NECA 407

Standard for Installing and Maintaining Panelboards

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(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:

> Panelboards shall be installed and maintained in accordance with NECA 407, *Standard for Installing and Maintaining Panelboards* (ANSI).

Use of *NEIS*™ is voluntary, and the National Electrical Contractors Association (NECA) assumes no obligation or liability to users of this publication. The 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 Federal 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

1.1 Products and Applications Included

This Standard describes installation and maintenance procedures for panelboards, and special procedures used for panelboards after adverse operating conditions such as a short-circuit, ground-fault, or immersion in water.

This Standard applies to panelboards rated 1000 Volts or less, AC and DC, with main disconnects or lugs, and with feeder or branch circuit overcurrent devices.

This Standard applies to single panelboards and multi-section panelboards that are installed in the field and used for distributing power in nonhazardous locations both indoors and outdoors.

1.2 Products and Applications Excluded

This publication does not apply to:

- Panelboards that are factory-installed within other equipment (such as switchgear, switchboards, industrial control panels)~~as part of a Listed enclosure or assembly~~
- Live-front panelboards
- Panelboards employing cast enclosures for hazardous or special service conditions
- Mobile, portable, or temporary panelboards

1.3 Regulatory and Other Requirements

All information in this publication is intended to conform to the National Electrical Code (ANSI/NFPA 70). Installers shall follow the NEC, applicable state and local Codes, manufacturer instructions, and contract documents when installing panelboards.

Only qualified persons as defined in the NEC and NFPA 70E familiar with the construction and installation of panelboards and trained in accordance with NFPA 70E shall perform the technical work described in this publication. Administrative functions such as receiving, handling, and storing required in Section 4, 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 NECA 1, Standard Practices for Good Workmanship in Electrical Construction (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 Standard 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 Standard 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 Standard 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 Standard, information related to another Code, Standard, or document, and supplemental application and design information and data, is included throughout this Standard 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 Standard are provided in informative annexes. Informative annexes are not part of the enforceable requirements of this Standard but are included for information purposes only.

2. Definitions

NOTE: The following terms are used in this Standard. The definitions below apply only to the context in which the terms are used in this Standard.

Branch Circuit, Multiwire. A branch circuit that consists of two or more ungrounded conductors that have a voltage between them, and a neutral conductor that has equal voltage between it and each ungrounded conductor of the circuit and that is connected to the neutral conductor of the system.

Panelboard. A single panel or group of panel units designed for assembly in the form of a single panel; including buses and automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet, enclosure, or cutout box placed in or against a wall, partition, or other support, and accessible only from the front.

Panelboard, Enclosed (Enclosed Panelboard). An assembly of buses and connections, overcurrent devices, and control apparatus with or without switches and other equipment, installed in a cabinet, cutout box or enclosure suitable for panelboard applications.

Panelboard, Flush-Mounted (Flush-Mounted Panelboard). A panelboard that is installed recessed into a wall, partition, or similar construction, such that the front of the cabinet is flush with the mounting surface.

Panelboard, Surface-Mounted (Surface-Mounted Panelboard). A panelboard that is installed

on the surface of a wall, partition, or similar construction, such that the cabinet is exposed on the mounting surface.

Reconditioned. Electromechanical systems, equipment, apparatus, or components that are restored to operating conditions. This process differs from normal servicing of equipment that remains within a facility, or replacement of listed equipment on a one-to-one basis. *NOTE: The term reconditioned is frequently referred to as rebuilt, refurbished, or remanufactured*.

3. Safety Procedures

Before performing cleaning, inspections, testing, maintenance, or repairs, electrically isolate conductors and equipment in accordance with established written procedures. All work and actions must conform to the requirements of NFPA 70E, Electrical Safety in the Workplace.

The process of de-energizing conductors and equipment is considered "live" work and can result in electric shock and an arc flash due to exposure or equipment failure. When de-energizing conductors and equipment, follow safety procedures for working on or near live circuits. Failure to observe these precautions may result in severe personal injury or death.

3.1 General

For electrical equipment to work properly, it must be handled carefully and installed, operated, and maintained correctly. Neglecting fundamental installation and maintenance requirements can lead to personal injury or death, and damage to conductors, electrical equipment, and other property.

Consider all circuits and 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, locked out of operation, and red tagged in accordance with OSHA requirements.

Do not work on energized conductors or equipment. Electrically isolate conductors and equipment in accordance with established procedures and manufacturer instructions.

Use care in opening and closing doors to energized equipment. Conductors and terminations may be exposed and within the reach of openings.

Do not enter equipment enclosures when components are energized. Do not remove access covers, doors, or panels when equipment is energized. Do not expose conductors, connections, or terminations when components are energized. Using established safety procedures, guard energized conductors and equipment in close proximity to work.

3.2 Safe Work Practices

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

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

Resolve discrepancies between installed conditions and electrical drawings. Have drawings corrected, if required. Provide warning labels on equipment and cables where necessary to indicate unexpected and potentially hazardous conditions.

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.

Use insulated hand tools when working on or around energized equipment. Use only properly rated tools for the energy present. Maintain tool inventories to ensure that all tools are accounted for prior to energizing equipment.

Ensure that egress from the work area is unobstructed, and that fire extinguishers approved for use in electrical fires are readily available.

Do not make any modifications to the equipment or attempt to operate equipment with interlocks or safety barriers removed. Engage lock-bars for compartment doors so equipped to prevent doors from accidentally closing.

3.3 Personal Protective Equipment (PPE)

Use appropriate Personal Protective Equipment (PPE) and established safety procedures when working on or near energized electrical equipment or equipment that has not been de-energized, tested, grounded, locked out of operation, and red tagged in accordance with NFPA 70E.

Wear appropriate PPE in accordance with the voltage and incident energy levels based on the electric shock and arc flash risk assessments for~~of~~ the equipment and the risk assessment of the tasks to be performed.

Use arc rated apparel appropriate for the incident energy exposure. Wear only~~100 percent~~ natural fiber garments as underlayers in accordance with NFPA 70E where underlayers are used~~clothing or flame-resistant apparel~~. Do not wear conductive articles such as watches, rings, or necklaces.

3.4 De-Energizing Electrical Equipment

Follow all manufacturer instructions and recommendations for electrically isolating equipment and components. Render equipment electrically safe. Follow lock-out/tag-out procedures. Disconnect all sources of power before opening any enclosures or compartments. Verify that source circuit breakers and switches are open.

Identify all sources of power to the conductors and equipment. Interrupt the load current before opening the disconnecting means for each power source. Where possible, visually verify that the blades of disconnecting means are fully open and that drawout-type circuit breakers are fully withdrawn.

Test conductors and equipment at both source and equipment terminals for the presence of voltage. Use electrical testing equipment rated for the operating voltage of the system. Test the voltage sensing equipment on a known, energized source immediately before and after testing the equipment to be tested to ensure that the voltage sensing equipment is operating properly.

Apply lockout/tagout devices in accordance with a formal, written policy and in accordance with NFPA 70E, Electrical Safety in the Workplace. Padlock and red tag all source switching devices in the open position. Protect against accidental energization of automatic or remotely controlled equipment by identifying, opening, locking, and tagging starting devices. Open and lock or tag all load isolation devices to ensure that there are no loads connected to the equipment. Remove locks and tags only after work is complete and tested, and all personnel are clear of the area.

Use Listed personal protective grounds that are sufficient for the available short circuit current of the system. Connect personal protective grounds to the line terminals of the main circuit breaker or main lugs, to the neutral terminal bus bar, if so equipped, and to the grounding terminals of the equipment. Provide warning signs at all primary disconnects indicating that the terminals are grounded. Do not remove the personal protective grounds until ready to test or energize conductors and equipment. Ground all possible sources of induced voltage and stored electric energy, such as conductors in close proximity to energized parts and capacitors.

Carefully inspect the work area and remove any tools and objects left inside before energizing conductors and equipment. Install all devices, panels, doors, and covers before energizing.

4. Receiving, Inspecting, Handling, and Storage

4.1 Receiving

Unload panelboards and components carefully, observing all packing label warnings and preventing damage to materials and components, or the loss of loose parts.

Compare panelboards and accessories received with the bill of materials to verify that the shipment is complete. If the shipment is not complete, notify the manufacturer immediately in writing and note shortages on the bill of materials.

Verify that panelboards and accessories received conform to the manufacturer quotation and shop drawings and/or approved submittals. If they do not, notify the manufacturer immediately in writing.

4.2 Inspecting

Unpack panelboards and components sufficiently to inspect for concealed damage resulting from shipping and handling.

Inspect panelboards and components for damaged or displaced parts, for loose, cracked, broken, or chipped components, for damage to circuit breakers or switches, for dirt or foreign material, and for the presence of water or moisture. Check shipping “tip” or “shock” indicators, if provided.

If damage or contamination has occurred, notify the shipper and manufacturer immediately in writing. Do not proceed with installation until appropriate actions to clean or replace damaged components have been taken. Repair or replace damaged components in accordance with manufacturer instructions.

If panelboards are to be stored prior to installation, restore original packing materials as much as possible, or cover with heavy plastic or canvas to protect panelboards from exposure to moisture, dust, dirt, and contaminants. When conditions permit, leave the packing materials intact until panelboards are ready for

installation.

4.3 Handling

Handle panelboards and accessories in accordance with manufacturer recommendations and instructions.

Handle panelboards and accessories carefully to avoid damage to the cabinet, front cover, panelboard, frame, and components. Avoid subjecting panelboards to impact, jolting, jarring, or rough handling.

4.4 Storage

Protect panelboards from dust, dirt, moisture, contamination, and physical damage. Cover with suitable temporary coverings to prevent deposits of dirt or other foreign material on movable parts and electrical contact surfaces.

Store panelboards in a clean, dry, heated building having a uniform temperature and adequate air circulation to prevent condensation.

Where storage in a heated building is not possible, store panelboards indoors in a clean, dry shelter having provisions for maintaining a uniform temperature and adequate air circulation to prevent condensation. In locations with high humidity, provide temporary dehumidification and remove panelboards from packing materials to permit adequate ventilation and to avoid mildew.

Where it is not possible to store panelboards indoors, protect panelboards from weather and contaminants. Install electric heating to maintain a uniform temperature above ambient to prevent condensation, or make temporary power connections to equipment heaters, if so equipped. Ensure that all cartons and other miscellaneous packing materials have been removed from panelboards before energizing any heaters. Where space heaters are supplied from auxiliary power transformers, take care to isolate low-voltage heater circuits before making temporary power source connections to prevent inadvertent energizing of the auxiliary transformer and associated primary wiring.

If panelboards are stored for extended periods of time, inspect the panelboard and spot check insulation resistance prior to installation. See Section 10.1. If any readings are low, consult the manufacturer for recommendations. In general, dry out, clean, and /or replace components as necessary and retest until insulation resistance results are suitable for placing panelboards into operation.

5. Installation

5.1 General

Install panelboards in accordance with manufacturer instructions, including specific panelboard markings, and in accordance with the NEC.

Review manufacturer supplied shop drawings, arrangement drawings (front, end, and plan view), connection diagrams, approved submittals and shop drawings, and equipment schedules before installation.

Verify that the panelboard has a rating not less than the minimum feeder capacity required for the calculated load. Verify that supply overcurrent devices for panelboards have a rating not greater than that of the panelboard. Panelboard overcurrent protection is permitted to be located within the panelboard or at any point on the supply side of the panelboard. For panelboards supplied through a transformer, provide overcurrent protection for the panelboard that is located on the secondary side of the transformer unless the transformer primary overcurrent protection complies with NEC Section 240.21(C)(1).

Ensure that panelboard short circuit current rating (SSCR) and circuit breaker interrupting ratings exceed the available fault current from the system as indicated by the contract documents, drawings and specifications, or the short-circuit and coordination study, if provided. Verify that panelboard and enclosure combinations have been evaluated for the application where the available fault current is greater than 10,000A.

Verify that series-rated panelboards meet the manufacturer Listing for series-rating. Check that panelboards are tested and marked with testing combinations of the line-side overcurrent device and load-side circuit breakers as required by NEC Article 240 for series-rated devices. Verify that series-rated panelboards are suitable for the application and are not installed in an application where selective coordination of overcurrent protection is required. See NECA 700 for additional information.

For panelboards supplied by interconnected electric power production sources, ensure that panelboard bus bar ampacities and overcurrent device ratings comply with NEC Section 705.12(B).

Coordinate panelboard locations to ensure that the required minimum working space clearances are maintained in accordance with NEC Article 110. Ensure that the working space permits the opening of equipment doors or hinged panels a minimum of 90 degrees. Provide sufficient access to permit removal of doors, covers, and panels for routine inspection, maintenance, and testing.

Verify that illumination is provided for panelboard working spaces in accordance with NEC Article 110.

5.2 Environmental Considerations

Verify that panelboards and enclosures are suitable for the installation location. Generally, locate panelboards away from sources of water. Provide panelboard enclosure types for use in specific locations other than hazardous (classified) locations in accordance with NEC Article 110.

Do not install panelboards in locations where the conditions would damage the equipment, such as where exposed to ambient temperatures above 40ºC (104ºF), corrosive or explosive fumes, dust, vapors, dripping or standing water, abnormal vibration, mechanical shock, high humidity, or other unusual operating conditions, unless the panelboard is designed and identified by the manufacturer for such conditions.

5.3 Installation of Cabinets

Locate cabinets so that they are readily accessible and not exposed to physical damage.

Install cabinets level and plumb. Mount the cabinet securely to the mounting surface using manufacturer approved methods, supports, and fasteners.

Provide suitable guards or temporary covers on the cabinet after installation and prior to the permanent

panelboard cover being installed to protect the cabinet and panelboard, once installed, from foreign substances such as paint, plaster, drywall compound, and acoustic ceiling spray.

Close unused openings in panelboard enclosures using identified closures or other approved means that provide protection substantially equivalent to the wall of the enclosure as necessary to return the enclosure to the environmental rating required by the application.

In damp or wet locations, locate surface-mounted cabinets to prevent moisture or water from entering and accumulating within the cabinet. Mount the cabinet with a minimum of 6 mm (1/4 inch) airspace between the cabinet and the wall or other supporting surface. Keep in mind that Code-compliant mounting standoffs are typically stamped into the panelboard cabinet or enclosure. See NEC Section 312.2 for additional information.

Cabinets installed in wet locations shall be weatherproof type.

5.3.1 Panelboard Clearances

For flush-mounted panelboards, install cabinets with the front edge set back not more than 6 mm (1/4 inch) from the finished surface of walls constructed of non-combustible material such as concrete or tile. Install cabinets with the front edge flush with or projecting slightly beyond the finished surface of walls constructed of combustible materials such as wood.

Allow a minimum of 1-meter (3 feet) clearance between the ceiling and the cabinet unless an adequate fireproof shield, such as a fireproof ceiling, is provided.

Mount surface-mounted panelboard cabinets located outdoors so that there is at least 6 mm (1/4 inch) of air space between the cabinet and the wall or other supporting surface. Keep in mind that Code-compliant mounting standoffs are typically stamped into the cabinet.

5.3.2 Supporting Panelboards.

Provide temporary cabinet supports for anchoring flush-mounted panelboards during wall construction. Provide structural floor supports to support the panelboard if required due to the wall construction or the panelboard weight and design.

Support cabinets independently of raceways.

Provide seismic restraints where required by the building Code, the approved plans, or the project specifications.

5.3.3 Multi-Section Panelboards

Ensure that all sections of multi-section panelboards have identical main bus and terminal ratings unless separate main overcurrent devices are provided.

Ensure that feeder conductors between sections are sized not less than the panelboard bus ampacity, or not less than separate main overcurrent protective devices, where installed.

Ensure adequate gutter space is available for wiring between sections.

5.4 Installation of Raceways and Cables

Coordinate cabinet installation with raceway and cable systems to maintain proper alignment.

Align floor-slab raceway stub-ups with openings in the bottom of the cabinets. Maintain alignment during placement of concrete using interlocking raceway spacer caps or a rigid template.

Install raceways in a manner that will prevent water that may accumulate in the raceways from entering and accumulating in cabinets.

Use properly sized and spaced knockouts to match feeder and branch-circuit raceway and cable layouts.

Use proper Listed fittings to attach cables and raceways to the cabinet.

Support raceways, cables, cable trays, and busways attached to cabinets independently from the cabinets themselves.

Provide raceway and cable fittings Listed for wet locations for raceways and cables that enter the top of panelboards in wet locations.

5.5 Installation of Panelboard

Clean the cabinet of all foreign materials prior to installing the panelboard in the cabinet. Contact the panelboard manufacturer before using products with hydrocarbon spray propellants or hydrocarbon-based sprays or compounds to clean, dry, or lubricate panelboard components during installation or maintenance, as these products will cause the degradation of certain plastics.

Verify that the cabinet is Listed for the installation of the specific panelboard.

Protect panelboard parts from contamination during installation.

Verify that component placement in the panelboard is in accordance with contract documents. If there is a discrepancy, contact the project manager and the engineer of record to determine the appropriate course of action.

Install the panelboard. Align and tighten the panelboard in the cabinet per manufacturer instructions. Adjust the panelboard so that the dead-front shield flange is 5mm (3/16 inch) or less from the front of surface-mounted cabinets, or from the surrounding wall surfaces for flush-mounted cabinets.

5.5.1 Circuit Breakers and Fuses

Ensure that circuit breakers and/or fuses are of the proper type, voltage class, and rating.

Ensure that circuit breakers and/or fuses conform to the engineering coordination study, if provided.

Ensure that each molded-case circuit breaker voltage rating is appropriate for the voltage and configuration of the system. Do not install a three-phase disconnect or overcurrent device to the bus of any panelboard that has less than three phase buses. Do not install Delta circuit breakers in panelboards.

Install an additional fastener on plug-in type overcurrent devices that are backfed and used to terminate field-installed ungrounded supply conductors in accordance with the manufacturer instructions.

Compare the placement of circuit breakers in the panelboard with the appropriate panel schedule on the approved plans. Notify the project manager and the engineer of record in writing of any discrepancies in the panelboard circuit breaker arrangement.

Install fuses after all conductors are installed and terminated.

5.6 Installation of Conductors

Perform insulation resistance testing of panelboards prior to terminating conductors. See Section 10.1.

Install conductors for panelboards equipped with ground-fault protection in accordance with manufacturer instructions.

Verify that terminals, connectors, and lugs are compatible with conductor types, sizing, and temperature ratings, considering over-sized conductors to compensate for ambient temperature, voltage drop, and harmonic load currents.

Ensure that all conductors installed in parallel are of the same length, insulation type, material type, and wire size, and that all conductors are terminated in the same manner for each individual phase.

Distribute and arrange conductors in the wiring gutters of cabinets. Train conductors neatly in groups, bundle, and wrap with wire ties after load balancing. See Section 6.5.2. Keep in mind that bundling conductors may impact conductor ampacity ratings.

Provide sufficient conductor lengths to reach the terminals and to avoid placing strain on the terminals. Maintain the largest practical bending radius of conductors.

Strip conductor insulation carefully. Do not nick or ring conductors. For aluminum conductors, clean all oxide from the stripped portion of the conductor, apply an anti-oxide inhibitor formulated to not damage thermoplastic insulation or supports, or as specified by the panelboard manufacturer, and insert immediately into the terminal.

Connect conductors to terminals using suitable hardware such as listed lugs, bolts, flat washers, locking washers, and nuts. Do not install more than one conductor in any termination unless the termination is marked as suitable for more than one conductor.

Check all bolts and terminals for tightness using a calibrated torque wrench or screwdriver. Refer to manufacturer instructions and markings for proper torque values. Keep in mind that the repeated tightening of loose connections will extrude aluminum conductors and may cause adverse operating conditions. Inspect aluminum conductors for extrusion and rework terminations, if required.

Where installed, ensure that all conductors of multiwire branch circuits originate from the same panelboard. Ensure that each multiwire branch circuit is provided with a means that will simultaneously disconnect all ungrounded conductors at the point where the branch circuit originates. Group the ungrounded and grounded circuit conductors of each multiwire branch circuit by cable ties or similar means in at least one location within the panelboard for identification purposes.

Identify conductors originating within each panelboard. The means of identifying ungrounded conductors are permitted to be by separate color coding, marking tape, tagging, or other approved means. Document the means of identifying conductors in a manner that is readily available or is permanently posted at each panelboard.

5.6.1 Four-Wire, Delta-Connected Systems

Ensure that the panelboard Listing information shows a delta wiring diagram for panelboards installed on delta-connected systems.

For panelboards installed on new three-phase, four-wire, delta-connected systems where the mid-point of one phase winding of the supply transformer is grounded, ensure that the B-phase is connected to the conductor with higher voltage to ground. Permanently and durably mark the phase busbar or conductor having the higher voltage to ground by an outer finish that is orange in color or by other effective means.

For panelboards installed on existing three-phase, four-wire, delta-connected systems where the mid-point of one phase winding of the supply transformer is grounded, ensure that the phase connected to the conductor with higher voltage to ground matches the convention used throughout the existing system, including the method of identifying the conductor with the higher voltage to ground.

Provide instruction and warning labels identifying phasing and voltages on the panelboard. See Section 6.2.1.

5.7 Grounding and Bonding

Ensure that metallic panelboard cabinets and metallic panelboard frames are in physical contact with each other and are connected to an equipment grounding conductor.

Provide an equipment grounding terminal bar within the cabinet for panelboards that are used with nonmetallic raceways or cables, or where separate equipment grounding conductors are provided. Bond the terminal bar to the cabinet and panelboard frame, if metal. Otherwise, bond the terminal bar to the equipment grounding conductor that is run with the panelboard feeder conductors, with the exception of an isolated grounding conductor that is permitted to pass through the panelboard without being connected to the terminal bar. See NEC Section 250.146(D).

Do not connect equipment grounding conductors to a terminal bar provided for grounded or neutral conductors unless the bar is identified for the purpose and is located where interconnection between equipment grounding conductors and grounded circuit conductors is permitted or required by Article 250.

Tighten grounding connectors and terminals, including screws and bolts, using a calibrated torque wrench or screwdriver. Refer to manufacturer instructions and markings for proper torque values. Keep in mind that the repeated tightening of loose connections will extrude aluminum conductors and may cause adverse operating conditions. Inspect aluminum conductors for extrusion and rework terminations, if

required.

Verify that neutral connections and bus bars are insulated and isolated from the equipment grounding conductor, the panelboard, the cabinet, and any isolated grounding conductors in other than service equipment applications. Install supplemental neutral terminal bars in accordance with the panelboard manufacturer instructions as required to accommodate the number of conductors for termination. Terminate each grounded conductor or neutral in an individual terminal that is not also used for another conductor. Parallel neutrals are permitted to be terminated in a single terminal that is identified for connection of more than one conductor.

Provide terminal bars for isolated grounding conductors that are insulated and isolated from the equipment grounding conductor, the panelboard, the cabinet, and any neutral conductors in other than service equipment applications. Keep in mind that isolated grounding conductors are permitted to pass through one or more panelboards without a connection to the panelboard grounding terminal in accordance with NEC Article 408.

Connect grounding conductors to the equipment grounding terminal bar. Install supplemental grounding terminal bars as required to accommodate the number of conductors for termination. Ensure that equipment grounding terminal bars are bonded to the cabinet or panelboard frame.

Terminate all equipment grounding and bonding conductors on a common equipment grounding terminal mounted on the cabinet. Bond all metallic cabinets and frames and raceway grounding bushings to the equipment grounding conductor. Bond all cabinets and grounding terminals of multiple-section panelboards together using properly sized bonding jumpers. Remove the paint as necessary to make grounding and bonding connections to painted equipment, frames, and enclosures.

See NEC Article 517 for additional grounding and bonding requirements for panelboards installed in healthcare facilities.

5.7.1 Service Entrance Panelboards

Bond all non-current carrying metallic parts of service equipment in accordance with applicable Codes and manufacturer instructions.

Install a main bonding jumper in accordance with NEC requirements and manufacturer installation instructions unless supplied by a high-impedance grounded neutral system in accordance with NEC Section 408.3(C).

Install a grounding electrode conductor in accordance with NEC requirements.

5.8 Accessories

Install any field-installed panelboard accessories and components in accordance with manufacturer instructions.

Connect all conductors for control, metering, and monitoring functions specific to the panelboard installation.

Check all installed panelboard accessories such as shunt trips, alarms, signals, contactors, and time clocks

for proper operation and voltage.

Remove the drain screws from cabinets for NEMA 3R rating, if provided.

5.9 Panelboard Pre-Checks

Clean the cabinet of any debris which has accumulated during the panelboard installation.

Check the tightness of all bolts and electrical connections using a calibrated torque wrench or screwdriver. Refer to manufacturer instructions and markings for proper torque values. Keep in mind that the repeated tightening of loose connections will extrude aluminum conductors and may cause adverse operating conditions. Inspect aluminum conductors for extrusion and rework terminations, if required.

Ensure that all blocking and packing materials have been removed from the cabinet.

Exercise switches, circuit breakers, and other operating mechanisms to ensure free operation.

Set adjustable time current trip devices to the settings specified in the engineering coordination study, if provided.

Ensure that all dead-front shields and panelboard barriers are properly aligned and tightened.

Protect the panelboard from on-going construction activities until the panelboard is cleaned, tested, and commissioned in accordance with Section 6.

6. Cleaning, Testing, and Commissioning

6.1 Cleaning

Maintain adequate ventilation during cleaning. Follow manufacturer instructions for cleaning materials and methods. Failure to follow the manufacturer instructions can result in equipment damage from the use of improper cleaning agents.

Remove trash, combustible material, and other debris from areas around panelboards.

Remove all debris from the cabinet. Remove all scraps of stripped insulation, wire, plaster, drywall compound, dust, and other foreign material. Vacuum the cabinet clean. Remove paint splatters and other spots, dirt, and debris. Touch up scratches to match the original finish.

Wipe down the panelboard and cabinet with a clean, dry, lint-free cloth.

6.2 Inspections

Compare the equipment nameplate with approved drawings and contract documents.

Verify that fuse and/or circuit breaker sizes and types correspond to approved drawings and the

engineering coordination study, if provided, as well as to the circuit breaker address for microprocessor-communication packages.

Check all bolts, connections, and terminations for tightness using a calibrated torque wrench or screwdriver. Refer to the manufacturer instructions and markings for proper torque values. Keep in mind that the repeated tightening of loose connections will extrude aluminum conductors and may cause adverse operating conditions. Inspect aluminum conductors for extrusion and rework terminations, if required.

Visually inspect the panelboard for physical damage. Repair physical damage, if practical and approved by the manufacturer. Consult the owner and panelboard manufacturer for recommendations for suitable protective barriers to prevent future damage.

Visually check the panelboard, cover, cabinet, raceways, cables, and conductors for proper grounding and bonding. Ensure that factory-installed panelboard grounding and bonding terminal bars, bus bars, straps, and conductors are properly connected.

Check the anchorage, mounting, clearances, alignment, and fit of the panelboard and components.

Confirm correct operation and sequencing of electrical and mechanical interlock systems, if so equipped. Attempt closure on locked-open devices. Attempt to open locked-closed devices.

6.2.1 Labeling

Confirm that panelboards are properly labeled, including voltage, interrupting ratings, and system configuration, as applicable. Verify that panelboards and enclosures are labeled as suitable for the installation location.

Provide identification and warning signs in accordance with NEC Section 408.3(F):

- For four-wire, delta-connected systems where the mid-point of one phase winding is grounded, provide instruction and warning labels identifying phasing and voltages on panelboards. Legibly and permanently field mark panelboards with: “Caution: _____ Phase Has _____ Volts to Ground.”
- For ungrounded AC systems that comply with NEC Section 250.21, legibly and permanently field mark panelboards with: “Caution: Ungrounded System Operating - _____ Volts Between Conductors.”
- For high-impedance grounded neutral AC systems that comply with NEC Section 250.36, legibly and permanently field mark panelboards with: “Caution: High Impedance-Grounded Neutral AC System Operating - _____ Volts Between Conductors and May Operate - _____ Volts to Ground for Indefinite Periods Under Fault Conditions.”
- For ungrounded DC systems that comply with NEC Section 250.169, legibly and permanently field mark panelboards with: “Caution: Ungrounded DC System Operating - _____ Volts Between Conductors.”
- For resistively-grounded DC systems, legibly and permanently field mark panelboards with: “Caution: DC System Operating - _____ Volts Between Conductors and May Operate - _____ Volts to Ground for Indefinite Periods Under Fault Conditions.”

Confirm that panelboards are field or factory marked to warn qualified persons of potential electric arc flash hazards. Verify that markings meet the requirements of NEC Article 110. Markings must be

located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment. *NOTE: ANSI Z535.4-2023, Product Safety Signs and Labels, provides guidelines for the design of safety signs and labels for application to products.*

Confirm that the method used to identify conductors originating within each panelboard is documented in a manner that is readily available or is permanently posted at each panelboard. The means of identifying ungrounded conductors are permitted to be by separate color coding, marking tape, tagging, or other approved means.

For each panelboard, affix a permanent label of sufficient durability to withstand the installed environment that identifies and provides the physical location of where the power to the panelboard originates. Do not use handwritten methods.

6.2.2 Switches

Operate switches to ensure smooth operation. Verify appropriate lubrication on moving parts and sliding surfaces. Visually check blade alignment, blade penetration, travel stops, and mechanical operation. Check indicating and control devices for proper operation. Check that phase barriers are in place, if applicable.

Inspect each fuse holder to determine whether it seems to be adequately supporting the fuse and that the fuseholder is securely attached to the mounting base.

Verify proper labeling.

6.2.3 Circuit Breakers

Operate circuit breakers to insure smooth operation.

Inspect circuit breaker for correct mounting. Check factory bus connections. Inspect circuit breakers for cracks or other defects.

Verify correct ratings. Adjust settings of adjustable circuit breakers in accordance with the engineering coordination study, if provided.

6.3 Acceptance Testing

Do not proceed with tests until deficiencies identified in Section 6.2 are corrected. Ensure that the panelboard is de-energized and electrically isolated. Follow the safety procedures in Section 3.

Test panelboards in accordance with manufacturer instructions. Record and maintain test results for future comparisons.

Perform insulation resistance testing. See Section 10.1.

Perform ground resistance testing. See Section 10.2.

Perform circuit breaker testing. See Section 10.3.

Measure the contact resistance across each switchblade and fuseholder of switches. The contact resistance values should not exceed the high levels of the normal range as indicated by the manufacturer published data. Investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

Correct deficiencies identified by inspections and tests, and retest panelboards.

Provide written reports of tests and observations. Make notes describing defective materials and unsatisfactory test results. Include details of repairs, replacements, adjustments, and corrective actions taken. Provide copies of reports to the general contractor, project manager, and engineer of record.

6.4 Installation of the Front Cover

Ensure that all tools and all personal protective grounding cables and devices are removed from inside panelboards prior to installing the cover.

Provide manufacturer filler plates for unused panelboard spaces. The closure methods must provide protection substantially equivalent to the wall of the enclosure.

Install the front cover. Ensure that no conductors are pinched between the cabinet and cover, and that all enclosure parts are properly aligned and tightened. Align the front cover squarely with building lines, and tighten.

6.4.1 Restore Finishes

Inspect exposed finishes. Remove burrs, dirt, and construction debris, and repair damaged finishes including chips, scratches, and abrasions to match the original finish. Apply suitable paint or other corrosion-resistant materials where finishes are damaged.

6.5 Energizing Panelboards

Consult the panelboard manufacturer for any abnormal operating conditions encountered. 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.

Ensure that all affected persons are notified prior to energizing panelboards.

Ensure that all personal protective grounds are removed, and the front access cover is installed and tightened prior to energizing panelboards.

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

Energize the panelboard. Measure and record the phase-to-phase and phase-to-neutral voltages.

6.5.1 Energizing Loads

Energize equipment supplied from the panelboard starting at the source end of the panelboard 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 panelboard, if applicable. Close main, feeder, and branch circuit devices in sequence.

Energize lighting circuits, contactors, motors, and heaters after all overcurrent devices have been closed.

Inspect the panelboard for mechanical rattles or excessive noise, such as humming. Investigate hardware that has not been tightened or metal parts that are improperly assembled as possible sources of extraneous noise.

Measure phase-to-phase, phase-to-neutral, phase-to-ground and neutral-to-ground voltages after loading the panelboards to verify proper operation and proper neutral-to-ground bonding, and to verify that voltage drop under load complies with NEC requirements.

Inspect all indicating and control devices for correct operation.

Perform an infrared scan of the panelboard under load. See Section 10.4.

6.5.2 Load Balancing

Measure and record steady state load currents at the panelboard feeder under normal operating conditions as advised by the owner.

Rearrange circuits within panelboards to balance the load between the phases to within 20 percent of each other. Maintain proper phasing for multi-wire branch circuits.

Perform circuit changes outside of the normal occupancy/working schedule of the facility. Make special arrangements with the owner to avoid disrupting critical 24-hour services such as for data center and healthcare applications.

Recheck loads under normal operating conditions after making circuit changes. Measure and record feeder load readings. Rebalance and recheck as required to balance loads.

Perform a final infrared scan of each panelboard after completing all required load balancing. See Section 10.4.

6.6 Circuit Directory

Provide a legible and permanent circuit directory or circuit description for each panelboard after completing all required load balancing. Mount the circuit directory on the face, inside of, or in an approved location adjacent to the panel door.

Clearly identify the specific and evident purpose or use of every circuit. Identify spare or unused

overcurrent devices. Provide a degree of detail and clarity that is unlikely to result in confusion between circuits. Clearly explain any abbreviations or symbols used. Do not identify circuits by transient conditions of occupancy.

Submit a record of all load measurements and circuit changes made during load balancing.

7. Closeout

7.1 Test Data and Manuals

Update contract documents with the final system configuration and parameters.

Submit test results and data from all factory and field testing of panelboards including a record of any actions taken to correct deficiencies.

Deliver as-built documents, test data, and panelboard manufacturer standard installation, operation, and maintenance manuals to the owner or general contractor in accordance with contract documents.

In the absence of contractual requirements, deliver a minimum of one set of all documents to the owner or general contractor. Have the owner or general contractor sign for delivered items.

7.2 Training

Provide training for the owner's maintenance personnel if required by contract documents. Discuss routine maintenance, operating procedures, and cleaning using the manufacturer standard installation, operation, and maintenance manuals as references. Notify the owner or general contractor a minimum of seven days in advance of training.

7.3 Spare Parts and Special Tools

Deliver spare parts and special tools to the owner or general contractor in accordance with contract documents.

In the absence of contractual requirements, deliver the panelboard manufacturer minimum recommended spare parts and special tools.

Have the owner or general contractor sign for delivered items.

8. Inspections and Maintenance

This section describes recommended procedures for the inspection, maintenance, and testing of panelboards. The installer is only responsible for these tasks if required or referenced by contract documents. Otherwise, these inspection and maintenance recommendations are provided as guidance for the owner.

Cleaning, inspection, maintenance, and testing should only be performed by qualified personnel on panelboards to which power has been turned-off, disconnected, and electrically isolated, unless required for testing, to prevent accidental contact with energized parts. Follow the safety procedures in Section 3. Follow all manufacturer warnings and instructions.

8.1 Frequency of Inspections and Maintenance

Make visual observations and record panelboard operational data periodically with panelboards energized and in service.

Perform cleaning, inspections, testing, and maintenance of panelboards at least annually, but as often as the operating environment requires to keep panelboards clean.

Clean, inspect, test, and maintain panelboards following any unusual operating condition in accordance with Section 9 and in accordance with panelboard manufacturer recommendations.

8.2 Record Keeping

Keep complete records of inspections, maintenance, testing, and repairs for each panelboard. Records should contain nameplate data, ratings, date of installation, reference drawings, manufacturer instructions, and spare part data.

Update testing and maintenance records to reflect the dates of inspections, testing, and maintenance as completed, along with a summary of the work performed.

Review testing and maintenance records annually to identify performance trends and changes in electrical characteristics over time.

8.3 Routine Inspections

Inspect areas and spaces around panelboards for any accumulation of dirt or dust. Remove accumulations of dirt or dust. Remove trash, combustible material, and other debris from areas around panelboards.

Use the rate of accumulation of dust and dirt on visible surfaces as a guide for scheduling cleaning, inspections, maintenance, and testing.

Check all accessible exterior panelboard and cabinet hardware for tightness.

Measure and record the ambient temperature around panelboards.

Check the operating temperature of panelboards that have been operating under normal load and at normal ambient temperature for a minimum of 3 hours by measuring the surface temperature on the dead-front surfaces of cabinets, access covers, doors, circuit breakers and switches. If the temperature exceeds manufacturer recommendations, de-energize the panelboard and investigate the source of overheating.

Inspect panelboards and cabinets for external signs of overheating. Check equipment installed near panelboards that might be an external source of heat. Eliminate external sources of heat to panelboards.

Measure and record panelboard voltages and load currents, if possible, noting the date and time of day the measurements were made. Provide comments regarding known variations in loading, such as load additions or equipment maintenance outages.

Visually inspect cabinets for physical damage. Repair physical damage, if practical and approved by the manufacturer. Consult the owner and panelboard manufacturer for recommendations for suitable protective barriers to prevent future damage.

Inspect areas and spaces around panelboards for evidence of water or moisture. Eliminate sources of water or moisture, or provide suitable protection for panelboards from sources of water.

8.4 Cleaning

Maintain adequate ventilation during cleaning.

Visually inspect panelboards for evidence of discoloration, abnormal dust accumulation, metal shards, or any other indication of overheating, wear, or other abnormal conditions prior to cleaning.

Plan the times of cleaning, inspections, testing, and maintenance to minimize outages.

Clean the cabinet with a brush, vacuum cleaner, or clean, dry, lint-free rags to remove any accumulation of dust, dirt, or other foreign matter. Do not use liquids, solvents or detergents when cleaning panelboards or components.

Avoid blowing dust into panelboards. Do not use a blower or compressed air.

Clean supports, terminals, and other major insulating surfaces with clean, dry, lint-free rags or soft-bristled brushes.

Thoroughly clean fusible switches inside and outside. Clean the contact areas of fuses and fuse holders. Clean the insulating area of fuses.

Remove dust, soot, grease, moisture, and foreign material from the surface of circuit breakers.

8.5 Infrared Scan

After cleaning panelboards and components in accordance with Section 8.4, energize the panelboard and perform an infrared scan. See Section 10.4.

8.6 Inspections

Compare the equipment nameplate data with the latest one-line diagram, if available.

Check the panelboard circuit directory for accuracy.

Verify appropriate anchorage, required area clearances, and correct alignment.

Inspect the panelboard for overall general condition and physical damage. Check for broken studs and loose or damaged wires, connectors, or terminations. Check all bolts, nuts, washers, and pins for tightness. Tighten loose hardware or use manufacturer replacement parts as required.

Inspect cabinets for signs of rust, corrosion, or deteriorating paint. Inspect cabinets for evidence of localized heat damage to the paint. Investigate sources of heat. Repair painted surfaces.

Check that covers are in place and fastened. Plug any unused knockouts using closure methods that provide protection substantially equivalent to the wall of the enclosure.

Inspect the panelboard for evidence of moisture. Seal off any cracks or openings which have allowed moisture to enter the cabinet. Look for any recent changes in sprinklers or other plumbing that might expose indoor panelboards to a source of liquids. Eliminate sources of water, moisture, or liquids, or provide adequate barriers to protect panelboards from sources of water, moisture, or liquids. Inspect and replace any components or devices that show evidence of damage from moisture.

Inspect panelboards and internal components for evidence of overheating, arc spatter, sooty deposits, and tracking. Investigate and correct sources of arcing or overheating. Consult the panelboard manufacturer for recommendations.

Verify that fuse and/or circuit breaker types and ratings correspond to record drawings and the engineering coordination study, if provided, as well as to the circuit breaker address for microprocessor communication packages, if so equipped. Record settings of adjustable trip circuit breakers and compare with the engineering coordination study. Notify the owner of discrepancies between actual circuit breaker settings and the engineering coordination study, if any.

Confirm correct operation and sequencing of electrical and mechanical interlock systems, if so equipped. Attempt closure on locked-open devices. Attempt to open locked-closed devices.

8.7 Terminations, Connections, and Lugs

Inspect all terminations, connections, and lugs for tightness using a calibrated torque wrench or torque screwdriver. Refer to manufacturer instructions and markings for proper torque values. Be careful not to overtighten or strip threads. Keep in mind that the repeated tightening of loose connections will extrude aluminum conductors and may cause adverse operating conditions. Inspect aluminum conductors for extrusion and rework terminations, if required.

Inspect terminations, connections, and lugs for alignment, physical damage, burns, corrosion, discoloration, flaking, heat damage, arcing, pitting, melting, deterioration, carbonization, cracks, chips, breaks, partial discharge, or moisture. Investigate and eliminate sources of any damage.

Follow manufacturer instructions for cleaning, repairing, and replacing damaged components. Plated parts may become dark over time due to oxidation. Do not remove this discoloration, as it will reduce the thickness of the plating. Consult the manufacturer for recommendations regarding discoloration of parts.

Rework overheated connections. Replace damaged components. Tighten connections to proper torque levels using a calibrated torque wrench or torque screwdriver after replacement. Refer to manufacturer instructions and markings for proper torque values.

8.8 Conductors and Raceways

Inspect supply conductors and terminations for overheating, discoloration, and oxidation. Investigate and correct any deficiencies.

Ensure that conductors are protected within their ampacity.

Visually check panelboard, cables, and raceways for proper bonding and grounding. Correct improper bonding and grounding.

Inspect conductors for discoloration, arcing, pitting, melting, and flaking of insulation and/or metal parts. Repair or replace damaged components in accordance with manufacturer instructions.

Inspect for frayed or broken wires. Replace conductors as necessary.

Check set screws in all raceway connectors for tightness and for stripped threads. Replace or repair connectors as necessary using manufacturer replacement parts.

Inspect raceways for moisture. Seal raceways and provide a means to drain moisture away from panelboards.

8.9 Switches

Operate each switch several times to ensure that mechanisms are free and in proper working order.

Check switches for damaged or broken parts, free movement, corrosion, dirt, and excessive wear. Verify proper blade penetration, travel stops, and mechanical operation.

Inspect contact surfaces, blades, and jaws for discoloration, overheating, pitting, arcing, and evidence of corona. Clean and dress readily accessible copper electrical contacts, blades, and jaws in accordance with manufacturer instructions. Many contact surfaces, such as arcing contacts, are silver tungsten or other types of materials that must never be dressed. When contacts made of these materials require maintenance, they must be replaced. If contact clips have lost their tension, replace clips or replace the switch. Contact the manufacturer for recommendations when repairing or replacing burned contacts.

Inspect arc chutes and phase insulating barriers. Repair or replace as required.

Lubricate operating mechanisms and sliding contact surfaces, if required, according to manufacturer instructions. If no instructions are given on the devices, sliding copper contacts, operating mechanisms, and interlocks may be lubricated with clean, light grease. Wipe off excess lubrication to avoid contamination.

Tighten fuseholder connections in accordance with manufacturer recommendations. Inspect each fuse holder to determine whether it seems to be adequately supporting the fuse and that the fuseholder is securely attached to the mounting base. Inspect fuse clips for discoloration, overheating, corrosion, or physical damage. Replace weak or burned clips. Install new fuse clips and suitable clamps. Use manufacturer replacement parts.

Measure the contact resistance across each switchblade and fuseholder. The contact resistance values

should not exceed the high levels of the normal range as indicated by the manufacturer published data. Investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

8.9.1 Fuses

Check all fuses to ensure that the correct types and ratings are installed. Where renewable fuses are used, examine fuse links to ensure that the correct link is installed. Ensure that non-current-limiting devices are not used as replacements for current-limiting devices.

Look for fuses that have been bridged with wire, metal strips, disks, or appear to have been forced or hammered into place. Replace with correct fuses and consult the manufacturer for recommendations for preventing a recurrence.

Look for evidence of overheating of cartridge fuses. Replace fuses having discolored or weakened casings. Investigate and correct the cause(s) of overheating.

Inspect ferruled or knife blades of cartridge fuses for corrosion or oxidation. Clean and polish contact surfaces. Clean surfaces with a non-corrosive cleaning agent. Plated parts may become dark over a period of time due to oxidation. Do not remove this discoloration, as it will reduce the thickness of the plating. Consult the manufacturer for recommendations regarding parts that show deterioration.

Measure fuse resistance. Investigate fuse-resistance values that deviate from each other by more than 15 percent. Replace defective fuses. Re-tighten plug fuses.

8.10 Circuit Breakers

Operate circuit breakers several times in order to exercise the mechanism and contacts, and to ensure smooth operation. Do not oil or grease parts of molded case circuit breakers.

Visually check circuit breakers for evidence of overheating and thermal damage. Investigate and eliminate sources of overheating.

Check circuit breakers for visual defects, chipping, cracks, breaks, burns, and deterioration. Replace damaged circuit breakers.

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

Inspect interchangeable trip-unit circuit breakers for tightness of the trip units.

Check circuit breaker terminals and connections for tightness using a calibrated torque wrench or torque screwdriver. Refer to manufacturer instructions and markings for proper torque values. Keep in mind that the repeated tightening of loose connections will extrude aluminum conductors and may cause adverse operating conditions. Inspect aluminum conductors for extrusion and rework terminations, if required.

8.11 Electrical Tests

Do not conduct testing until all discrepancies identified in Section 8 are corrected. Test panelboards in accordance with Section 6.3.

8.12 Re-energizing Panelboards

Energize panelboards in accordance with Section 6.5.

Measure phase-to-phase and phase-to-neutral voltages. Investigate any source voltage imbalance greater than 3 percent.

Measure panelboard feeder and branch load currents. Ensure that conductors are properly sized and protected for the actual supplied load. Balance loads as necessary in accordance with Section 6.5.2 and update the circuit directory in accordance with Section 6.6, if required.

Perform a final infrared scan. See Section 10.4.

9. Inspection and Re-Energization After Adverse Operating Conditions

Panelboards are not permitted to be reconditioned. Panelboards may be replaced within an existing enclosure. In the event that the replacement panelboard has not been listed for the specific enclosure and the available fault current is greater than 10,000 Amperes, the completed assembly must be field labeled, and any previously applied listing marks on the cabinet that pertain to the panelboard must be removed.

9.1 Inspection and Testing Following a Short-Circuit or Ground-Fault

Consult the manufacturer for recommendations before performing any testing or maintenance following a short-circuit or ground-fault. Panelboards that are modified in the field may require evaluation by a qualified safety certification organization to validate that the equipment continues to meet the requirements of the applicable product safety standard.

Identify and remove the cause of the short-circuit or ground-fault.

Clean, inspect, test, and maintain the panelboard in accordance with Section 8.

Inspect all overcurrent protective devices that operated for possible arc-damage to the contacts, arc chutes and/or insulation. Do not open sealed devices. Replace any sealed units that are suspected of sustaining damage. Consult the manufacturer for recommendations.

Check for arcing paths or strike points to ground and from phase-to-phase. Eliminate sources of arcing and clean carbon deposits on insulating surfaces in accordance with manufacturer recommendations.

Inspect the panelboard for physical damage to structural components, bussing, and conductors. Check for mechanical distortion, thermal damage, metal deposits, or products of combustion. Consult the

manufacturer for recommendations.

Examine all devices and bus supports for cracks or breakage. Consult the manufacturer for recommendations.

Perform electrical testing as specified in Section 6.3, including primary current injection testing of circuit breakers. Compare insulation resistance test results with previous test results and with the original factory test data corrected for temperature variations using the manufacturer recommended multipliers. Correct deficiencies or replace components in accordance with manufacturer recommendations.

Re-energize the panelboard in accordance with Section 8.12.

9.2 Panelboards Soaked By or Submersed Under Water

Panelboards or components of panelboards that are subject to exposure to water should be evaluated using the guidelines outlined in NEMA GD 1-2019, Evaluating Water-Damaged Electrical Equipment, and the UL publication, "Considerations for Flood Immersed Products." Consult the manufacturer and the local inspection authority before cleaning up panelboards or components. Panelboards that are modified in the field may require evaluation by a qualified safety certification organization to validate that the equipment continues to meet the requirements of the applicable product safety standard. Refer to NEMA PB 1.1. 2013 for maintenance or contact panelboard manufacturer for maintenance guidance.

De-energize and lockout panelboards in accordance with Section 3.

Clean and dry all parts of the panelboard carefully using clean, dry cloths. Dry panelboards using external heaters. Do not exceed 82ºC (180ºF) when drying panelboards using heaters.

Inspect individual devices for the possible entrance of water, dirt or foreign matter.

Do not open sealed devices. Replace all sealed accessories and components suspected of contamination. Remove and replace all fuses. Remove and replace all water-damaged circuit breakers.

Perform insulation-resistance testing of the panelboard. See Section 10.1.

If insulation resistance measurements are below 100 megohms but above 1 megohm, operate the panelboard at lower than rated voltage for a short time, if possible, to improve the insulation resistance values to acceptable levels. Consult the manufacturer for recommendations.

Re-energize the panelboard in accordance with Section 8.12.

10. Testing Procedures

10.1 Insulation Resistance Testing

Perform insulation resistance testing of panelboards, circuit breakers and switches using a megohmmeter with 1000VDC test voltage setting. Disconnect all accessories and electronic devices that may be subjected to the test voltage. Perform insulation resistance testing of control circuit wiring to ground using the 500VDC test voltage setting for conductors rated 300V, and the 1000VDC test voltage setting

for conductors rated 600V. Follow manufacturer recommendations when testing solid-state components.

Test panelboards from phase-to-ground and from phase-to-phase with all switches and circuit breakers in both the open and closed positions, with all instrumentation and control fuses removed, and with no loads connected to the panelboard. Measure the insulation resistance across each open pole of circuit breakers and switches.

Ground all phases not being tested. Measure and record insulation resistance at one minute following the application of the test voltage. Ground each phase at the completion of the test for a minimum of one minute.

Record the megohm values of each phase and between each phase, along with the description of the instrument, voltage level, humidity, temperature, time, and date of the test.

Consult panelboard manufacturer published data for acceptable test results. If published data is not available, investigate any values which deviate from previous test results under similar conditions by more than 50 percent of the lowest value. Investigate any results less than 1 megohm with the overcurrent protective devices in the open position for possible tracking on insulation or insulation breakdown.

10.2 Ground Resistance Testing

For a Fall-of-Potential test, measure the ground resistance of the main grounding electrode or system. The resistance between the main grounding electrode and ground should be no greater than five ohms. Notify the project manager and engineer of record of any deficiencies in writing immediately.

For a Point-by-Point test, measure the ground resistance between the grounding system and panelboard frames, cabinets, and neutrals. Investigate resistance values that exceed 0.5 ohms.

Test panelboards equipped with ground-fault protection for proper operation in accordance with manufacturer instructions.

10.3 Primary Current Injection Testing of Circuit Breakers (Optional)

Primary current injection testing is recommended for circuit breakers rated 100 amperes and higher. Primary current injection testing is performed with specialized equipment to inject sufficiently high magnitudes of current into the terminals of the circuit breaker to cause its operation. Only qualified persons should perform primary current injection testing. Follow test equipment and panelboard manufacturer instructions for primary current injection testing.

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

Determine the short-time pickup and delay.

Determine the ground-fault pickup and time delay.

Determine the instantaneous pickup current using the run-up or pulse method. Instantaneous pickup values of molded-case circuit breakers should be within manufacturer published tolerances.

The trip characteristic of breakers should fall within the manufacturer published time-current characteristic tolerance band, including adjustment factors. Replace circuit breakers exceeding the specified trip time at 300 percent of pickup.

Verify the correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and anti-pump functions.

10.4 Infrared Scan

Provide supplemental barriers and safety precautions during infrared scan to prevent accidental contact with exposed energized components. Follow the safety procedures in Section 3.

Perform infrared scan in accordance with the panelboard and test equipment manufacturer instructions.

De-energize the panelboard. Remove accessible covers, doors, and panels.

Energize the panelboard and turn on all normal loads supplied by the panelboard.

Perform the infrared scan of all panelboard electrical connections and terminals while the panelboard is energized and operating under maximum load conditions.

Use an infrared scan device designed to measure actual operating temperatures, or designed to detect significant deviations from surrounding conditions. Provide documentation of the device calibration.

Prepare a report identifying the panelboard tested and describing the results of the infrared scan. Include notations of the deficiencies detected, remedial actions taken, and results from retesting after remedial actions. Maintain a permanent record of all infrared scan results to track electrical characteristics of panelboards over time.

Consult the panelboard manufacturer for recommendations for repair or replacement if infrared scan results indicate overheating of components.

De-energize the panelboard. Observe the safety procedures in Section 3. Test the panelboard to confirm that it is de-energized. Install all accessible covers, panels, and doors. Re-energize the panelboard and loads in accordance with Section 8.12.

(This Annex is not part of the Standard)

11. Annex A: Reference Standards

This publication, when used in conjunction with the National Electrical Code and panelboard manufacturer literature, provides sufficient information to install and maintain panelboards operating at 600 Volts or less. The following publications may also provide useful information:

National Electrical Manufacturers Association
1300 North Seventeenth Street, Suite 1847
Rosslyn, VA 22209
(703) 841-3200
(703) 841-3300 Fax
www.nema.org

NEMA PB 1-2011, *Panelboards*

NEMA PB 1.1-2013, General Instructions for Proper Handling, Installation, Operation, and Maintenance of Panelboards Rated 600 Volts or Less

NEMA GD 1-2019, Evaluating Water Damaged Electrical Equipment

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9101
(617) 770-3000
(617) 770-3500 Fax
www.nfpa.org

NFPA 70-2023, *National Electrical Code* (ANSI)

NFPA 70B-2023, *Electrical Equipment Maintenance* (ANSI)

InterNational Electrical Testing Association
106 Stone Street
P. O. Box 678
Morrison, CO 80465
(303) 697-8441 tel
(303) 697-8341 fax
www.netaworld.org

NETA ATS-2021, *Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*

NETA MTS-2023, *Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*

National Electrical Contractors Association
NECA Standards & Safety
National Electrical Contractors Association
1201 Pennsylvania Ave. NW, Suite 1200
Washington, D.C. 20004
(301) 215-4504
(301) 215-4500 Fax
orderdesk@necanet.org
www.neca-neis.org

Current *National Electrical Installation Standards*™ Published by NECA