

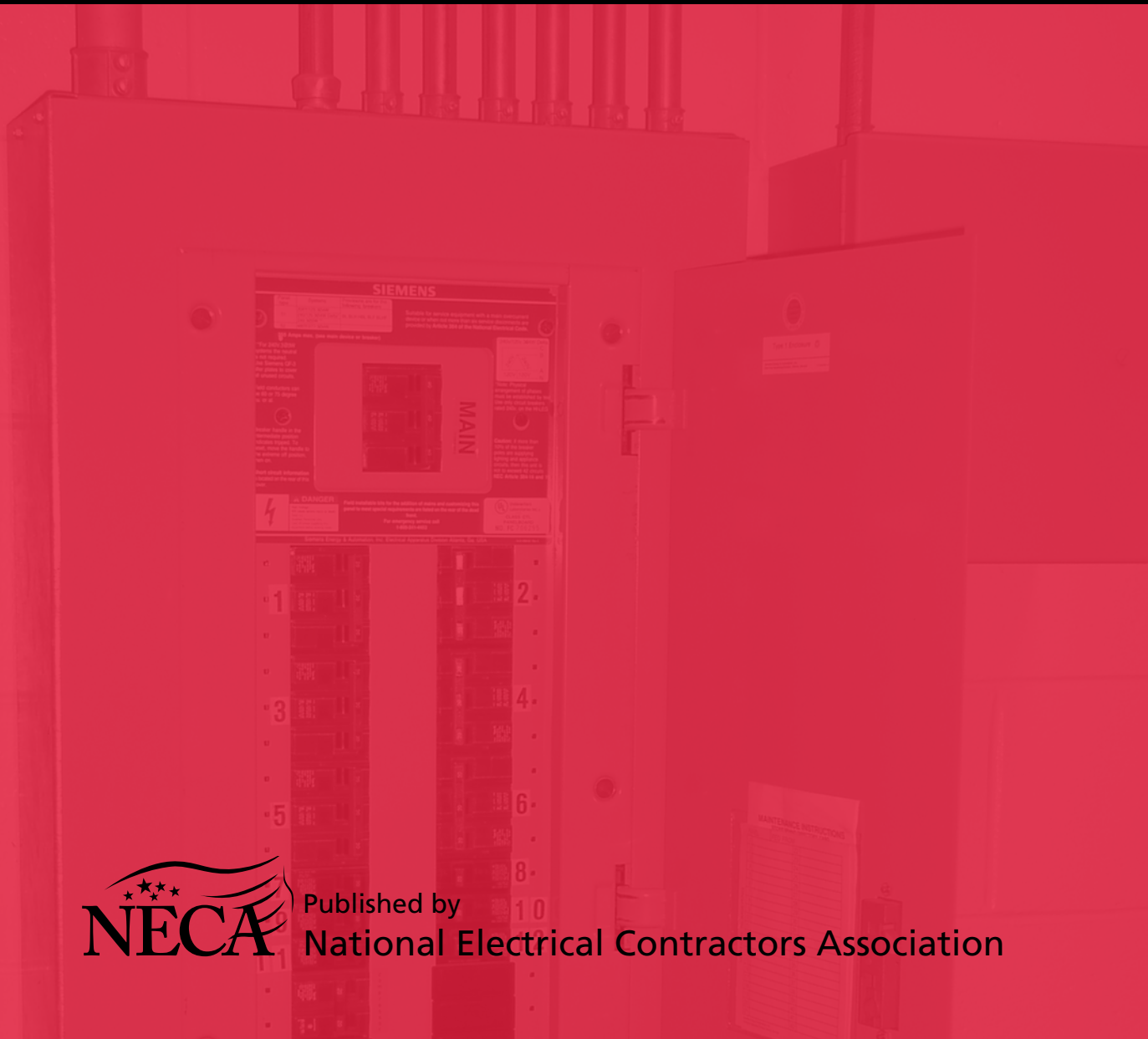


NECA 407-2009

Standard for

Installing and Maintaining Panelboards

AN AMERICAN NATIONAL STANDARD



Published by
National Electrical Contractors Association

An American National Standard

NECA 407–2009

Standard for

**Installing and Maintaining
Panelboards**



*National
Electrical
Installation
Standards™*

Published by
**National Electrical
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National Electrical Installation Standards™

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(This foreword is not a part of the standard)

Foreword

National Electrical Installation Standards™ 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 407-2009, *Standard for Installing and Maintaining Panelboards* (ANSI).

Use of *NEIS* is voluntary, and the National Electrical Contractors Association 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) in effect at the time of publication. 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 when installing electrical products and systems. Users should also comply with OSHA occupational safety regulations as well as follow manufacturer's 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 after adverse operating conditions such as a short-circuit, ground-fault, or immersion in water.

This standard applies to panelboards rated 600 Volts AC or less, with main disconnects or lugs rated 1600 Amperes or less, and with feeder or branch circuit overcurrent devices rated 1200 Amperes or less.

This publication applies to single panelboards, multi-section panelboards, and load centers used for distributing power for commercial, institutional, and industrial loads in nonhazardous locations both indoors and outdoors.

1.2 Products and Applications Excluded

This publication does not apply to live-front panelboards, panelboards employing cast enclosures for hazardous or special service conditions, or panelboards designed primarily for residential or light commercial service equipment.

1.3 Regulatory and Other Requirements

All information in this publication is intended to conform to the National Electrical Code (ANSI/NFPA Standard 70). Installers should always follow the NEC, applicable state and local codes, and manufacturer's installation instructions when installing and maintaining panelboards. Install panelboards within the limits of all applicable electrical ratings including voltage, amperage, and short-circuit current ratings.

Only qualified persons familiar with the construction and operation of panelboards should perform the installations described in this publication. The term “qualified person” is defined in Article 100 of the NEC. Administrative functions receiving, handling and storing, required in Section 4 and other tasks can be performed under the supervision of a qualified person.

Other *National Electrical Installation Standards* provide additional guidance for installing particular types of electrical products and systems. A complete list of *NEIS* is provided in Annex A.

2. Definitions

- 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** A single panel or group of panel units designed for assembly in the form of a single panel; including buses, connectors, terminals, and/or lugs, automatic overcurrent devices such as circuit breakers, fuses, or both, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet, cutout box, or enclosure placed in or against a wall or partition and accessible only from the front.
- 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.

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* and applicable OSHA regulations.

The process of de-energizing and verification is considered “live” work and can result in an arc flash hazard. 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

- a) For electrical equipment to work properly, it must be handled carefully and installed, operated, and maintained correctly. Neglecting fundamental installation and maintenance requirements may lead to personal injury or death, and damage to conductors, electrical equipment, and other property.
- b) 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.
- c) Do not work on energized conductors or equipment. Electrically isolate conductors and equipment in accordance with established procedures and manufacturer’s instructions and recommendations.
- d) Use care in opening and closing doors to energized equipment. Conductors and terminations may be exposed and within the reach of openings.

- e) Do not enter equipment enclosures when components are energized. Do not remove access covers, doors, panels, etc., 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

- a) Perform preliminary inspections and tests prior to beginning work to determine existing conditions. Check existing conditions against available record documents.
- b) 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.
- c) Resolve discrepancies between installed conditions and electrical drawings. Have drawings corrected, if required. Provide warning labels on equipment, cables, etc., where necessary to indicate unexpected and potentially hazardous conditions.
- d) 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.
- e) 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.

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

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

3.3 Personal Protective Equipment (PPE)

a) 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.

b) Wear appropriate PPE in accordance with the incident energy levels of the equipment.

c) Wear 100 percent natural fiber clothing or flame resistant apparel. Do not wear conductive articles such as watches, rings, etc.

d) Personal Protective Equipment (PPE) must be in accordance with NFPA 70E 130.7 (C) and (D), task hazard analysis.

3.4 De-Energizing Electrical Equipment

a) Follow all manufacturer's 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.

b) 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 blades of disconnecting means are fully open and that draw-out-type circuit breakers are fully withdrawn.

c) Test conductors and equipment at both sources 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.

d) 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. Remove locks and tags only after work is complete and tested, and all personnel are clear of the area. 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 the equipment.

e) 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 stored electric energy and induced voltage such as capacitors and conductors in close proximity to energized parts..

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

4. Receiving, Inspecting, Handling and Storage

4.1 Receiving

- a) Unload panelboards and components carefully, observing all packing label warnings and preventing damage to materials and components, or the loss of loose parts.
- b) 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.
- c) Verify that panelboards and accessories received conform with the manufacturer's quotation and shop drawings and/or approved submittals. If they do not, notify the manufacturer immediately in writing.

4.2 Inspection

- a) Unpack panelboards and components sufficiently to inspect for concealed damage resulting from shipping and handling.
- b) Inspect panelboards and components for damage or displacement of parts, for loose, cracked, broken, or chipped components, for damage to circuit breakers or switches, for dirt or foreign material, and for presence of water or moisture. Check "tip" or "shock" indicators, if provided.
- c) 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 the panelboard have been taken.
- d) Repair or replace damaged components in accordance with manufacturer instructions.

- e) 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

- a) Handle panelboards and accessories in accordance with manufacturer recommendations and instructions.
- b) Handle panelboards and accessories carefully to avoid damage to the cabinet, front cover, panelboard, frame, and components. Avoid subjecting panelboards to impact, jolting, jarring, rough handling, etc.

4.4 Storage

- a) 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.
- b) In locations with high humidity, remove panelboards from packing materials to permit adequate ventilation and to avoid mildew.
- c) Store panelboards in a clean, dry, heated building having a uniform temperature and adequate air circulation to prevent condensation.
- d) 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.

e) 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 power-source connections to prevent inadvertent energizing of the auxiliary transformer and associated primary wiring.

f) If panelboards are stored for extended periods of time, inspect the panelboard and spot check insulation resistance prior to installation (see 10.1). If any readings are low, dry out, clean, and/or replace components as necessary before placing panelboards into operation. Consult the manufacturer for recommendations.

5. Installation

5.1 General

- a) Install panelboards in accordance with manufacturer installation instructions and recommendations, specific panelboard ratings.
- b) Review manufacturer supplied shop drawings, arrangement drawings (front, end, and plan view), connection diagrams, approved submittals, and equipment schedules before installation.
- c) Ensure that panelboard short circuit current ratings and circuit breaker interrupting ratings exceed the available fault current from the system. Verify that series-rated panelboards meet the manufacturer's listing for series-rating.
- d) Verify that overcurrent devices in panelboards supplying emergency circuits or legally required standby circuits meet the applicable requirements for selective coordination.
- d) Coordinate panelboard locations to ensure that the NEC required minimum working space clearances are maintained. Ensure that the working space permits at least a 90-degree opening of equipment doors or hinged panels. Provide sufficient access to permit removing doors, covers, and panels for routine inspection, maintenance, and testing.

5.2 Environmental Considerations

- a) Verify that panelboards and enclosures are labeled as suitable for the location intended. Generally, locate panelboards away from sources of water.
- b) Do not locate panelboards where exposed to ambient temperatures above 40°C (104°F), corrosive or explosive fumes, dust, vapors, dripping or standing water, abnormal vibration, mechanical shock,

high humidity, or unusual operating conditions, unless the panelboard is designed and identified by the manufacturer for such conditions.

- c) Do not install panelboards in locations where the conditions would damage the equipment.

5.3 Installation of Cabinets

- a) Locate cabinets so that they are readily accessible and not exposed to physical damage.
- b) Install cabinets level and plumb. Mount the cabinet securely to the mounting surface using manufacturer recommended methods, supports, and fasteners.
- c) Provide suitable guards or temporary covers on the cabinet after installation and prior to the permanent panelboard cover being installed to protect the cabinet from foreign substances such as paint, plaster, and acoustic spray.
- d) 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.
- e) Installation height of highest overcurrent device intended for installation in the cabinet does not exceed 2.0 m (6 ft 7 in.).

5.3.1 Panelboard Clearances

- a) Flush-Mounted Panelboards. Install cabinets with the front edge set back not more than 1/4 inch (6 mm) 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.

- b) Allow a minimum of 3 feet (1 m) clearance between the ceiling and the cabinet unless an adequate fireproof shield, such as a fireproof ceiling, is provided.
- c) Secure surface-mounted panelboard cabinets located outdoors so that there is at least 1/4 inch (6 mm) of air space between the cabinet and the wall or other supporting surface. Keep in mind that mounting standoffs are typically stamped into the cabinet.

5.3.2 Supporting Panelboards

- a) Provide temporary cabinet supports for anchoring flush-mounted panelboards during wall construction.
- b) Supply structural floor supports to support the panelboard if required due to the wall construction or the panelboard weight and design.
- c) Support cabinets independently of raceways.
- d) Provide seismic restraints where required by the building code, the approved plans, or the project specifications.

5.3.3 Multi-Section Panelboards

- a) Ensure that all sections of multi-section panelboards have identical main bus and terminal ratings unless separate main overcurrent devices are provided.
- b) Ensure that feeder conductors between sections are properly sized.
- c) Ensure adequate gutter space is available for wiring between sections.

5.4 Installation of Raceways and Cables

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

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

- c) Install raceways in a manner that will prevent water that is accumulating in the raceways from entering and accumulating in the cabinet.

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

- e) Use proper, listed fittings to attach cables and raceways to the cabinet.

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

5.5 Installation of Panelboards

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

- b) Verify that the cabinet is listed for the installation of the specific panelboard.

- c) Protect panelboard parts from contamination during installation.

- d) 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.

- e) Install the panelboard. Align and tighten the panelboard in the cabinet per manufacturer instructions.

- f) Adjust the panelboard so that the dead-front shield flange is 3/16 inch (5mm) or less from the

front of surface-mounted cabinets, or from the surrounding wall surfaces for flush-mounted cabinets.

- g) Install fuses after all conductors are installed and terminated.
- h) Verify the maximum height of overcurrent device in the panelboard does not exceed 2.0 m (6 ft, 7 in.) above the floor or working platform.
- i) Where required, verify that arc-flash warning labels in accordance with the NEC are applied.

5.5.1 *Circuit Breakers and Fuses*

- a) Ensure that circuit breakers and/or fuses are of the proper type, voltage class, and rating.
- b) Ensure that circuit breakers and/or fuses conform to the engineering coordination study provided by the owner, if required.
- c) Ensure that the circuit breakers and/or fuses conform to the listed series ratings for the panelboard, if required.
- d) Ensure that each circuit breaker and/or fuse voltage rating is appropriate for the voltage and configuration of the system.
- e) 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 circuit breaker arrangement.
- f) Remove the drain screws from cabinets for NEMA 3R rating, if provided.
- g) 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's instructions.
- h) Ensure that fuse blocks are positioned correctly for the type of fuse intended to be inserted.

5.6 **Installation of Conductors**

Perform insulation resistance testing of panelboards prior to terminating conductors (see 10.1).

- a) Install conductors for panelboards equipped with ground-fault protection in accordance with manufacturer recommendations.
- b) 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, harmonic load currents, etc.
- c) Ensure that all conductors installed in parallel are the same length, insulation type, material type, and wire size, and that all conductors are terminated in the same manner for each individual phase.
- d) Distribute and arrange the conductors in the cabinet wiring gutters. Train conductors neatly in groups, bundle, and wrap with wire ties after balancing the loads (See 6.6). Keep in mind that bundling conductors may impact conductor ratings. Identify and group multi-wire branch circuits with the specific grounded conductor associated with the multi-wire branch circuit.
- e) Provide sufficient conductor lengths to reach the terminals and to avoid placing strain on the terminals. Maintain the largest practical bending radius of conductors.
- f) 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 supports, or as specified by the panelboard manufacturer, and insert immediately into the terminal.
- g) 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.

h) Check all bolts and terminals for tightness using a calibrated torque wrench or screwdriver. Refer to manufacturer's instructions and markings for proper torque values. 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.

5.6.1 *Four-Wire, Delta-Connected Systems*

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

b) 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 identified phase is connected to the conductor with higher voltage to ground.

c) 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.

d) 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.

e) Provide instruction and warning labels identifying phasing and voltages on the panelboard. Legibly and permanently field mark the panelboard with: "Caution: _____ Phase Has _____ Volts to Ground."

f) Ensure that overcurrent devices installed in the high leg have the appropriate phases-to-phase and phase-to-ground voltage ratings.

5.7 **Grounding and Bonding**

a) Tighten grounding connectors and terminals, including screws and bolts, using a calibrated torque wrench or screwdriver. Refer to manufacturer's instructions and markings for proper torque values. 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.

b) Verify that neutral connections and busbars are insulated and isolated from the equipment grounding conductor, the panelboard, the cabinet, and any isolated grounding conductors in other than service equipment applications. Ensure that isolated grounding conductors remain insulated and isolated and are installed in compliance with the provisions in Articles 408 and 250 of the NEC. Install supplemental neutral terminal bars in accordance with the panelboard manufacturer recommendations as required to accommodate the number of conductors for termination.

c) 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.

d) Terminate all grounding and bonding conductors on a common equipment grounding terminal on the cabinet. Bond all metallic cabinets and frames. 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, enclosures, etc.

5.7.1 *Service Entrance Panelboards*

a) Bond all non-current carrying metallic parts of service equipment in accordance with applicable codes and manufacturer recommendations.

b) Install a main bonding jumper per NEC requirements and manufacturer installation instructions.

- c) Install grounding electrode conductors from all grounding electrodes present to the grounding terminal of the service panel, per NEC requirements (Part III of Article 250).
- g) Protect the panelboard from on-going construction activities until the panelboard is cleaned, tested, and commissioned in accordance with Section 6.

5.8 Accessories

- a) Install any field-installed panelboard accessories and components in accordance with manufacturer's instructions.
- b) Connect all conductors for control, metering, and monitoring functions specific to the panelboard installation.
- c) Check all installed panelboard accessories such as shunt trips, alarms, signals, contactors, time clocks, etc., for proper operation and voltage.

5.9 Panelboard Pre-Checks

- a) Clean the cabinet of all debris which has accumulated during the panelboard installation.
- b) Check the tightness of all bolts and electrical connections using calibrated torque wrench or screwdriver. Refer to manufacturer's instructions and markings for proper torque values. 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.
- c) Ensure that all blocking and packing materials have been removed from the cabinet.
- d) Exercise switches, circuit breakers, and other operating mechanisms to ensure free operation.
- e) Set adjustable time current trip devices to the settings specified in the engineering coordination study supplied by the owner, if required.
- f) Ensure that all dead-front shields and panelboard barriers are properly aligned and tightened.

6. Cleaning, Testing, and Commissioning

6.1 Cleaning

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

- a) Remove trash, combustible material, and other debris from areas around panelboard.
- b) Remove all debris from the cabinet. Remove all scraps of wire, plaster, dust, and other foreign material. Vacuum the cabinet clean. Remove paint splatters and other spots, dirt, and debris. Touch up scratches to match original finish.
- c) Wipe down the panelboard and cabinet with clean, dry, lint-free cloth.

6.2 Inspections

- a) Compare the equipment nameplate with approved drawings and contract documents.
- b) Verify that fuse and/or circuit breaker sizes and types correspond to approved drawings and the coordination study provided by the owner, if applicable, as well as to the circuit breaker's address for micro-processor-communication packages.
- c) Check all bolts, connections, and terminations for tightness using a calibrated torque wrench or screwdriver. Refer to the manufacturer's instructions and markings for proper torque values. 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.

d) 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.

e) Visually check the panelboard, cover, cabinet, conduits, raceways, 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.

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

g) 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.

h) Confirm that the panelboard is properly labeled, including voltage, interrupting ratings, and system configuration, as applicable.

6.2.1 Switches

a) 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.

b) 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.

- c) Verify proper labeling.

6.2.2 Circuit Breakers

- a) Operate circuit breakers to ensure smooth operation.

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

- c) Verify correct ratings. Adjust settings of circuit breakers in accordance with the coordination study supplied by owner, if applicable.

- d) Ensure that overcurrent devices for multi-wire branch circuits provide a means for simultaneous interruption of all ungrounded conductors of the branch circuit by either identified handle ties or use of multi-pole (common-trip) circuit breakers.

6.3 Acceptance Testing

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

- a) Test panelboards in accordance with manufacturer recommendations and maintain test results for future comparisons.

- b) Perform insulation resistance testing (see 10.1).

- c) Perform ground resistance testing (see 10.2)

- d) Perform circuit breaker testing as required by the NEC or specifying engineer. (see 10.3)

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

- f) Correct deficiencies identified by inspections and tests, and retest panelboards.

- g) Provide written reports of tests and observations. Record the defective materials and unsatisfactory test results. Include details of repairs, replacements, and adjustments made. Provide copies of reports to the general contractor, project manager, and engineer of record.

6.4 Installation of the Front Cover

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

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

- c) 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 original finish. Apply suitable paint or other corrosion-resistant finish 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 and property damage can occur when the equipment is energized.

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

- b) Ensure that all personal protective grounds are removed, and the front access cover is installed and tightened prior to energizing panelboards.
- c) Ensure that there is no load on the panelboard and that all load isolation devices are open and locked or tagged.
- d) Energize the panelboard. Measure the phase-to-phase and phase-to-neutral voltages.

6.5.1 Energize equipment supplied from the panelboard

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. Close main, feeder, and branch circuit devices in sequence.

- a) Energize lighting circuits, contactors, motors, and heaters after all overcurrent devices have been closed.
- b) Inspect the panelboard 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.
- c) Measure phase-to-phase, phase-to-neutral, phase-to-ground and neutral-to-ground voltages after loading panelboard to ensure proper operation and to verify proper neutral-to-ground bonding.
- d) Inspect all indicating and control devices for correct operation.
- e) Perform an infrared scan as may be required to verify equipment heating conditions are within normal operating temperatures (see 10.4).

6.6 Balancing Loads

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

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

c) 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 facsimile machines, on-line data processing, and computing, transmitting, and receiving equipment.

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

e) Provide a typed panelboard circuit directory. Clearly identify the specific purpose of every circuit. Identify spare or unused overcurrent devices. Revise the directory to reflect circuit changes required to balance loads. Submit a record of all load measurements and circuit changes made.

f) Perform a final infrared scan of each panelboard after balancing the loads (see 6.5.1 e and 10.4).

7. Closeout

7.1 Test Data and Manuals

- a) Update contract documents with the final system configuration and parameters.
- b) Submit test results and data from all factory and field testing of panelboards including a record of any actions taken to correct deficiencies.
- c) Deliver as-built documents, test data, and panelboard manufacturer's standard installation, operation, and maintenance manuals to the owner or general contractor in accordance with contract documents.
- d) In the absence of contractual requirements, deliver a minimum of one set of all documents to the owner or general contractor.

7.2 Training

Provide training for the owner's maintenance personnel, if required by contract documents. Discuss routine maintenance, operating procedures, cleaning,

etc., using the manufacturer's 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

- a) Deliver spare parts and special tools to the owner or general contractor in accordance with contract documents.
- b) In the absence of contractual requirements, deliver the panelboard manufacturer's minimum recommended spare parts and special tools.
- c) 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, so that no accidental contact can be made with energized parts. Follow the safety procedures in Section 3. Follow all manufacturer's warnings and instructions.

8.1 Frequency of Inspections and Maintenance

- a) Make visual observations and record panelboard operational data periodically with panelboards energized and in service.
- b) Perform cleaning, inspections, testing, and maintenance of panelboards at least annually, but as often as the operating environment requires to keep panelboards clean.
- c) 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

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

- b) Update testing and maintenance records to reflect the dates of inspections, testing, and maintenance, along with a summary of the work performed.
- c) Review testing and maintenance records annually to identify performance trends and changes in electrical characteristics over time.

8.3 Routine Inspections

- a) Inspect areas and spaces around panelboards for any accumulation of dirt or dust. Remove any accumulations of dirt or dust. Remove trash, combustible material, and other debris from areas around panelboards.
- b) Use the rate of accumulation of dust and dirt on visible surfaces as a guide for scheduling cleaning, inspections, maintenance, and testing.
- c) Check all accessible exterior panelboard and cabinet hardware for tightness.
- d) Measure and record the ambient temperature around panelboards.
- e) 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 the manufacturer's recommendations, de-energize the panelboard and investigate the source of overheating.
- f) Measure and record panelboard voltage and load currents, if possible, noting the date and time of day. Provide comments regarding known variations in

loading, such as load additions or equipment maintenance outages.

g) 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.

h) 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.

i) 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.

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

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

c) 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.

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

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

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

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

8.5 Infrared Scan

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

b) De-energize the panelboard in accordance with Section 3.

8.6 Inspections

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

b) Check the panelboard circuit directory for accuracy.

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

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

e) 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.

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

g) 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.

h) 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.

i) Verify that fuse and/or circuit breaker sizes and types correspond to record drawings and coordination study supplied by the owner, if available, as well as to the circuit breaker's address for microprocessor communication packages, if equipped. Record settings of adjustable circuit breakers and compare with engineering coordination study supplied by owner, if available. Notify the owner of discrepancies between actual circuit breaker settings and the coordination study.

j) 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

a) Inspect all terminations, connections, and lugs for tightness using a calibrated torque wrench or screwdriver. Refer to manufacturer's instructions and markings for proper torque values. Be careful not to overtighten or strip threads. 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.

b) 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.

c) Follow manufacturer recommendations for cleaning, repairing, and replacing damaged parts. 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 discoloration of parts.

d) Replace overheated connections. Tighten connections to proper torque levels using a calibrated torque wrench or screwdriver after replacement. Refer to manufacturer's instructions and markings for proper torque values.

8.8 Conductors and Raceways

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

b) Ensure that conductors are protected within their ampacity.

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

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

e) Inspect for frayed or broken wires. Replace or repair conductors as necessary.

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

g) Inspect conduits for moisture. Seal conduits which are a source of moisture and provide means to drain moisture away from the panelboard.

8.9 Switches

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

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

c) Inspect contact surfaces, blades, and jaws for discoloration, overheating, pitting, arcing, and corona. Clean and dress readily accessible copper electrical contacts, blades, and jaws in accordance with manufacturer recommendations. Many contact surfaces, such as arcing contacts, are silver tungsten or other types of materials that must never be dressed. When contacts 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.

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

e) Lubricate operating mechanism and sliding contact surfaces, if required, according to manufacturers 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.

f) 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's replacement parts.

g) 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's 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

a) Check all fuses to assure 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.

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

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

d) 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.

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

f) Verify that fuse blocks are positioned correctly to accept the type of fuse intended to be inserted.

8.10 Circuit Breakers

a) 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.

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

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

- d) 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 function.
- e) Inspect interchangeable trip-unit circuit breakers for tightness of the trip units.
- f) Check circuit breaker terminals and connections for tightness using calibrated torque wrench or screwdriver. Refer to manufacturer's instructions and markings for proper torque values. 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

- a) Energize panelboards in accordance with Section 6.5.
- b) Measure phase-to-phase and phase-to-neutral voltages. Investigate source of voltage unbalance greater than 3 percent.
- c) Measure panelboard feeder and branch load currents. Ensure that conductors are properly sized and protected for actual loading. Balance loads as necessary in accordance with Section 6.6.
- d) Perform a final infrared scan (see 10.4).

9. Inspection and Re-Energization After Adverse Operating Conditions

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

Consult the manufacturer for recommendations before performing any testing or maintenance following short-circuit or ground-fault.

- a) Identify and remove the cause of short-circuit or ground-fault.
- b) Clean, inspect, test, and maintain the panelboard in accordance with Section 8.
- c) Inspect the overcurrent protective device(s) 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.
- d) Check for arcing paths or strike points to ground and from phase-to-phase. Eliminate sources of arcing and clean carbon paths on insulating surfaces in accordance with manufacturer recommendations.
- e) Inspect the panelboard for physical damage in structural components, bussing, and conductors. Check for mechanical distortion, thermal damage, metal deposits, or products of combustion.
- f) Examine all devices and bus supports for cracks or breakage.
- g) 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's recommended multipliers.

Factory test results typically exceed 100 megohms. Correct deficiencies or replace components in accordance with manufacturer recommendations.

- h) Re-energize the panelboard in accordance with Section 8.12.

9.2 Panelboard Soaked By or Submersed Under Water

Consult the manufacturer and the local inspection authority before cleaning up or restoring water damaged panelboards or components.

- a) De-energize and lockout panelboard in accordance Section 3.
- b) Clean and dry all parts of the panelboard carefully using clean, dry cloths. Dry the panelboards using external heaters. Do not exceed 180oF (82oC) when drying panelboards using heaters.
- c) Inspect individual devices for the possible entrance of water, dirt or foreign matter.
- d) 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.
- e) Perform insulation-resistance testing of the panelboard (see 10.1).
- f) 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.

g) Re-energize the panelboard in accordance with Section 8.12.

9.3 Inspecting and Re-energizing Panelboard Sprayed or Splashed with Clean Water

Consult the manufacturer for proper procedures for specific panelboard components. In the absence of manufacturer recommendations, follow the procedure described in Section 9.2.

10. Testing Procedures

10.1 Insulation Resistance Testing

- a) Perform insulation resistance testing of panelboards, circuit breakers and switches using a 1000 V DC megohmmeter. 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 a 500 V DC megohmmeter for conductors rated 300 V, and a 1000 V DC megohmmeter for conductors rated 600 V. Follow manufacturer recommendations when testing solid-state components.
- b) 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.
- c) Ground all phases not being tested. Measure 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.
- d) 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.
- e) Consult panelboard manufacturer's 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

- 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.
- b) *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.
- c) Test panelboards equipped with ground-fault protection for proper operation in accordance with manufacturer recommendations.

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. Primary current injection testing should only be performed by qualified personnel. Follow test equipment and panelboard manufacturer's recommendations and instructions for primary current injection testing.

- a) 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.

- b) Determine the short-time pickup and delay.
- c) Determine the ground-fault pickup and time delay.
- d) Determine the instantaneous pickup current using run-up or pulse method. Instantaneous pickup values of molded-case circuit breakers should be within manufacturer's published tolerances.
- e) The trip characteristic of breakers should fall within the manufacturer's published time-current characteristic tolerance band, including adjustment factors. Replace circuit breakers exceeding the specified trip time at 300 percent of pickup.
- f) 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.
- f) Prepare a certified report identifying the panelboard tested and describing the results of the infrared scan. Include notations of the deficiencies detected, remedial action taken, and results from retesting after remedial action. Maintain a permanent record of all infrared scan results to track electrical characteristics of panelboards over time.
- g) Consult the panelboard manufacturer for repair or replacement recommendations if infrared scan results indicate overheating of components.
- h) 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, doors, etc. Re-energize the panelboard and loads in accordance with Section 8.12.

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.

- a) Perform the infrared scan in accordance with the panelboard and test equipment manufacturer recommendations.
- b) De-energize the panelboard. Remove accessible covers, doors, etc.
- c) Energize the panelboard and turn on all normal loads supplied by the panelboard.
- d) Perform the infrared scan of all panelboard electrical connections and terminals while the panelboard is energized and operating under maximum load conditions.
- e) Use an infrared scanning device designed to measure actual operating temperatures, or designed to detect significant deviations from surrounding conditions. Provide documentation of the device calibration.

(This annex is not part of the standard)

Annex A: Reference Standards

This publication, when used in conjunction with the National Electrical Code and panelboard manufacturers' 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 tel
(703) 841-3300 fax
www.nema.org

NEMA PB 1-2006, *Panelboards*

NEMA PB 1.1-2007, *General Instructions for Proper Handling, Installation, Operation, and Maintenance of Panelboards Rated 600 Volts or Less* (ANSI)

NEMA Guidelines for Handling Water Damaged Electrical Equipment

National Fire Protection Association
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
(617) 770-3000 tel
(617) 770-3500 fax
www.nfpa.org

NFPA 70-2008, *National Electrical Code* (ANSI)

NFPA 70B-2006, *Electrical Equipment Maintenance* (ANSI)

InterNational Electrical Testing Association
106 Stone Street
P.O. Box 678
Morrison, CO 80465
(303) 697-8441 tel
(303) 697-8431 fax
www.netaworld.org

NETA ATS-2007, *Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*

NETA MTS-2005, *Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*

Underwriters Laboratories Inc.
333 Pfingston Rd.
Northbrook, IL 60062-2096
Phone: (877)-854-3577
Fax: 847-407-1395

ANSI/UL 67 Panelboards

National Electrical Contractors Association
3 Bethesda Metro Center, Suite 1100
Bethesda, MD 20814
301-215-4504
301-215-4500 fax
www.neca-neis.org

Current *National Electrical Installation Standards*™ published by NECA:

NECA 1-2006, *Standard for Good Workmanship in Electrical Construction* (ANSI)

NECA 90-2004, *Recommended Practice for Commissioning Building Electrical Systems* (ANSI)

NECA 100-2006, *Symbols for Electrical Construction Drawings* (ANSI)

NECA 101-2006, *Standard for Installing Steel Conduits (Rigid, IMC, EMT)* (ANSI)

NECA 102-2004, *Standard for Installing Aluminum Rigid Metal Conduit* (ANSI)

NECA/AA 104-2006, *Recommended Practice for Installing Aluminum Building Wire and Cable* (ANSI)

NECA/NEMA 105-2007, *Recommended Practice for Installing Metal Cable Tray Systems* (ANSI)

NECA 111-2003, *Standard for Installing Nonmetallic Raceways (RNC, ENT, LFNC)* (ANSI)

NECA/NACMA 120-2006, *Standard for Installing Armored Cable (AC) and Metal-Clad Cable (MC)* (ANSI)

NECA 200-2008, *Recommended Practice for Installing and Maintaining Temporary Electric Power at Construction Sites* (ANSI)

NECA 202-2006, *Standard for Installing and Maintaining Industrial Heat Tracing Systems* (ANSI)

NECA 230-2003, *Standard for Selecting, Installing, and Maintaining Electric Motors and Motor Controllers* (ANSI)

NECA/FOA 301-2004, *Standard for Installing and Testing Fiber Optic Cables* (ANSI)

NECA 303-2005, *Standard for Installing Closed-Circuit Television (CCTV) Systems* (ANSI)

NECA 305-2001, *Standard for Fire Alarm System Job Practices* (ANSI)

NECA 331-2004, *Standard for Building and Service Entrance Grounding and Bonding*

- NECA 400-2007, *Standard for Installing and Maintaining Switchboards* (ANSI)
- NECA 402-2007, *Recommended Practice for Installing and Maintaining Motor Control Centers* (ANSI)
- NECA/EGSA 404-2007, *Standard for Installing Generator Sets* (ANSI)
- NECA 406-2003, *Standard for Installing Residential Generator Sets* (ANSI)
- NECA 407-2009, *Standard for Installing and Maintaining Panelboards* (ANSI)
- NECA 408-2009, *Standard for Installing and Maintaining Busways* (ANSI)
- NECA 409-2009, *Standard for Installing and Maintaining Dry-Type Transformers* (ANSI)
- NECA 410-2005, *Standard for Installing and Maintaining Liquid-Filled Transformers* (ANSI)
- NECA 411-2006, *Standard for Installing and Maintaining Uninterruptible Power Supplies (UPS)* (ANSI)
- NECA 420-2007, *Standard for Fuse Applications* (ANSI)
- NECA 430-2006, *Standard for Installing Medium-Voltage Metal-Clad Switchgear* (ANSI)
- NECA/IESNA 500-2006, *Standard for Installing Indoor Commercial Lighting Systems* (ANSI)
- NECA/IESNA 501-2006, *Standard for Installing Exterior Lighting Systems* (ANSI)
- NECA/IESNA 502-2006, *Standard for Installing Industrial Lighting Systems* (ANSI)
- NECA 503-2005, *Standard for Installing Fiber Optic Lighting Systems*
- NECA/BICSI 568-2006, *Standard for Installing Commercial Building Telecommunications Cabling* (ANSI)
- NECA/MACSCB 600-2003, *Recommended Practice for Installing and Maintaining Medium-Voltage Cable* (ANSI)
- NECA/NEMA 605-2005, *Recommended Practice for Installing Underground Nonmetallic Utility Duct* (ANSI)

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