to another while the switchgear is energized. *NOTE: For some switchgear, circuit breakers can only be racked in or racked out with the cell door open. For arc-resistant switchgear, the circuit breaker should be racked in or racked out only with the compartment door closed and latched. Arc-resistant switchgear that requires the door to be open to perform the racking operation must be tested and shown to meet the arc-resistant requirements with the door open.*

Verify that the circuit breaker is in the OPEN position. Circuit breakers must be in the OPEN position when racked out of the cubicle. Interlock mechanisms allow the racking shaft to rotate only when the circuit breaker is in the OPEN position.

Close the circuit breaker compartment door.

Place the racking handle into the racking port and engage the racking shaft.

Rotate the racking handle counterclockwise. If the circuit breaker does not easily rack out of its compartment, reconnect the circuit breaker and repeat the above steps as needed. Do not apply excessive force to rack out the breaker. If satisfactory results are not achieved, consult the manufacturer for recommendations.

Continue rotating the racking shaft until the racking position indicator reads TEST/DISCONNECTED. The racking handle will stop when the final position is reached. Do not over-torque the racking shaft. Do not attempt to apply excessive force if the breaker does not show in the TEST/DISCONNECTED position. Consult the manufacturer.

When the circuit breaker is moved from the TEST to the DISCONNECTED position, the auxiliary contacts are disconnected.

9.3.5 Removing Circuit Breakers from Compartments

Open the circuit breaker compartment door.

Inspect the circuit breaker OPEN/CLOSE indicator to confirm that the circuit breaker is open.

Use the manufacturer approved removal device, such as a lifting truck, to remove the circuit breaker from the circuit breaker compartment.

Move the release handle to release the circuit breaker from the TEST/DISCONNECTED position. Operate the latch (if provided) to release the circuit breaker from the TEST position. On most designs, it is necessary to trip the circuit breaker before the circuit breaker can be released. If springs are not already discharged, there will be a loud noise as the closing springs discharge when the circuit breaker is withdrawn from the compartment.

Move the circuit breaker out of the compartment, and roll the circuit breaker out onto the manufacturer approved removal device~~a lifting truck~~, where required. Secure circuit breakers onto the removal device~~lifting truck~~ in accordance with manufacturer provisions.

9.4 Potential Transformer Drawout Units

Inspect the potential transformer drawout unit. PT drawout units may be located on the front of the switchgear, or the back of the switchgear. Keep in mind that removing drawout potential transformers from energized switchgear may cause the automatic operation of switchgear and/or the loss of power. *NOTE: For arc-resistant switchgear, the front compartment door of PT rollout fuse trays is frequently interlocked to prevent opening unless the rollout tray is in the disconnected position.*

9.4.1 Racking Out PT Drawout Units

Some PT drawout units are removed by grasping, operating, and pulling handles on the front of the drawers to withdraw them from contact with the primary bus. Utilize appropriate PPE, including flash/blast suit, hood, and gloves, in accordance with the arc flash study to get the level of PPE as defined in NFPA 70E. Refer to the arc flash study for the equipment to determine the appropriate level of PPE in accordance with NFPA 70E. The description which follows is generic. Follow the manufacturer instructions for the equipment.

With the PT compartment door closed, insert the racking handle into the racking port and engage the handle onto the racking shaft. *NOTE: For arc-resistant switchgear, the front compartment door of PT rollout fuse trays is frequently interlocked to prevent opening unless the rollout tray is in the disconnected position.*

Rotate the handle counterclockwise. Consult the manufacturer for recommendations if the PT drawer does not easily rack out. Never force the primary fuse drawout unit into or out of the compartment. If the racking mechanism is not operating easily, inspect the equipment and remove any foreign objects or debris, or contact the manufacturer for recommendations.

NOTE: The grounding contact chains or straps that extend from the ground bar at the top of the PT drawout compartment should touch the fuse ground tabs on the PT drawout unit when the PTs are disconnected and have the required clearance distance from energized parts. The grounding contact chains or straps should have required clearance from energized parts when the PTs are connected.

Continue rotating the racking handle counterclockwise until the PT drawout unit is fully racked into the DISCONNECTED position.

Open the PT drawout door.

9.4.2 Racking In PT Drawout Unit

Utilize appropriate protective equipment.

Close the PT drawout unit compartment door. *NOTE: For arc-resistant switchgear, the front compartment door of PT rollout fuse trays is frequently interlocked to prevent opening unless the rollout tray is in the disconnected position.*

Insert the racking handle into the racking port and engage the handle onto the racking shaft.

Rotate the racking handle clockwise until the PT drawer is fully racked into the CONNECTED position. If the PT drawout unit does not easily rack into the CONNECTED position, rack the unit to the DISCONNECTED position, and remove any objects or debris from the compartment. Repeat the above steps as needed. If the results are not satisfactory, consult the manufacturer for recommendations.

9.5 Grounding and Testing Devices

Grounding and testing devices are used in switchgear to ground circuit conductors for maintenance, to apply potential for cable testing, and to provide access for phase matching and rotation testing. Grounding and testing devices are safety and testing devices and do not have any load or fault current interrupting capability. Grounding and testing devices are optional and may not be provided for all installations.

Installing and operating grounding and testing devices can result in an unintended arc event if installed in energized equipment, or if some system parameters are unknown. Follow specific manufacturer instructions when installing or operating grounding and testing devices.

Store grounding and testing devices in their designated switchgear compartment. Do not store grounding and testing devices in spare or bused circuit breaker compartments.

10. Testing and Commissioning Switchgear

Vibration and mechanical stresses imposed by transit and installation can adversely affect the switchgear assembly and its component devices. Inspect the switchgear and components before energizing. If this inspection reveals that the switchgear assembly or any component device is out of adjustment, make adjustments in accordance with the manufacturer instructions.

Many times, construction contracts require testing of switchgear by an independent third party. Such testing shall be conducted in compliance with the switchgear manufacturer instructions. Conducting tests other than those recommended by the manufacturer could compromise insulation systems or other portions of the switchgear. Comply with contractual requirements for testing and commissioning switchgear. In the absence of contractual requirements, comply with the following recommendations for testing and commissioning switchgear.

In the absence of manufacturer instructions, refer to NECA 90, ANSI/NETA ATS, or ANSI/NETA ECS.

10.1 Components

Test switchgear, circuit breakers, control power transformers, current transformers, potential transformers, meters, relays, batteries, and battery chargers in accordance with switchgear, component, and test equipment manufacturer instructions.

10.2 Recordkeeping

Record the results of all testing and turn over to the owner to be maintained to track changes in electrical characteristics over time. Follow manufacturer instructions for recording data. Record the date, time, and environmental conditions, such as temperature and humidity, during testing. Note whether equipment is housed in an environmentally-controlled space. Note the weather conditions for outdoor equipment at the time of testing.

Record the general condition of the equipment along with the model number, general condition, and calibration history of all test equipment. Include the names of persons making tests and witnesses.

Unless infrared inspection ports are provided, infrared scanning is typically conducted with doors open and/or covers removed, exposing the user to shock and arc-flash hazards. Appropriate PPE must be worn when conducting infrared scanning. For infrared testing, prepare a certified report identifying the equipment, components, and locations tested and describing the results of the infrared scan. Include notations of deficiencies detected, temperature differences between the areas of concern and reference areas, probable causes of temperature differences, load conditions at the time of inspections, and recommended actions. Provide thermal photographs of each deficient area. Identify areas that were not inspected or not observed due to inaccessibility.

10.3 General Conditions

Follow safe electrical work practices in accordance with NFPA 70E. See Section 3.

Compare equipment nameplate data with drawings and specifications, and with one-line diagrams, when available.

Inspect the physical and mechanical condition of equipment, looking for physical damage, corrosion, dents, scratches, contamination, and accumulations of dust, dirt, and debris.

Ensure that switchgear is de-energized and properly locked out before cleaning. Clean switchgear using a High Efficiency Particulate Air filter (HEPA) vacuum or other non-conductive cleaning equipment. Do not clean switchgear using compressed air, which can distribute dust, dirt, and debris and contaminate critical switchgear components.

Ensure that switchgear is de-energized and properly locked out before cleaning. Wipe away any dust or dirt that may have accumulated inside each switchgear vertical section, paying close attention to insulators and insulating material. If the bus is insulated, remove dirt, dust, and other foreign material from the insulation bus in accordance with manufacturer instructions, such as using a clean, soft, lint-free cloth. Follow the switchgear manufacturer instructions for cleaning switchgear. See Section 11 for additional information.

Repair physical damage in accordance with the manufacturer instructions.

10.3.1 Switchgear

Verify appropriate anchorage, required area clearances, and correct alignment. Inspect all doors, panels, and sections for proper fit and alignment, and for missing hardware. Inspect insulators for evidence of physical damage or contaminated surfaces.

Verify that fuses and/or circuit breakers conform to drawings and to the coordination study. Verify microprocessor-communication package addresses.

Confirm correct operation and sequencing of electrical and mechanical interlocks. If any interlocking systems do not operate as intended, they must be repaired to manufacturer specifications before the system is energized and operated. *NOTE: Verify that potential mis-operation of interlocks will not cause harm to the system prior to testing interlocks for proper operation.* Attempt closure on locked-open devices. Attempt to open locked-closed devices. For key-interlocked equipment and devices, make key exchange with devices operated in off-normal positions. Verify that key interlocks prevent the simultaneous closure of switches as indicated on contract documents, drawings and specifications. Ensure that only the minimum number of keys is available to ensure safe operation of switchgear key interlocks in accordance with the manufacturer instructions.

Verify correct barrier and shutter installation and operation.

Verify contact lubricant on moving current-carrying components as recommended by the switchgear manufacturer. Verify lubrication on moving and sliding surfaces as recommended by the switchgear manufacturer. Exercise all mechanical components, including manually-operated and power-operated switches. Consult manufacturer for approved lubricants. Incorrect lubricants may cause damage to current-carrying parts or mechanisms.

Inspect all mechanical indicating devices for correct operation.

Verify that filters are in place and/or vents are clear. Verify proper operation of ancillary switchgear equipment, such as space heaters and exhaust fans.

For arc-resistant switchgear, ensure that plenums and ducts have no loose or missing hardware. If any self-tapping screws are stripped out, install a nut with locking hardware on the backside of the screw and torque in accordance with manufacturer instructions. Inspect air filters on ducts, if present, and replace with identical filters if soiled or clogged. Check all labyrinths, grillwork, and air passages for obstructions and accumulations of dirt. Check to ensure that all dynamic flaps are open to allow natural airflow and that all pressure relief flaps are properly closed. *NOTE: Ventilation flaps are designed to close automatically during an internal arcing fault, while pressure relief flaps are designed to open during an internal arcing fault.*

10.3.2 Instrument and Control Power Transformers

Inspect control power transformers for physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.

Verify that current transformer (CT) and potential transformer (PT) ratios correspond to approved shop drawings. Verify that primary and secondary fuse ratings or circuit breakers match the approved shop drawings. Verify that CT and PT secondary circuits are correct, intact, and comply with approved shop drawings. Verify adequate clearances between primary and secondary circuit wiring.

Verify correct operation of transformer withdrawal mechanisms and drawout disconnecting and

grounding contacts and interlocks. Verify required grounding and shorting connections provide contact, including CT shorting terminal blocks.

10.3.3 Medium-Voltage Circuit Breakers

Follow manufacturer instructions for recording data. Record as-found and as-left operation counter readings.

Confirm the correct application of the manufacturer recommended lubricants.

Inspect anchorage, alignment, and grounding.

Perform all manufacturer-recommended mechanical operational tests on both the circuit breaker and its operating mechanism.

Measure critical distances such as contact gap as recommended by the manufacturer.

Perform timing tests in accordance with circuit breaker manufacturer instructions. *NOTE: Timing tests are used to assess the overall capability of the circuit breaker, and to verify control circuits, check moving parts of the circuit breaker, validate manufacturer specifications for operating time, determine the wear of the contacts, and check the results of service, maintenance, and repair*. Remove each circuit breaker from its compartment and connect the timing test set in accordance with manufacturer and test kit operating and safety instructions. See Section 3. Record the results of all testing and turn over to the owner to be maintained to track changes in electrical characteristics over time.

10.3.4 Meters and Protective Relays

Inspect meters, relays, and cases for physical damage. Remove shipping restraint material, if applicable.

Tighten case connections. Verify tightness of mounting hardware and connections. Inspect covers for correct gasket seal. Clean cover glass. Inspect shorting hardware, connection paddles, and/or knife switches. Verify the target reset.

Inspect meters and relays for foreign material, particularly in disk slots of damping and electromagnets of induction disk relays. Remove any foreign material from the case.

Verify that the metal cases or frames of instruments, meters, relays, and instrument and control transformers are connected to the equipment grounding conductor in accordance with NEC 495.37.

For induction disk relays, verify disk clearances. Verify contact clearance and spring bias. Inspect spiral spring convolutions. Inspect disks and contacts for freedom of movement, end play, alignment of rotating disk(s) and correct travel. Burnish contacts as needed. Inspect bearings and/or pivots.

Using calibrated instruments, verify watt-hour meter operation, and verify that meters read properly at all cardinal points. Adjust watt-hour meters according to manufacturer published data. Verify all instrument multipliers.

Set relays and confirm proper fuse sizes and types in accordance with the Engineer's specified values indicated in the coordination study report and related material. Test meters and protective relays at the

specified settings.

10.3.5 Station Batteries

Verify the adequacy of battery support racks or cabinets, mounting, anchorage, and clearances.

Inspect for evidence of corrosion at terminals, connections, and racks or cabinet. Verify correct application of manufacturer approved corrosion inhibiting grease on contact surface areas of all cell-to-cell and terminal connections including connection hardware.

Verify proper ventilation of the battery room or enclosure.

Verify the existence of suitable eyewash equipment.

Vented Lead-Acid Cells

- Verify the correct electrolyte levels in each battery cell. Electrolyte levels should be at the manufacturer recommended reference point.
- Measure the electrolyte specific gravity and temperature of all cells. Specific gravity should be in accordance with manufacturer recommended values. Temperature differential between cells should not be greater than 3°C (5°F).
- Verify the presence and correct installation of flame arresters.

Nickel Cadmium Cells

- Verify the correct electrolyte levels in each cell. Electrolyte levels should be at the high-level mark.
- Measure the electrolyte temperature. Temperature differential between cells should not be greater than 3°C (5°F).
- Verify the presence and correct installation of flame arresters on vented cells.

Valve Regulated Lead Acid (VRLA) Cells

- Check for excessive jar/cover distortion.
- Measure the temperature of the negative terminal of each cell. The temperature of the negative terminal should not be greater than 3°C (5°F) above ambient in a free-standing installation.

10.4 Electrical Testing

Perform electrical testing in accordance with switchgear, component, and test instrument manufacturer instructions. Ensure switchgear and components are in an electrically safe work condition prior to performing any testing in accordance with Section 3. Thoroughly clean switchgear prior to testing. Observe manufacturer warning labels. Wear appropriate PPE. In the absence of manufacturer instructions, refer to NECA 90, ANSI/NETA ATS, and ANSI/NETA ECS.

10.4.1 Contact Resistance

Inspect all bolted electrical connections of switchgear, circuit breakers, instrument transformers, meters, protective relays, batteries, and battery chargers for high resistance using one of the following methods:

- For bolted electrical connections in switchgear and for circuit breakers, test using a DC current

supply of 100A and a millivolt drop meter to determine the contact or joint resistance.

- Use a low-resistance ohmmeter. Compare bolted connection resistance measurements to values of similar connections. Investigate any values which deviate from similar connections by more than 50 percent of the lowest value.
- Verify tightness of accessible bolted electrical connections using a calibrated torque-wrench in accordance with manufacturer published data.
- Perform infrared testing in accordance with 10.6. Note the locations of infrared testing.

10.4.2 Ground-Resistance Test

Verify that the ground system is in compliance with drawings and specifications. Visually inspect all ground conductors and connections.

Perform a fall-of-potential test or alternative in accordance with IEEE Standard 81, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System, on the main grounding electrode system.

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

The resistance between the main grounding electrode and ground system should be no greater than five ohms for commercial or industrial systems and one ohm or less for generating or transmission station grounds unless otherwise specified by the owner. Investigate point-to-point resistance values which exceed 0.5 ohm.

10.4.3 Insulation Resistance

Perform insulation resistance tests in accordance with switchgear, component, and test instrument manufacturer instructions.

Disconnect and isolate conductors, components, and equipment normally connected to equipment under test, including phase and neutral connections, surge arresters, meters, relays, and control power and instrument transformers.

Ground conductors, components, and equipment not being tested. Perform insulation resistance tests on:

- Each bus, phase-to-phase and phase-to-ground, at 2500 volts DC for one minute. *NOTE: Test bus in its entirety. Do not separate bus between sections or shipping splits.*
- Current transformers, from wiring-to-ground, and control wiring at 1000 volts DC for one minute. Isolate control circuits from power sources and from ground and measure insulation resistance to ground. For units with solid-state components, follow manufacturer instructions for testing, including limiting the insulation resistance test voltage.
- Voltage transformers and control power transformers, from winding-to-winding and each winding-to-ground. Consult the manufacturer recommended values for acceptable test voltages. Measure insulation resistance at one-minute intervals for ten minutes.
- Medium-voltage circuit breakers, from pole-to pole, pole-to-ground, and across open poles at 2500 volts DC minimum.
- Protective and control relays, including solid-state and multi-function relays, from circuit-to-frame. Follow the manufacturer instructions for allowable testing procedures for solid-state and

microprocessor-based relays.

Insulation resistance values for bus, circuit breakers, control power transformers, voltage transformers, and current transformers should be in accordance with manufacturer published data, or a minimum of 1000 megohms for switchgear rated less than 15 kV and 5000 megohms for switchgear rated 15 kV and above. Control wiring insulation resistance should be a minimum of two megohms. Consult the manufacturer for recommendations for any results that are lower than these minimums.

Do not perform DC high potential tests until insulation resistance levels are raised above minimum levels.

10.4.4 High Potential (Withstand) Test

High potential testing can cause insulation failure and should be used with caution. Perform high potential testing in accordance with switchgear, component, and test instrument manufacturer instructions. See IEEE C37.20.2, IEEE Standard for Metal-Clad Switchgear, and IEEE C37.20.3, IEEE Standard for Metal-Enclosed Interrupter Switchgear (1 kV-38 kV), for new installations, and IEEE C37.59, Requirements for Conversion of Power Switchgear Equipment, for existing installations. Complete all insulation resistance testing prior to high potential testing, and review test results to determine suitability for high potential testing.

Humidity, wind, and surface conditions can impact DC high potential testing. Record the ambient temperature and relative humidity at the time of high potential testing.

Disconnect and ground surge arresters, instrument transformers, control transformers, conductors, and similar equipment before high-potential testing. Ground all conductors and conductor shields. Ground conductors, components, and equipment not under test during each application of voltage.

Perform a DC or, preferably, AC high potential (withstand) test on each bus phase-to-ground with phases not under test grounded, in accordance with the manufacturer instructions. *NOTE: Test bus in its entirety. Do not separate bus between sections or shipping splits.* Apply the test voltage for one (1) minute. Consult the manufacturer for recommended test voltages. DC high potential voltage failures should be followed by an AC high potential voltage test to eliminate false negative results.

Perform vacuum bottle integrity (high potential) testing on medium-voltage vacuum circuit breakers across each vacuum bottle with the breaker in the open position in strict accordance with manufacturer published data. Do not perform this test unless the contact displacement of each interrupter is within manufacturer tolerances. Do not exceed the maximum voltage stipulated for this test. Keep in mind that some DC high-potential test sets are half-wave rectified and may produce peak voltages in excess of the breaker manufacturer recommended maximum. Under certain conditions, DC high potential testing can cause x-ray emissions from circuit breaker vacuum bottles. Provide adequate barriers and protection against x-ray radiation during this test. See ANSI C37.85, Switchgear - Alternating-Current High-Voltage Power Vacuum Interrupters - Safety Requirements For X-Radiation Limits, for further information. The vacuum interrupter bottle should withstand the DC high potential voltage applied.

Perform dielectric withstand testing of instrument transformers primary windings with the secondary windings grounded. Test voltages should not exceed manufacturer recommendations. Apply test voltage for one minute.

The insulation should withstand the high potential test voltage applied. Consult the transformer manufacturer for recommendations for any deficient test results.

Upon satisfactory completion of the test, reconnect surge arresters, instrument transformers, control transformers, conductors, and similar equipment. Tighten connections to manufacturer recommended torque levels.

10.4.5 Instrument Transformer Tests

10.4.5.1 Polarity Tests

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

Perform a polarity test on each current transformer. Perform a ratio-verification test using the voltage or current method in accordance with IEEE C57.13.1, IEEE Guide for Field Testing of Relaying Current Transformers.

Polarity results should agree with equipment markings and system drawings.

10.4.5.2 Transformer Burden Test

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

Measure current circuit burdens at transformer terminals and determine total burden.

Compare measured burdens to calculated burdens supplied by the owner, if available. Verify that load burdens do not exceed transformer ratings.

10.4.5.3 Coupling-Capacitor Voltage Transformers

Measure capacitance of the capacitor sections. Capacitance of capacitor sections of coupling-capacitance voltage transformers should be in accordance with manufacturer published data.

Measure power factor/dissipation factor in accordance with test equipment manufacturer published data. Power factor/dissipation factor should be in accordance with test equipment manufacturer published data.

10.4.5.4 Voltage Transformer Secondary Wiring Integrity Tests

Disconnect voltage transformers at secondary terminals and connect secondary wiring to a known secondary voltage. Confirm correct potential at all devices.

Energize the primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.

Connect secondary wiring to voltage transformers and energize with system voltage. Confirm correct potential at all devices.

10.4.5.5 Current Circuit Testing

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

Perform current tests by primary injection, where possible, with magnitudes such that a minimum of 1.0 ampere flows in the secondary circuit. Where primary injection is impractical, utilize secondary injection with a minimum current of 1.0 ampere.

Measure the current at each device.

10.4.6 Medium-Voltage Circuit Breakers

Perform a contact resistance test.

Verify trip, close, trip-free, and anti-pump functions.

Trip each circuit breaker by operation of each protective device.

Perform insulation resistance tests across each pole with the contacts open and with the contacts closed.

Perform a pole insulation resistance test on each pole-to-frame and each pole-to-pole.

10.4.7 Interrupter Switches

Interrupter switches are properly adjusted at the factory before shipment. Vibration and mechanical stresses imposed by transit and installation can adversely affect switch alignment. Inspect each interrupter switch for proper alignment. Check and adjust the interrupter switch alignment as needed in accordance with manufacturer instructions.

Check bolted bus connections for proper tightness in accordance with manufacturer published torque values.

For interrupter switches equipped with stored energy mechanisms, verify that mechanical interlocks prevent access to the switch compartment unless the stored energy mechanism is in the discharged or blocked position.

When fuse mountings are supplied, check to ensure that the fuse mountings are securely fastened and that the fuses are securely clamped in place. If non-disconnect type mounted fuses are supplied, check that the plastic knobs that hold the fuses in place are hand tight. Inspect fuse clips for tightness and alignment.

If disconnect fuses are supplied, check to see that they are latched completely closed.

For fuses fitted with removable or maintainable components, such as expulsion-type, boric acid fuses with a discharge filter on the lower end of the fuse, check that such components are secured and tightened in accordance with manufacturer instructions.

Replace fuses in interrupter switches in accordance with Section 11.5.

Perform high potential testing on medium-voltage air switches on each pole-to-ground and pole-to-pole for one (1) minute on each pole, phase-to-phase and phase-to-ground with the switch closed and across each open pole with all other poles grounded. Apply voltage in accordance with manufacturer published data. If no evidence of thermal damage, arcing or smoke, dielectric discharge or corona, or other indication of insulation failure is observed by the end of the total time of voltage application, the switch is considered to have passed the test.

10.4.8 Control Wiring Performance Testing

Check control wiring terminations for tightness.

Perform system function tests upon completion of equipment tests.

Refer to the most current one-line diagram to identify each remote control and protective device. Conduct tests as required to verify satisfactory performance of each of the control features.

Develop test parameters for the purpose of evaluating performance of all PLC-controlled devices, input sensors, and output components and their function as an integrated system within design requirements.

Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.

Verify the correct operation of all sensing devices, alarms, and indicating devices.

Verify correct function of control transfer relays located in switchgear with multiple power sources. Perform phasing check on switchgear, such as double-ended switchgear, to ensure correct bus phasing from each source across tie breakers.

10.4.9 Protective Relays and Controls

Record the results of all testing and turn over to the owner to be maintained to track changes in electrical characteristics over time. Follow manufacturer instructions for recording data.

Inspect targets and indicators.

Verify pickup and dropout of electromechanical targets.

Verify correct operation of all light-emitting diode indicators.

Set contrast for liquid-crystal display readouts.

Set relays in accordance with Engineer's specified values, electrically test, and verify functional operation of relays. *NOTE: Test protective relays and controls not listed below in accordance with manufacturer instructions*:

- **Timing Relay** (ANSI Device Number 2 or 62): Verify the time delay. Verify proper operation of the instantaneous contacts.

- **Distance Relay** (ANSI Device Number 21): Verify the maximum reach. Verify the maximum torque angle. Verify the offset.
- **Volts Per Hertz Relay** (ANSI Device Number 24): Verify the pickup frequency at rated voltage. Verify the pickup frequency at a second voltage level. Verify the time delay.
- **Synchronism-Check Relay** (ANSI Device Number 25): Verify the closing zone at rated voltage. Verify the maximum voltage differential that permits closing at zero degrees. Verify the live line, live bus, dead line, and dead bus set points. Verify the time delay. Verify the dead bus/live line, dead line/live bus, and dead bus/dead line control functions.
- **Undervoltage Relay** (ANSI Device Number 27): Verify the dropout voltage. Verify the time delay. Verify the time delay at a second point on the timing curve for inverse time relays.
- **Directional Power Relay** (ANSI Device Number 32): Verify the minimum pickup at maximum torque angle. Verify the closing zone. Verify the maximum torque angle. Verify the time delay. Verify the time delay at a second point on the timing curve for inverse time relays.
- **Loss of Excitation Relay** (ANSI Device Number 40): Verify the maximum reach. Verify the maximum torque. Verify the offset.
- **Reverse Phase or Phase Current Balance Relay** (ANSI Device Number 46): Verify the pickup of each unit. Verify the percent slope. Verify the time delay.
- **Negative Sequence Current Relay** (ANSI Device Number 46N): Verify the negative sequence alarm level. Verify the negative sequence minimum trip level. Verify the maximum time delay. Verify two points on the time-current characteristic curve.
- **Phase Sequence Voltage Relay** (ANSI Device Number 47): Verify the positive sequence voltage to close the normally open contact. Verify the positive sequence voltage to open the normally closed contact (undervoltage trip). Verify the negative sequence trip. Verify the time delay to close the normally open contact with the sudden application of 120% of pickup. Verify the time delay to close the normally closed contact upon removal of voltage when previously set to rated system voltage.
- **Machine or Transformer Replica-type Thermal Relay** (ANSI Device Number 49R): Verify the time delay at 300 percent of setting. Verify a second point on the operating curve. Verify the pickup.
- **Machine or Transformer Temperature Relay** (ANSI Device Number 49T): Verify the trip resistance. Verify the reset resistance.
- **Instantaneous Overcurrent Relay** (ANSI Device Number 50): Verify the pickup. Verify the dropout.
- **AC Time Overcurrent Relay** (ANSI Device Number 51): Verify the minimum pickup. Verify the time delays at two points on the time current curve.
- **Power Factor Relay** (ANSI Device Number 55): Verify the tripping angle. Verify the time delay.
- **Overvoltage Relay** (ANSI Device Number 59): Verify the overvoltage pickup. Verify the time delay to close the contact with sudden application of 120% of pickup.
- **Voltage Balance Relay** (ANSI Device Number 60): Verify the voltage difference to close the contacts with one source at rated voltage.
- **Transformer Sudden Pressure Relay** (ANSI Device 63): Verify the rate-of-rise or the pickup level of suddenly applied pressure in accordance with manufacturer specifications. Verify the operation of the 63 FPX seal-in circuit. Verify the trip circuit to remote breaker.
- **Ground-Protective Relay** (ANSI Device Number 64): Verify the maximum impedance to ground causing relay pickup.
- **AC Directional Overcurrent Relay** (ANSI Device Number 67): Verify the directional unit minimum pickup at maximum torque angle. Verify the closing zone. Verify the overcurrent unit pickup. Verify the overcurrent unit time delay at two points on the time-current curve.

- **AC Reclosing Relay** (ANSI Device Number 79): Verify the time delay for each programmed reclosing interval. Verify lockout for unsuccessful reclosing. Verify the reset time. Verify the instantaneous overcurrent lockout.
- **Frequency Relay** (ANSI Device Number 81): Verify the frequency set points. Verify the time delay. Verify the undervoltage cutoff.
- **Carrier or Pilot-Wire Receiver Relay** (ANSI Device Number 85): Verify the overcurrent pickup. Verify the undercurrent pickup. Verify the pilot wire ground pickup level.
- **Differential Relay** (ANSI Device Number 87): Verify the operating unit pickup. Verify the operation of each restraint unit. Verify the slope. Verify the harmonic restraint. Verify the instantaneous pickup.
- **Multi-function solid-state relays.** Perform manufacturer recommended tests and self-testing of relays. Document functional settings of relays using printouts or by scrolling through relay settings. Record model number, style number, serial number, firmware revision, software revision, and rated control voltage. Download all events from the event recorder in filtered and unfiltered mode before performing any tests on the relay. Download the sequence-of-events recorder prior to testing the relay. Verify operation of light-emitting diodes, display, and targets. Record the passwords for all access levels. Clean the front panel and remove foreign material from the case. Check tightness of connections. Verify that the frame is grounded in accordance with manufacturer instructions. Download settings from the relay. Print a copy of the settings for the report and compare the settings to those recommended by the Engineer or as specified in the coordination study. Connect the backup battery. Set the clock if not controlled externally. Apply voltage or current to all analog inputs and verify correct registration of the relay meter functions. Check functional operation of each element used in the protection scheme as described for electromechanical and solid-state relays in accordance with each relay function, above. Check operation of all active digital inputs. Check all output contacts or solid-state outputs, preferably by operating the controlled device such as circuit breaker, auxiliary relay, or alarm. Check all internal logic functions used in the protection scheme. For pilot schemes, perform a loop-back test to check the receive and transmit communication circuits, and perform satellite synchronized end-to-end tests (if applicable). For pilot schemes with direct transfer trip (DTT), perform transmit and received DTT at each terminal. Upon completion of testing, reset all min/max recorders, fault counters, sequence of events recorder, and all event records.

Verify that each set of relay contacts perform its intended function in the control scheme including breaker trip tests, close inhibit tests, ANSI Device 86 lockout tests, and alarm functions.

After the equipment is initially energized, measure the magnitude and phase angle of all inputs and compare to expected values.

Always use manufacturer recommended tolerances.

Upon completion of all testing and setting of protective relays, verify proper operation of touchscreen controls and other software or PLC driven controllers. Test all remotely activated control functions, such as SCADA, for proper operation in accordance with manufacturer instructions. Complete system testing prior to energizing switchgear, when possible. See Section 10.5. Also, see NECA 90 for additional guidance for system testing.

10.4.10 Station Batteries

Measure the inter-cell/jar connection resistance. Inter-cell connection resistance should be within the

manufacturer allowable values for the battery cell type and for the application. Inter-cell/jar resistance should not vary by more than ten percent or five microohms, whichever is greater, over the average for each type of connection (i.e., inter-cell, inter-tier, inter-rack).

Set the float and equalizing levels for battery chargers. Battery terminal float and equalize voltage should be within the manufacturer recommended operating range for the type of batteries installed.

Measure each cell voltage and total battery voltage with the battery charger energized in the float mode of operation. Cell voltage should be in accordance with manufacturer published data.

For VRLA batteries, measure the AC ripple voltage and the current imposed on the battery. AC ripple voltage and current imposed on VRLA batteries should be within acceptable limits for the battery as specified by the battery manufacturer.

Perform a capacity load test in accordance with manufacturer specifications and with the following IEEE standards. Capacity load tests of new installations may be less than rated capacity when delivered. Unless 100 percent capacity upon delivery is specified for lead acid cells, initial capacity can be as low as 90 percent of rated capacity. Capacity usually increases in the first several years until rated capacity is reached.

- IEEE 450, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.
- IEEE 1106, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications.
- IEEE 1188, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications.

10.4.11 Battery Chargers

Verify the correct AC input voltage.

Verify the charger output voltage regulation from no load to full load. The output voltage regulation should be within the charger specifications.

Verify the output voltage range in both float and equalize modes. The output voltage range should be within the charger specifications.

Measure the AC input current with the charger at full rated load. The AC input current with the charger at full rated load should be within the charger specifications.

Measure the current limit output of the charger. The current limit output and voltage should be within the charger specifications.

Measure the charger AC ripple voltage and current. The AC ripple voltage and current should be within the charger specifications and within acceptable limits of the battery as specified by the battery manufacturer.

Verify the temperature compensation function of the battery charger, if applicable. The temperature compensation function should be within the specifications of the charger and battery.

Verify all charger instrumentation and alarms.

Set the float and equalized voltages in accordance with the battery manufacturer published data.

10.5 Energizing Switchgear

Follow safe electrical work practices in accordance with NFPA 70E. See Section 3.

Energizing switchgear has the hazard of electric shock, explosion, and arc flash. Use appropriate PPE and follow safe electrical work practices. All personnel involved in start-up procedures should be thoroughly familiar with the manufacturer information and installation drawings before working on switchgear. Ensure that all power supplying switchgear is turned off before starting work. See Section 3 for additional guidance.

Qualified personnel should be present when the equipment is energized for the first time. If short circuit conditions caused by damage or poor installation practices have not been detected in the procedure specified above, serious personal injury or death and property damage can occur when the equipment is energized.

Coordinate the start-up of utility service entrance rated switchgear with the local electric utility company.

Energize switchgear in accordance with the manufacturer instructions. Consult the switchgear manufacturer for any abnormal operating conditions encountered.

Ensure that all personal protective grounds are removed.

Ensure that all affected persons are notified prior to energizing switchgear. Perform final pre-energization inspection. Ensure installation is complete, wiring connections are made, debris removed, compartments vacuum clean, and no tools are left behind before removing personal protective grounds.

Ensure that all accessible covers, plates, weathershields, and doors are installed and tightened prior to energizing switchgear.

Ensure that there is no load on the switchgear and that all load isolation devices are open and locked out and tagged out.

Ensure all active arc flash systems are enabled.

Ensure that all personnel are outside of any arc flash boundaries.

Energize control power to the switchgear. Verify proper operating voltages. Verify that all instrumentation, metering, touchscreens, and other control displays properly indicate the actual operating condition of the switchgear at each step as switchgear is energized. Set switchgear controls to MANUAL, if applicable.

Energize the main switchgear bus. For switchgear with multiple sources of power, energize power sources one at a time. Verify proper operating voltages. For switchgear with multiple sources of power, verify proper phasing across tie breakers.

Energize loads supplied from the switchgear starting at the source end of the switchgear and working

toward the load. Remove locks and tags and close load isolation devices to verify proper phase rotation, with regard to the utilization equipment supplied from the switchgear. Close main, feeder, and branch circuit devices in sequence.

Inspect switchgear for mechanical rattles or excessive humming. Investigate hardware that has not been tightened or metal parts that are improperly assembled as possible sources of extraneous noise. Listen for corona from PT leads that may be too close to the main bus. De-energize and ensure switchgear is in an electrically safe work condition as needed to make minor repairs and adjustments.

Measure secondary phase-to-phase and phase-to-neutral voltages after loading switchgear to ensure proper neutral-to-ground bonding. Verify proper rotation of motors supplied from the switchgear. Record measurements to assist in troubleshooting problems with low voltages at utilization equipment.

Verify that all instrumentation, metering, touchscreens, and other control displays properly indicate the actual operating condition of the switchgear.

Check space heaters for proper operation, if so equipped.

Set switchgear controls to AUTOMATIC, if applicable. Perform operational and functional testing of switchgear in accordance with contract documents, drawings and specifications, and in accordance with manufacturer instructions.

10.6 Infrared Survey

Unless infrared inspection ports are provided, infrared scanning is typically conducted with doors open and/or covers removed, exposing the user to shock and arc-flash hazards. Appropriate PPE must be worn when conducting infrared scanning.

Infrared surveys are recommended for equipment that cannot be de-energized and taken out of service or where an outage is problematic or difficult to coordinate. Perform infrared scanning in accordance with switchgear and test equipment manufacturer instructions after switchgear has been energized and placed under load.

Because infrared surveys should be performed during periods of maximum possible loading but not less than 10 percent of rated load of the electrical equipment or the maximum load available, whichever is greater, infrared surveys may not accurately depict the resistance of high-capacity medium-voltage connections and terminations.

Equipment should not be tested when exposed to direct sunlight. Perform infrared inspection of outdoor equipment at night or when equipment is not exposed to direct sunlight.

Shiny surfaces do not emit radiation energy efficiently, and can be hot while appearing cool in an infrared image. Additionally, plastic and glass covers in electrical enclosures are not transparent to infrared radiation.

Provide supplemental barriers and use safety precautions during infrared scan to prevent accidental contact with exposed energized components. Comply with NFPA 70E and use appropriate PPE. See Section 3 for additional safety recommendations.

Use infrared test equipment that detects emitted radiation and converts detected radiation to a visual

signal. Imaging equipment should be capable of detecting a minimum difference of 1°C at 30°C (2°F at 86°F). Provide documentation of equipment calibration.

Ensure equipment is in an electrically safe work condition in accordance with Section 3. Remove all accessible covers, plates, weathershields, and doors as needed to reveal bus, cable terminations, instrument transformers, protective relays, control power transformers, and similar equipment.

Perform infrared testing of all accessible current-carrying devices, namely main switchgear buses, circuit breakers, instrument transformers, meters, protective relays, batteries, and battery charger electrical connections, while energized and operating under maximum load conditions. Allow switchgear to reach thermal steady state.

Investigate differences in temperature gradient in accordance with switchgear and test instrument manufacturer instructions. Typically, temperature differences of 1°C at 30°C (2°F at 86°F) between similar components under similar loading are normal. Temperature differences of 4°C at 15°C (7°F at 59°F) may indicate possible deficiencies which warrant investigation.

Repair or replace suspect external electrical equipment, terminations, and connections in accordance with manufacturer instructions. Repeat infrared survey on affected components after making repairs.

Prepare an infrared survey report that includes a description of the equipment tested, any discrepancies found, the temperature differences between areas of concern and reference areas, the probable causes of any temperature differences, areas that were inspected, areas that were not inspected that were inaccessible and/or unobservable, and the general load conditions of the equipment at the time of the inspection. Include photographs and/or thermographs of the deficient areas along with additional recommended remedial actions needed for repairs.

11. Maintenance Procedures

11.1 General

Follow the manufacturer recommended maintenance intervals. Also, see NFPA 70B. In general, perform visual and mechanical inspections of switchgear every 12 months, and perform maintenance and electrical testing of switchgear every 24 months. Inspections, maintenance, and testing should be performed more frequently for critical equipment, such as in a data center or healthcare facility, for a harsh operating environment, or as recommended by the equipment or component manufacturer.

In general, follow the inspection, testing, and commissioning procedures outlined in Section 10 when servicing, maintaining, and testing switchgear. Maintain records of service, maintenance, testing, and repairs in accordance with Section 10. Follow the switchgear and testing equipment manufacturer instructions and the safety recommendations in Section 3.

Clean components when needed in accordance with manufacturer instructions using approved materials, means, and methods. Carefully select manufacturer approved solvents to clean switchgear to ensure compatibility with materials. Do not use liquid or spray cleaners unless specifically approved by the switchgear manufacturer. Certain cleaners and solvents can degrade electrical insulation. Additionally, liquid and spray cleaners introduce residues that can damage or interfere with electrical or mechanical functions, or that can attract conductive contaminants that can cause tracking on insulating surfaces.

Failure to use proper cleaning methods and chemicals can cause damage to the product that could result in death, serious injury, damage to equipment, damage to property, consequential loss, loss of revenue, and environmental impacts.

Determine the available fault current from the utility or primary source and compare with overcurrent protective device interrupting capabilities. Notify the owner of any discrepancies.

Coordinate all maintenance and repair work in utility service entrance rated switchgear compartments with the local electric utility company.

For additional information, see ANSI/NETA MTS.

11.2 Switchgear Room Maintenance

Maintain switchgear rooms and vaults in a clean, dry, and ventilated condition at all times. Do not use switchgear rooms and vaults for storage of supplies or equipment.

Check that seals for raceways that penetrate exterior walls or the roof or floor of switchgear rooms and vaults are intact and effectively prevent the entry of moisture, rodents and insects.

Check environmental control equipment, such as ventilation fans and unit heaters, in switchgear rooms and vaults for proper operation. Adjust controls as needed for proper environmental regulation. Clean and lubricate equipment in accordance with manufacturer instructions.

Ensure proper operation of forced-air ventilation for battery rooms or enclosures. Verify the existence and the proper operation of suitable eyewash equipment, if applicable, by checking maintenance tags on equipment.

11.3 Visual Inspections

Ensure that accessible covers, plates, doors, and weathershields, if applicable, are installed, secure, and locked, if applicable, to prevent unauthorized access. Inspect sheet metal, doors, panels, and sections for damage, dents, scratches, fit, and alignment. Repair damage in accordance with manufacturer instructions.

Examine switchgear for the evidence of corrosion, chemical attack, moisture, and water leakage from outside sources, such as raceways or roof or wall seams. Examine vents and verify that vents are clear. Verify that air filters, where installed, are in place and clean.

For arc-resistant switchgear, ensure that plenums and ducts have no loose or missing hardware. If any self-tapping screws are stripped out, install a nut with locking hardware on the backside of the screw and torque in accordance with manufacturer instructions. Inspect air filters on ducts, if present, and replace with identical filters if soiled or clogged. Check all labyrinths, grillwork, and air passages for obstructions and accumulations of dirt. Check to ensure that all dynamic flaps are open to allow natural airflow and that all pressure relief flaps are properly closed. *NOTE: Ventilation flaps are designed to close automatically during an internal arcing fault, while pressure relief flaps are designed to open during an internal arcing fault.*

Inspect switchgear for proper alignment, anchorage, grounding, and required workspace clearances. Inspect all indicating devices for proper operation. Notify the owner of any deficiencies.

11.4 Switchgear Maintenance

Ensure switchgear is in an electrically safe work condition in accordance with Section 3 prior to performing any service, maintenance, repairs, or testing. Switchgear must be completely disconnected from all power sources and grounded before performing any internal inspections. Failure to completely disconnect switchgear from all power sources prior to inspections may result in severe injury or death and damage to equipment.

Inspect switchgear for the overall general condition of components. Check for physical damage, corrosion, dents, scratches, contamination, and accumulations of dust, dirt, and debris, cracked insulation, broken leads, evidence of overheating and arcs, and defective wiring. Inspect switchgear for evidence of moisture or tracking on insulating surfaces (corona). Visually check that all grounding connections are intact.

Inspect the physical and mechanical condition of equipment, looking for physical damage. Inspect internal switchgear compartments for proper anchorage and correct alignment of components. Wipe away any dust or dirt that may have accumulated in compartments, paying particular attention to insulators and insulating material. If the switchgear bus is insulated, clean the insulation in accordance with manufacturer instructions. Repair physical damage in accordance with manufacturer instructions.

Inspect all bolted electrical connections of switchgear, including main, neutral, and ground bus, circuit breakers, instrument transformers, meters, protective relays, controls, batteries, and battery chargers, for high resistance with a calibrated torque wrench. Refer to the manufacturer instruction for proper torque levels. Bolt torque levels must be in accordance with manufacturer instructions.

Inspect conductors for damage, such as from insulating supports or barriers, and from cable ties or other means of securing/supporting the conductors. Check for evidence of tracking and corona damage on insulating barriers and supports. Replace damaged conductors and supports. Provide physical protection of conductors to prevent similar damage in the future, as needed.

Perform insulation resistance tests in accordance with switchgear, component, and test instrument manufacturer instructions, and in accordance with Section 10.

Inspect all meters and relays. Check all protective relays to ensure they are subjected to the correct electrical signals (amps, volts, and watts). Examine meters and protective relays for mechanical or electrical damage and wire connection tightness. Check the condition of meter face and face gaskets. Clean meters and relays as needed in accordance with manufacturer instructions.

Check all surge arresters and lightning arresters for physical damage. Inspect for signs of corona and tracking. Inspect ground and discharge connections for integrity and that the ground lead on each device is individually attached to a ground bus or ground electrode. Clean all insulators and arresters in accordance with manufacturer instructions. Apply manufacturer approved insulator treating fluid to all insulators and arresters. Verify that surge counter, if present, is correctly mounted and electrically connected.

Inspect medium-voltage vacuum circuit breakers for anchorage, alignment, and grounding. Check the cell fit and element alignment. Operate medium-voltage circuit breakers to ensure proper operation.

Perform minimum pickup voltage tests on trip and close coils. Check condition of brushes and limit switches on spring charging motors, if applicable.

Verify correct operation of all indicating and control devices.

Verify proper operation of space heaters and controllers, if applicable.

Inspect the operation of shutters. Verify correct barrier and shutter installation and operation.

Inspect ground system for adequate termination at all devices. Verify that building steel, water system and ground grid are effectively bonded. Make sure that the panels and cabinets are bonded to the grounding system, but that they are not used as part of the grounding system. On the main grounding electrode or system, perform fall of potential and ground resistance testing in accordance with Section 10.

Energize switchgear and perform infrared scan of switchgear in accordance with Section 10.

Perform operational and functional testing in accordance with Section 10.

11.4.1 Lubrication

Inspect switchgear and components, such as sliding potential transformer (PT) drawers, air switches, and circuit breakers, for cleanliness and for the need of lubrication. Clean equipment and components and lubricate as necessary.

Use only manufacturer-approved lubricants and conductive grease on moving current-carrying parts and on moving and sliding surfaces.

Lubricate moving current-carrying parts and mechanical moving and sliding surfaces. Remove excess lubrication with a clean cloth to prevent the accumulation of dust or dirt. Clean lubricant from insulating surfaces immediately. Do not use non-conductive grease on any current-carrying contact surface.

11.4.2 Battery System Maintenance

Inspect station batteries, battery system components, and battery racks and support structures for physical damage, damaged insulation, bulging or distorted cases, leaks, corrosion, sulphation, and discoloration.

Clean the support rails, battery cells, and cell connectors in accordance with manufacturer instructions. Coat battery connections with antioxidant when recommended by the manufacturer.

Ensure that flame arresters on vented batteries are clean and clear of obstructions.

Inspect the grounding of the battery racks and battery system, if applicable. Check that all battery mounting hardware is tight. Check all battery connections for proper torque. Do not over-torque cell terminal connections, which can distort lead posts and cause permanent damage.

Measure the battery system charging voltage and the voltage of each individual cell to ensure that batteries are not overcharging.

Vacuum any debris from vents and heat sinks of battery chargers. Remove dust and dirt from the interior of battery chargers using a vacuum. Check battery charger gauges and indicators for proper operation. Set the float and equalizing levels for battery chargers in accordance with the manufacturer recommended operating range for the type of batteries installed.

11.4.3 Insulation and Conductor Maintenance

De-energize circuits before entering enclosures. Complete insulation resistance testing before cleaning conductors. Inspect conductors and insulation for signs of overheating, thermal damage, or weakened insulation.

Remove loose dust and debris using a vacuum with HEPA filter. Remove accumulations of dust and dirt from conductors, live parts, insulators, component insulation, and enclosure surfaces using a clean, soft, lint-free cloth. Follow the switchgear manufacturer instructions for cleaning switchgear. See Section 11 for additional information.

After cleaning conductors and insulation, measure conductor insulation resistance again. Keep a record of these readings for future reference in determining when trends occur that would indicate a lowering of the insulation resistance.

Periodic high potential tests are not required and are recommended only after repair of high voltage current-carrying parts or insulation, or when the trend of insulation resistance readings indicates it to be advisable. This field test should be made before the main cables are connected and should not exceed the manufacturer recommended test voltages.

11.4.4 Maintenance of Medium-Voltage Switches

Inspect medium-voltage switches for physical damage and proper alignment. Check switches for correct blade alignment, blade penetration, and travel stops. Inspect contacts for alignment, pressure, burns, and corrosion. Verify that phase-barrier mounting is intact. Check arc interrupter operation.

Check fuse linkages and elements for proper holder and current rating. Check each fuse holder for adequate mechanical support of each fuse. Inspect fuse clips for tightness and alignment. Verify that fuse sizes and types are in accordance with drawings, short-circuit study, and coordination study, if available. Verify that expulsion-limiting devices are in place on all fuses having expulsion-type elements.

Inspect interphase linkages and operating rods to make sure that they are not bent or distorted, and that all fastenings are secure.

Check the mechanical operation of the switch. Observe the operation of the switch and check for approximately the simultaneous closing of all blocks and for complete closing.

Inspect arcing horns for signs of thermal damage or burning. *NOTE: Some manufacturers provide "arcing horns" (conductors that are formed to create a spark-gap between the switch arm and the blade contact) that are used to protect the switch arm and blade contact from damage due to arcing when opening or closing the switch under load.*

Inspect flexible braids or slip ring contacts commonly used for grounding the operating handle. Replace braids showing signs of corrosion, wear, or broken strands.

Measure fuse resistance. Investigate fuse resistance values that deviate from each other by more than 15 percent.

Where non-shielded medium-voltage conductors are routed through insulating barriers, inspect conductors for evidence of damage and inspect barriers for evidence of tracking and corona damage. Replace damaged conductors and barriers. Provide physical protection of conductors to prevent similar damage in the future, as needed.

11.5 Replacing Medium-Voltage Fuses

Ensure equipment is in an electrically safe work condition in accordance with NFPA 70E and Section 3 prior to performing any service, maintenance, repairs, or testing on any medium-voltage fuse. Ensure that all sources that could energize the fuse, including backfeed sources, are opened, padlocked, and tagged out to prevent inadvertent energization or backfeed. Failure to completely disconnect equipment from all medium-voltage voltage sources may result in equipment damage, serious injury, or death.

Operate interrupter switches by rotating the handle downward. Before opening the door, verify that all switch blades are disengaged from their break jaws by looking through the cubicle window. Use a supplemental light source, such as a flashlight, as needed.

Using appropriate PPE, open the cubicle door and test for voltage in accordance with Section 3. Discharge any static charge from current-carrying components and install personal protective grounds between the work area and all possible sources.

Remove and replace fuses in accordance with manufacturer instructions.

Remove personal protective grounds and re-energize equipment in accordance with Section 10.5.

(This Annex is not part of the Standard)

Annex A: Reference Standards

ANSI C37.85-2020, Switchgear - Alternating-Current High-Voltage Power Vacuum Interrupters - Safety Requirements For X-Radiation Limits

ANSI Z535, Safety Alerting Standards

ASTM F855-2020, ASTM Standard Specifications for Temporary Grounding Systems to be Used on De-energized Electric Power Lines and Equipment,

IEEE C2-2023, National Electrical Safety Code

IEEE C57.13.1-2017, IEEE Guide for Field Testing of Relaying Current Transformers

IEEE C37.20.2-2022, IEEE Standard for Metal-Clad Switchgear

IEEE C37.20.3-2013, IEEE Standard for Metal-Enclosed Interrupter Switchgear (1 kV–38 kV)..

IEEE Guide C37.20.7-2017, IEEE Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults

IEEE C37.59-2018, Requirements for Conversion of Power Switchgear Equipment

IEEE Standard 81-2012, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

IEEE 450-2020, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications

IEEE 1106-2015, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications

IEEE 1188-2014, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications

NEMA GD 1-2019, Evaluating Water-Damaged Electrical Equipment

ANSI/NETA Acceptance Test Specifications (ATS) 2021

ANSI/NETA Electrical Commissioning Specification (ECS) 2020

ANSI/NETA Maintenance Test Specifications (MTS) 2023

NFPA 70-2023, National Electrical Code

NFPA 70B-2023, Standard for Electrical Equipment Maintenance

NFPA 70E-2024, Standard for Electrical Safety in the Workplace