



Recommended Practice for
Installing and Maintaining

Switchboards



Published by
National Electrical
Contractors Association



NECA 400–1998
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Switchboards



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Table of Contents

Foreword	v
1. Scope	1
2. Switchboard Receiving, Handling and Storing	2
2.1 Receiving the Switchboard	2
2.2 Handling the Switchboard	2
2.3 Storing the Switchboard	3
3. Installation	4
3.1 Location	4
3.2 Foundation Preparation	4
3.3 General Installation Instructions	5
3.4 Installing Vertical Sections	5
3.5 Joining Switchboard Sections	5
3.6 Anchoring the Switchboard	5
3.7 Installing Cables	6
3.8 Installing Interconnection Between Switchboard Sections	6
3.9 Ground Bus Splice Connections	7
3.10 Grounding and Bonding	7
3.11 Busway Connections	8
3.12 Conduit Area	8
3.13 Cable Pulling	9
3.14 Cable Terminations	9
4. Pre-Energizing Checkout Procedure	11
4.1 General	11
4.2 Insulation Test	11
4.3 Current Transformers	11
4.4 Circuit Breakers and Fusible Switches	11
4.5 Ground-Fault Protection	12
4.6 Interconnection	12
4.7 Power Fuses and Control Power Disconnect	12
4.8 Clean-up	12
4.9 Close-up	12
5. Energizing the Switchboard	13

- 6. Maintaining the Switchboard 14**
 - 6.1 General Inspection 14
 - 6.2 Bus Bar Joints 14
 - 6.3 Field Testing Molded-Case Circuit Breakers 15
 - 6.4 Field Testing Bolted Pressure Switches 15
 - 6.5 Field Testing Fusible Switches 15
 - 6.6 Fuse Replacement 15
 - 6.7 Ground-Fault Protection Systems 15

- 7. Adverse Circumstances 16**
 - 7.1 Inspection Following a Short-Circuit or Ground-Fault Condition 16
 - 7.2 Replacing a Switchboard Soaked by or Submerged Under Water 16
 - 7.3 Inspecting and Re-Energizing a Switchboard Sprayed or Splashed with Clean Water 16

- 8. Torque Requirements 18**

- 9. Switchboard Insulation Resistance Chart 20**

- 10. Operations and Maintenance Documents 21**

- Appendix A: Reference Standards 22**

(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:

Deadfront distribution switchboards rated 600 volts or less shall be installed and maintained in accordance with NECA 400, ***Recommended Practice for Installing and Maintaining Switchboards***.

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.

Everything in this publication is intended to comply with the edition of the National Electric Code® (NEC) in effect at the time of publication. *NEIS*™ are not intended to duplicate NEC requirements nor to

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1. Scope

This recommended practice describes installation procedures for deadfront distribution switchboards rated 600 volts or less. It also covers periodic routine maintenance procedures for switchboards, and special procedures to be used after adverse circumstances such as a short-circuit, ground-fault, or immersion in water.

This recommended practice is intended to define what is meant by installing equipment in a “neat and workmanlike manner” as required by the National

Electrical Code, Section 110-12. 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 manufacturers’ instructions when installing and maintaining switchboards.

Only qualified persons familiar with the construction and operation of switchboards should perform the work described in this publication.

2. Switchboard Receiving, Handling and Storing

2.1 Receiving the Switchboard

- a) Unload carefully, observing all packing label warnings.
- b) Use forklifts or other loading equipment only for palletized shipments.
- c) Leaving protective coverings in place as much as possible, open and inspect the switchboard completely for shipping damage. Undamaged material should be carefully repacked unless intended for immediate installation. *(NOTE: Depending on company policy or project circumstances, it may be necessary to receive, unpack and check all material at the company shop or other staging area, in which case careful repacking is essential.)*

2.2 Handling the Switchboard

Switchboards are typically large, bulky pieces of equipment weighing several hundred pounds or more. The packing list will provide the actual weight of each item. Handle the switchboard properly in order to avoid injury to personnel and damage to equipment. Verify that the lifting capacity of the handling equipment is more than the weight to be moved. Obtain the shipping weight and type of truck making the delivery prior to receiving the shipment. Delivery on an open truck at the job-site is recommended.

Suitable protection against the weather must be provided if the equipment is designed only for indoor installation (NEMA Type 1).

There are two primary ways of lifting the equipment: with lifting straps and without lifting straps, using a

sling instead. Using the manufacturer's lifting straps is the preferable method when these are supplied.

2.2.1 Handling with lifting straps

Switchboard manufacturers provide lifting straps as standard equipment when the weight of the switchboard section(s) does not exceed the recommended capacity of the lifting straps. Use a rigid spreader or a spanner beam to provide vertical lift on the lifting straps (*see Figure 1*), and avoid damage to the frame or finish. Follow lifting warning labels on the switchboard.

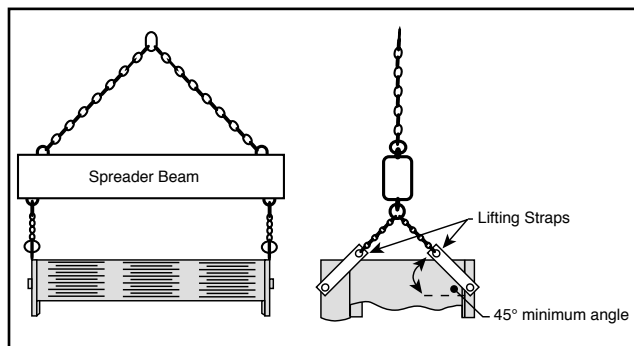


Figure 1

2.2.2 Handling without lifting straps

Lifting straps are not furnished on switchboards when the weight of the section(s) exceeds their capacity, or when the lifting straps would cause stress to the switchboards. They also are not provided when the design does not permit, such as NEMA Type 3R outdoor equipment with overhangs. These switchboards can be handled by either slings, forklifts, rollers or a combination of these means. Typically, a handling warning is provided on those switchboard sections for which lifting straps are not provided.

a) **Sling:** A crane or suitably rigged equipment with a chain arranged in a sling, or wire cable with safety hooks and shackles, should be used to lift a switchboard shipping section not equipped with lifting straps. Rig the sling completely around the switchboard and shipping stringers (see Figure 2), and use a forklift or jacks to lift the switchboard vertically off the floor to attach the sling.

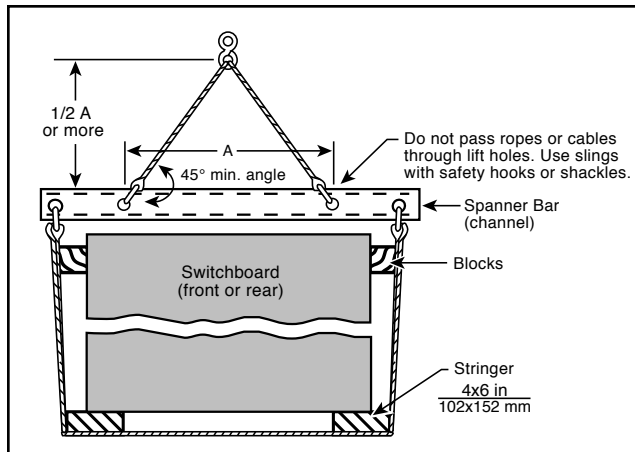


Figure 2

b) **Forklifts:** Forklifts are an alternate method of handling switchboards. Verify that the capacity of the forklift is more than the weight of the load to be lifted. Always insure that the fork lengths extend under the entire switchboard and extend beyond the opposite side (see Figure 3). Move the forks to the furthest-most left and right locations and use a safety strap when moving or handling switchboards.

c) **Rollers:** If equipment is not available for lifting the switchboard, or the ceiling is not high enough, rollers suitable for the application may be used to move the switchboard into position. A forklift or jacks can be used to initially lift the switchboard and position it on the rollers. Rollers should be positioned approximately every 18 inches, and be at least the width of the switchboard for stability. Extreme care should be taken when using rollers due to switchboard height and weight. Rollers are most suitable for moving switchboards on a level surface; use a winch or chainfall where inclines must be traveled over to prevent “runaway.”

2.3 Storing the Switchboard

a) Cover the switchboard with a tarp or plastic to keep the equipment from getting wet and accumulating dust or debris (cement dust can be corrosive and cause insulation breakdown when it accumulates across insulators). The cover should be heavy enough to keep from tearing during wind gusts at the storage location.

b) To reduce condensation within the switchboard, store the switchboard indoors whenever possible to keep harmful condensation from accumulating inside the enclosure.

c) Install a minimum of 250 watts of heat per vertical section, even for outdoor enclosures. Remove all loose packing or materials that could catch fire prior to applying the heat.

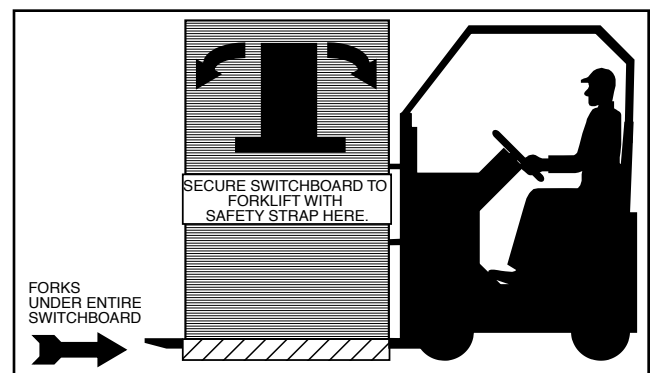


Figure 3

3. Installation

Proper installation is essential to the proper operation of all switchboard components. Thoroughly study associated instruction manuals, literature and drawings before attempting to install the switchboard. In most cases, this information will already have been requested prior to the shipment of the switchboard to enable advanced planning.

3.1 Location

- a) The floor plan of the structure for an inside switchboard, or the site plan for an outdoor switchboard will show the area where the switchboard is to be installed. The location of the switchboard should comply with all building codes and at minimum should meet the working space requirements of the National Electrical Code, Section 110-26. (*NOTE: Provisions for temporary ramps or installation hoists may require working clearances greater than NEC minimums.*)
- b) Consult the switchboard drawings to determine where accessibility is required for the switchboard (e.g., a rear access switchboard cannot be placed against a wall).
- c) Indoor switchboards in damp locations require shielding to prevent moisture and water from entering and accumulating. If the room temperature around the indoor switchboard is not between 77° - 104°F (25° - 40°C), use a minimum of 250 watts of heating per vertical section until a suitable environment can be provided.
- d) In locations where a sump pump is required, the pump should be properly working before the switchboard is installed to prevent accumulation of water that may seriously damage the switchboard and its

internal components (*see Section 7, Adverse Circumstances*). The sump pump should be connected to a standby power source.

3.2 Foundation Preparation

- a) The floor or foundation on which the switchboard will be installed needs to be strong enough to support the weight of the switchboard without bowing or sagging. A concrete surface is preferred.
- b) In special instances where earthquakes may occur, 4000 psi concrete should be used along with specific anchoring means such as stud anchors, sleeves anchors or concrete anchor bolts (anchoring hardware is not supplied as a standard item with most switchboards). Performance of the switchboard under earthquake conditions is directly related to the foundation preparation. (*NOTE: Local building codes may have seismic requirements that affect switchboard installation. Installers should consult these codes or coordinate with the general contractor prior to installing switchboards.*)
- c) A level mounting pad raised four inches above the general floor level is typical with the surrounding floor area gently sloping toward a drain. To ensure correct bus bar alignment within the switchboard and to enable bolting vertical sections together it is critical that the mounting pad or floor be smooth and level. (*NOTE: Provisions for temporary ramps or installation hoists may require working clearances greater than NEC minimums.*)
- d) If floor channels are embedded in the concrete pad, they should be level over the entire length of the switchboard in order to avoid distortion of the switchboard structure.

e) Before pouring the concrete for the pad, install all conduits including future conduits required for bottom entry into the switchboard. Consult the switchboard drawing bottom view during this process to verify that the conduit layout matches the available conduit entry area into the switchboard. The manufacturer will already have taken into account the National Electrical Code and product listing requirements for conduit entry.

f) Embedded conduits typically project above the finished pad approximately 2 inches. If embedded conduits project more than 2 inches above the concrete pad, it may be necessary to lift each shipping section vertically into place using a crane, timbers, jacks, or forklift. After the sections are installed, and appropriate extension sleeves added to the conduits, the maximum projection should be 3 inches; NEC Section 384-10 prohibits projections greater than 3 inches.

3.3 General Installation Instructions

a) Clean dirt and debris from the pad and surrounding area where the switchboard will be located before moving the switchboard into its final position.

b) Remove the shipping skids before installing the switchboard on the pad.

c) If the switchboard is equipped with bottom closure plates, temporarily remove these plates and set them aside. Cut holes for the conduits entering the bottom of each enclosure in the bottom plates (if supplied) based on that section's conduits. Once the vertical sections have been installed, reinstall the bottom closure plates.

d) Block the opening of each conduit with material that rodents will not be able to gnaw through, squeeze through, or push out of the way. Bottom closure plates will not keep out rodents that come in through the conduits.

3.4 Installing Vertical Sections

3.4.1 Initial placement

a) If the switchboard has incoming cables or busway near or in its center, start with that vertical section first and work outward on each side.

b) If the switchboard is left-feed, start from the left. If right-feed, start from the right.

c) If the switchboard is close-coupled to a transformer, start at the transformer and work away from the transformer.

3.4.2 Positioning

Position each shipping section carefully, following the instructions in 2.2 Handling the Switchboard. Level with shims if necessary, and align each section with the previous section. Proper alignment will make joining the structures and through-bus easier.

(NOTE: Improper alignment of the through-bus may result in property loss, death, or serious injury.)

3.4.3 Lifting straps

Remove lifting straps or slings so that vertical sections can be joined flush. Leave lifting straps or hardware on the switchboard if their removal is not required to join adjacent sections flush together.

3.5 Joining Switchboard Sections

a) Open or remove the front and, if necessary, the rear door or panels that provide access for bolting the adjacent shipping sections together.

b) Torque the bolts based on the manufacturer's instructions. *(NOTE: The authority having jurisdiction may require that all bolts connecting bus sections be inspected for proper torque prior to closing up the switchboard.)*

3.6 Anchoring the Switchboard

Switchboard sections are freestanding structures but hard bumps or shifting movements can result in damage to interior components, conduit hubs and cable/busway connections. Therefore, each vertical section of the switchboard is anchored to the floor. Some manufacturers provide formed base channels that run the entire length of the switchboard, mounting holes in the structure base, or both. (See Figure 4)

Anchor each section using the hardware recommended (but not usually supplied by) the switchboard manufacturer and torque the bolts to their recommended value.

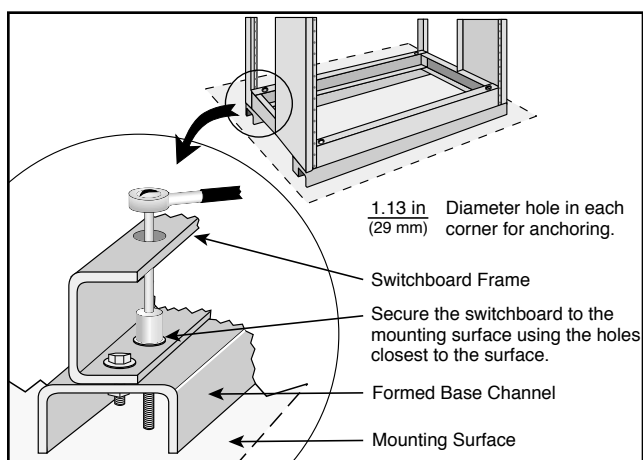


Figure 4

3.6.1 Seismic considerations

Carefully follow the plans and specifications when anchoring a switchboard for seismic conditions since the top of the switchboard structure can move as much as 3 inches in any direction. (NOTE: Local building codes may have seismic requirements that affect switchboard installation. Installers should consult these codes or coordinate with the general contractor prior to installing switchboards.)

3.7 Installing Cables

Install the incoming service conductors and load side cables after all switchboard sections are properly

joined together and the entire switchboard structure is anchored to the floor. If the switchboard is in a seismic environment and cables or busway enter at the top of the switchboard, it is necessary to take into account the motion of the top of the switchboard during a seismic occurrence. (NOTE: If the switchboard consists of only one shipping section, proceed to 3.10 Grounding and Bonding.)

3.8 Installing Interconnections Between Switchboard Sections

Switchboard vertical sections are electrically connected together using either through-bus or cables.

3.8.1 Through-bus splice connections

Through-bus splice connections are extremely important to the performance of the switchboard, since these connections are expected to carry the full current intended for their operation. Failure to properly make through-bus splice connections may result in property damage, death, or serious injury.

- Through-bus splice kits are provided by the switchboard manufacturer when more than one section is required to be electrically connected together by through-bus.
- Splice kits may come in separate boxes, be installed on the through-bus of one or more vertical sections, or be stored inside the sections to be spliced.
- Follow the proper sequence of hardware installation, as specified in the manufacturer's installation

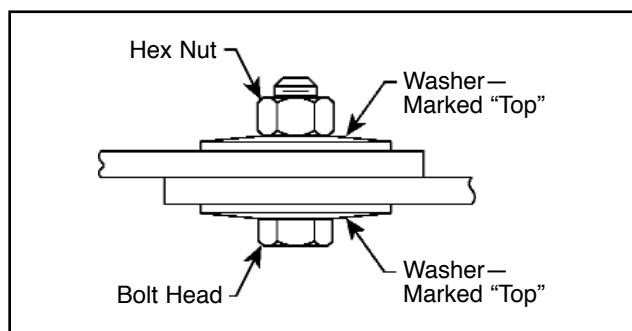


Figure 5

instructions. Install conical washers such that their convex or “top” side is against the nut (*see Figure 5*).

d) Torque the splice bolts to their recommended values. Mark each torqued connection with a permanent marker.

e) The through-bus of some switchboards is covered with an insulating material. Follow the manufacturer’s instructions for installing insulation on each through-bus splice connection.

3.8.2 Cable interconnections

Install the interconnection cables (which may or may not be supplied by the manufacturer) between sections as shown on manufacturer’s drawings. Torque all connections to the manufacturer’s recommended values.

3.9 Ground Bus Splice Connections

Ground bus splice kits are provided by switchboard manufacturers when more than one section is required to be electrically connected (*see Figure 6*). Proper installation of ground bus splice connections is essential to providing a low-impedance path to ground for temporary currents resulting from phase-to-ground short circuits.

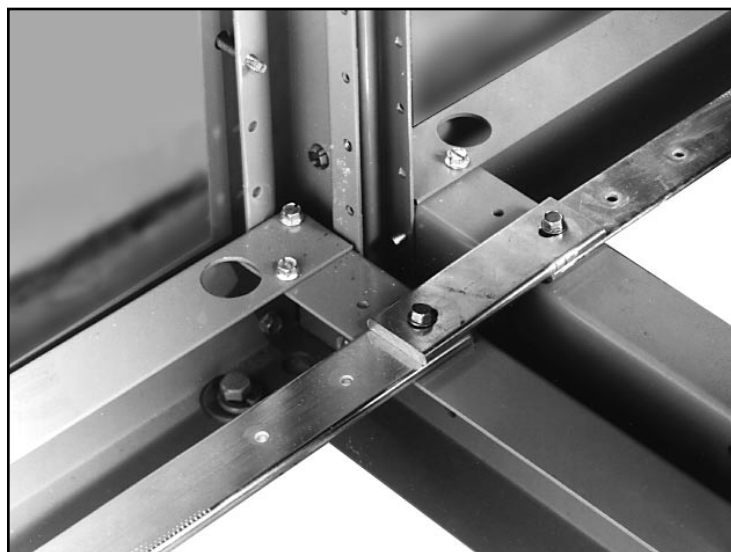


Figure 6

a) Splice kits may come in separate boxes, be installed on the ground bus of one or more sections, or be stored inside the switchboard sections.

b) Follow the proper sequence of hardware installation, as specified in the manufacturer’s installation instructions. Install conical washers such that their convex side is against the nut.

c) Torque the splice bolts to the recommended value. Mark each torqued connection with a permanent marker.

3.10 Grounding and Bonding

3.10.1 Grounded systems — service-entrance switchboards and switchboards used on separately derived systems

NEC Section 250-30(a) describes complete grounding requirements for grounded separately derived systems.

a) Run a grounding electrode conductor from the grounding electrode at the installation site to the grounding electrode conductor connection, commonly called a ground lug, located on the switchboard ground bus (*see Figure 7*).

b) NEC Section 250-64 describes requirements for



Figure 7

grounding electrode conductor material, installation, and size.

- c) Torque the ground lug binding screw based on the manufacturer's recommendation or crimp in accordance with the crimp tools instructions.
- d) For service entrance equipment, or a switchboard used on a separately derived system, install the main bonding jumper between the neutral bus and the ground bus. A label on the front of the switchboard will identify the section(s) that incorporate the main bonding jumper(s).
- e) Torque the hardware of the main bonding jumper in accordance with the manufacturer's recommendations.
- f) Equipment ground-fault protection will be rendered inoperative if the system is grounded downstream from the ground fault sensor.
- g) For switchboards with multiple source of power, there will be two or more main bonding jumpers to install.

3.10.2 Ungrounded systems — service-entrance switchboards and switchboards used on separately derived systems

NEC Section 250-30(b) describes complete grounding requirements for ungrounded separately derived systems.

- a) Run a grounding electrode conductor from the ground electrode at the installation site to the grounding electrode conductor connection, commonly called the ground lug, located on the switchboard ground bus (*see Figure 7*).
- b) NEC Section 250-64 describes requirements for grounding electrode conductor material, installation, and size.
- c) Torque the ground lug binding screw based on the manufacturers recommendation or crimp per the crimp tools instruction.

3.11 Busway Connections

Power is often distributed from switchboards using busway, also called bus duct. Busway is provided in

different configurations by different manufacturers; one typical configuration is shown in *Figure 8*.

- a) When connecting busway, install conical washers such that the convex side of the washer is against the nut.
- b) Confirm proper phasing of the busway before energizing the busway run.
- c) Do not use the switchboard to support the weight of the busway. Support the busway independently of the switchboard.

3.12 Conduit Area

- a) The switchboard conduit entry drawings show the available conduit entry for the switchboard. External circuit cables for each section should be routed into and through these designated conduit areas, then routed internally to their designated termination areas.
- b) Do not use the switchboard to support the weight of the conduits. Support the conduits independently of the switchboard.
- c) If a bottom plate is furnished, remove it to cut holes for the conduit and cable entry. Bottom plates with holes are not furnished as standard item.

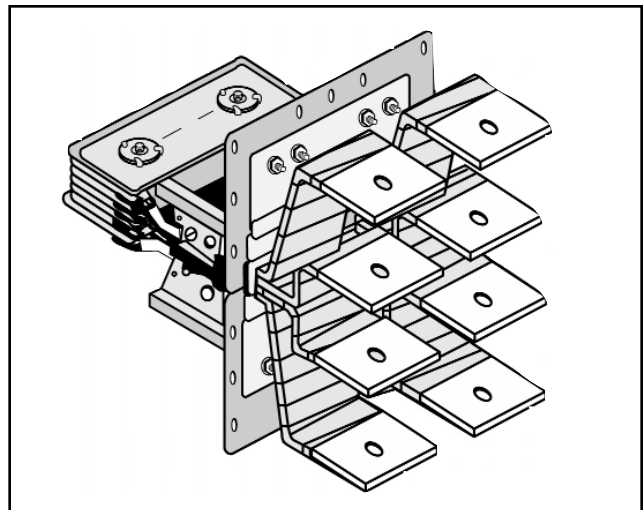


Figure 8

Re-install the bottom plates after the holes are made. Saw kerf between conduit holes in bottom plate for installations where individual conductors are run in individual conduits, such as duct bank risers.

d) Under seismic conditions, the top of the switchboard may move up to 3 inches in any direction. Any cables entering the top of the switchboard need sufficient slack to accommodate this motion. If the floor of the switchboard is designed for movement during a seismic event, the cables entering the bottom of the switchboard should also have enough slack to accommodate this motion.

e) Use approved hubs and ring connectors to protect the cables and prevent condensation from entering the switchboard through the conduits.

f) Bond all conduits, stubs, and ring connectors to the switchboard enclosure following the manufacturer's recommendations.

3.13 Cable Pulling

Switchboard components are arranged to provide clearance and wire bending space for both line and load cables. Each cable should be pulled into the switchboard to conform to the arrangement specified on the switchboard drawings.

a) Verify that the lugs correspond to the switchboard cable schedule and are suitable for the cables being terminated. Consult the markings on overcurrent protective devices to determine that the conductor size range is correct and the temperature rating is appropriate. Conductors rated 90°C are permitted to be used with most connectors and terminals, but only at 75°C ampacity. Some overcurrent protective devices, mostly those listed for operation at 100 percent of rated ampacity, *require* the use of 90°C conductors sized at 75°C ampacity.

b) Consult NEC Article 310 to calculate the proper size and number of conductors for the loads served.

c) Prior to pulling the cables into the switchboard, plan ahead as to which overcurrent device to cable first. This is particularly important for group-mounted constructions.

d) Cable pulling lubricants should not be allowed to drip or come into contact with overcurrent devices and/or plating of the bus bars. Remove all pulling compound from the interior of the switchboard prior to energizing the unit.

e) Position the conductors in the switchboard enclosure so they are not subject to physical damage. If any conductors are in contact with structural members, place suitable protective material at the contact point to protect the cable insulation.

f) NEC Section 300-20(a) requires that all phase and grounded conductors of the same circuit pass through the same metal opening together. Otherwise, a magnetic loop will be created causing overheating within the switchboard.

g) Where required, brace or lace the conductors in accordance with the manufacturer's instructions or consulting engineer's specification.

h) Train cables within wire gutters of switchboards in a neat and workmanlike manner.

3.14 Cable Terminations

Terminating and tightening cable connections to the manufacturer's recommended torque is imperative for a satisfactory connection. Follow these steps when terminating conductors at the switchboard:

a) Strip a sufficient length of insulation from the cable end to fit it into the full length of the lug barrel. Use a proper insulation stripping tool to avoid nicking conductor strands. Stripping cable too long should be avoided since the through-air clearance could be reduced below the minimums required by the NEC.

b) Mechanical lugs (set-screw type) are the most common type of connector furnished with switchboards. Torque these lugs in accordance with the manufacturer's recommendations to avoid stripping threads or cracking the lug body.

c) When compression lugs are used to terminate aluminum conductors, remove oxides from the conductors and apply an anti-oxidant compound to the alu-

minum conductor before inserting into the lug body. Oxides on aluminum conductors are poor conductors and will cause abnormal heating at the connection.

d) Remove compression lugs from their point of termination in order to crimp them onto cables. Follow

the manufacturer's recommendation as to the proper number of crimps and their position on the lug. Use the recommended sealant. Re-install the crimp lugs to the lug pad and torque the hardware used with the lugs.

4. Pre-Energizing Checkout Procedure

4.1 General

Conduct a complete inspection of the switchboard before it is energized to ensure that the components within the switchboard function properly.

- a) Check all field installed bus bar connections for correct torque value.
- b) Check all accessible connections for tightness.
- c) Check all factory and field installed lug terminations for the correct torque value.
- d) Visually check the bussing insulators for cracks and supports for damage.
- e) Check to insure that dents or other damage to the enclosure have not resulted in clearances that violate NEC requirements.
- f) Remove foam blocks, packing material, and temporary cushioning from the switchboard and components inside the switchboard.
- g) Check all relays, meters and instrumentation device wiring and terminations.

4.2 Insulation Test

Perform a dc insulation test on the switchboard and record the value for future maintenance tests; a switchboard insulation resistance chart is shown in Section 9. Values less than 1 megohm are typically unacceptable. Prior to this test, remove control power fuses and any other equipment that should not be subjected to this level of potential.

4.3 Current Transformers

Ensure that current transformers secondary terminals are connected to a load or are shorted together, using shorting straps or terminal block shorting screws. (*CAUTION: Open secondary terminals may have high voltages, which could be a hazard to people or equipment.*) The shorting means are removed when the current transformers operate normally with their intended load.

4.4 Circuit Breakers and Fusible Switches

- a) Manually open and close all circuit breakers and fusible switches to ensure proper operation.
- b) Adjust the magnetic trip on thermal magnetic circuit breakers to their proper setting based on the system study or switchboard schedule. A setting too low for a load that has a high peak inrush current will trip the circuit breaker on start-up.
- c) Electronic circuit breakers have functions such as long-time, instantaneous, short-time, and ground fault, that requires initial adjustment. Settings typically are provided in a coordination study prepared by the consulting engineer, or other persons responsible for the switchboard set-up. (*NOTE: These values typically are not found on the drawings supplied by the switchboard manufacturer.*) If values are not provided, consult the manufacturer's circuit breaker instruction manual for values that will set the electronic circuit breaker functions to emulate thermal magnetic circuit breaker characteristics.

4.5 Ground-Fault Protection

- a) The trip and time-delay on ground-fault protective equipment are typically set by the manufacturer at their lowest settings. Adjust these settings based on information provided in a coordination study prepared by the consulting engineer, or other persons responsible for the switchboard set-up.
- b) Some ground-fault protection systems require field connections at the job site. Consult the switchboard interconnection wiring diagram for details.
- c) Check the ground-fault circuitry and establish that there are no grounds on the neutral downstream from the service entrance point.
- d) The NEC requires that the ground-fault protection system be performance tested when first installed, and that a written record of this test be available to the authority having jurisdiction. A testing group with experience in switchboard ground-fault testing should perform an injection test.

4.6 Interconnections

Verify that all interconnecting wiring between switchboard sections has been connected.

4.7 Power Fuses and Control Power Disconnects

Replace all control power fuses removed in the Insulation Test (see Section 4.2) and turn on all control power disconnects.

4.8 Clean-up

Vacuum all scrap, wire, dust and other debris from the switchboard. Do not use compressed air to blow debris out of the switchboard, since debris may, instead, settle inside devices and impair their ability to function.

4.9 Close-up

Replace all covers. Check for any pinched wires and close all doors. Make sure that the enclosure parts are properly aligned and fastened securely.

5. Energizing the Switchboard

Hazards exist in energizing a switchboard; energizing should only be performed by qualified electrical personnel.

If a short circuit or ground-fault condition exists, caused by damage or poor installation practices, and this is not detected and corrected during the check-out procedures, serious personal injury and/or damage to the switchboard can result when the switchboard is first energized. Follow the steps below to energize the switchboards; read all steps before proceeding.

Step 1 Turn off all downstream loads. No load should be on the switchboard when it is first energized.

Step 2 Use remote operators, if available, to close devices and energize switchboards and loads for the first time.

Step 3 Prior to energizing any circuit that supplies rotating machinery, verify that the phase sequence is correct. Serious damage can result to motors and similar equipment rotating in the wrong direction.

Step 4 One by one, close each circuit breaker or fusible switch in the switchboard.

Step 5 Proceed to energize (turn on) the downstream loads (lighting circuits, contactors, heaters, motors, etc.) one at a time.



6. Switchboard Maintenance

Periodic maintenance of switchboards extends their service life and increases their reliability. Maintenance includes visual checks, cleaning, lubrication and exercising of component parts. The interval between maintenance checks varies depending on the environment (such as ambient temperature and conditions in the switchboard room), and usage of the equipment. The maximum interval recommended for switchboard inspection is one year; the first inspection taking place no more than one year after the original installation. The switchboard should be inspected whenever an overcurrent device opens, or a phase-to-phase short circuit or ground-fault occurs (see Section 7.1).

6.1 General Inspection

- a) De-energize the switchboard, then test to verify that no voltage exists and that an alternate source of power is not involved. Then vacuum the inside of the switchboard to remove any debris, dirt, or dust that has accumulated, noting anything unusual such as signs of insects or rodent activity or moisture. Wipe the bus bars, insulators, conductors and other parts with a clean, dry lint-free cloth. Do not use chemicals or petroleum-based solvents on plastics or insulating materials, since these may degrade the plastics or insulating materials.
- b) Visually check the inside of the switchboard for moisture, condensation build-up or signs of any previous wetness. Moisture causes insulation failures and rapid oxidation of current carrying parts. Pay particular attention to conduit entrances and leaks at the top of the switchboard between sections. Remove any moisture present inside the switchboard and seal off all leaks.
- c) Prior to de-energizing the switchboard, perform an infrared scan. Visually inspect the switchboard for signs of overheating. Discoloration and flaking of

insulation or metal parts are indications of possible overheating. Correct conditions that caused the overheating, and replace the affected parts before re-energizing the switchboard.

- d) Carefully inspect all switchboard devices for any worn-out, cracked or missing parts.
- e) Exercise the devices several times to verify that they are working properly. Many circuit breakers have a test feature which trips, exercises and lubricates the mechanism. This method of exercising circuit breakers should be used if available; otherwise, operate the circuit breaker manually.
- f) Verify that all key interlocks and door interlocking provisions are working properly.

6.2 Bus Bar Joints

- a) Consult the manufacturer's recommendations concerning bus bar joints and re-torque where required. (*NOTE: Some switchboard manufacturers indicate that their joints are maintenance-free and that additional torquing after installation may actually degrade the connection.*)
- b) Indications of pitting, corrosion, discoloration and annealing due to heat require that the affected part of the bus assembly must be replaced. Use of abrasive materials to correct the problem is not recommended since joints are one of the most critical parts of the bussing system. Use hardware and washers of a grade identical to or better than the hardware replaced.

6.3 Field Testing Molded-Case Circuit Breakers

- a) Consult the manufacturer's instructions.

- b) Exercise the operating mechanism during the periodic inspection.
- c) If the circuit breaker uses solid-state circuitry or a microprocessor, run the self-diagnostics if available.
- d) For electronic circuit breakers, use the test set to run trip unit tests automatically with user prompts.

6.4 Field Testing Bolted Pressure Switches

- a) Consult the manufacturer's instructions.
- b) Exercise the operating mechanism during the periodic inspection.
- c) Check the cover interlock with the switch "ON." The cover should not open using normal hand force.
- d) Lubricate parts as required in accordance with the manufacturers recommendations.

6.5 Field Testing Fusible Switches

- a) Consult the manufacturer's instructions.
- b) Exercise the operating mechanism during the periodic inspection.
- c) Check the cover interlock with the switch "ON." The cover should not open using normal hand force.
- d) Inspect the switch interior for any broken parts and replace as necessary.
- e) Check the fuse mounting clips or bolted contacts area for corrosion or discoloration indicating the presence of overheating. Replace the parts as required.

6.6 Fuse Replacement

It is important that power be turned off when replacing fuses. Always check the line and load ends of fuses for the presence of voltage before starting fuse replacement procedures.

- a) Look for indications that the switchboard may be fed from multiple sources.

- b) Turn the fusible switch "OFF" before opening the door. Do not defeat the cover interlock to gain access to the fuses.

- c) Visually check the position of the switch blades to confirm that all switch blades have disconnected from their line connection. If all switch blades are not in the correct position, consult the manufacturer's recommendation for this abnormality.

- d) A current-limiting fuse cannot be replaced with a non-current limiting fuse and no attempt should be made to defeat any rejection feature in the switchboard fusible device. Certain switchboard manufacturers do not recommend the use of renewable link fuses in their equipment.

6.7 Ground-Fault Protection Systems

- a) Check the terminal connections on the ground-fault protection system at least once a year for tightness and corrosion. Replace any components physically or electrically damaged. Depending on the system, ground-fault testing may be conducted with or without tripping main or branch overcurrent protective devices. Testing with trip is preferable since it ensures the whole system is functioning.

- b) If the ground fault protection system does not operate properly and additional equipment has been connected to the installation since the last maintenance test/check, de-energize the entire system, disconnect the main bonding jumper, and check for continuity between the neutral and ground on the load-side of the main bonding jumper. If grounds are found, remove them and test again. If no grounds are now detected and the ground-fault protection system is still not functioning properly, contact the switchboard manufacturer.

- c) If the ground-fault protection system does not operate properly and no additional equipment has been connected to the installation since the last maintenance test/check, check the devices for physical or electrical damage and replace accordingly. Check wiring for damage or loose connections and correct any problems found.

7. Adverse Circumstances

Special procedures are necessary to determine whether a switchboard can safely remain in service following a short-circuit, ground-fault, or exposure to water.

7.1 Inspection Following a Short-Circuit or Ground-Fault Condition

Do not attempt to re-energize a switchboard following a short-circuit or ground-fault condition within the switchboard. Do not re-energize a feeder or branch over-current protection device in the switchboard that has opened due to a short circuit or ground-fault until the problem downstream has been corrected.

Following a short-circuit or ground-fault within a switchboard, inspect the equipment thoroughly as described in 6.1 to verify that damage has not occurred to conductors or insulators within the switchboard. *(NOTE: The insulating properties of some organic insulating materials may deteriorate during an electrical arc. Replacement of the damaged insulating material is the only remedy.)*

7.1.1 Short-circuits develop high mechanical stresses that can damage conductors and insulation. Improper and loosened connections may result in conductors pulling out of their terminations on subsequent short-circuits; for this reason all connections should be inspected and, if necessary, re-evaluated. Great care must be taken in evaluating the cause of the short-circuit. Do not replace the fuse(s) and turn the overcurrent protective device back on, or reset the circuit breaker, without first determining whether it is safe to energize the circuit. Phase-to-phase short-circuits that originate on bus bars can travel the length of the bussing system through the switchboard, and the greatest damage may not occur where the arcing condition originated.

Conduct an insulation test to determine the integrity of the switchboard insulation prior to re-energizing the switchboard.

7.1.2 Ground-faults are unintentional current paths between a phase conductor and ground.

Depending on the magnitude of the ground-fault and its duration, carbon build-up and metallic splatter may need to be removed, insulators cleaned or replaced, and bus bar material or connections replaced. Perform phase-to-phase and phase-to-ground insulation tests, with a minimum reading of one megohm, prior to turning the switchboard power back on.

7.2 Replacing a Switchboard Soaked By or Submerged Under Water

- a) Do not work on energized electrical equipment when standing in water.
- b) Do not energize a switchboard that is wet.
- c) Do not clean or repair a switchboard that has been exposed to large volumes of water or submerged. Current-carrying parts, insulation systems, and electrical/electronic components may be damaged beyond repair through contamination by chemicals, river or creek water, sewage and other pollutants. In this event, replace the switchboard rather than attempt to repair it.

7.3 Inspecting and Re-Energizing a Switchboard Sprayed or Splashed with Clean Water

Apply heat (a minimum of 250 watts per section) to the switchboard to dry it out until visible signs of dampness

cannot be seen. Remove materials that could catch fire prior to applying the heat. Consult the manufacturer's recommendations for specific guidelines on how to insure that it is safe to re-energize the switchboard, or follow this procedure:

7.3.1 Preliminary Inspection

Follow the steps in Section 7.3.2 to re-energize the switchboard *only* if a preliminary inspection verifies that the following conditions are satisfied:

- a) There are no signs of physical damage to the equipment.
- b) The switchboard has not been soaked or submerged in water.
- c) The water that has been in contact with the switchboard has not been contaminated with sewage, chemicals or other substances.
- d) Water has not entered any area of the switchboard enclosure that contain wiring, and has not come into contact with any live part. Look for water entering through conduits.

If *all* of the conditions listed above are satisfied, proceed as follows:

7.3.2 Cleaning, testing, and re-energizing a switchboard

Step 1 Completely de-energize and electrically isolate the switchboard so that contact cannot be made with energized parts.

Step 2 Wipe off all moisture from bus bars, insulators, and insulating materials with a clean, dry, lint free cloth. Never use cleaning agents or sprays unless specifically recommended by the switchboard manufacturer.

Step 3 Prepare the switchboard for an insulation resistance test by disconnecting all line-side supply conductors and all load-side conductors to isolate the switchboard from the wiring system. Turn all circuit breakers or fusible switches to the "ON" position. Voltage cannot be present on the switchboard during the insulation resistance test.

Step 4 Use a dc insulation resistance tester with a capacity of 500-1000 Volts dc to perform phase-to-ground and phase-to-phase insulation tests. (*NOTE: Use of an AC dielectric tester is not recommended.*)

- a) Measure each phase (A, B, C) to ground with the circuit breakers or fusible switches "ON."
- b) Measure each phase to another phase with the circuit breakers or fusible switches "ON." Record the values of the insulation resistance on the insulation resistance chart shown in Section 9.

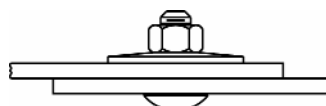
Step 5 Do not re-energize the equipment if any of the resistance measurements are less than 0.5 megohm (500,000 ohms). If moisture is the cause of the low resistance readings, the moisture can be removed from the switchboard by providing a minimum of 250 watts of heat per vertical section.

Step 6 If the resistance measurements are greater than 0.5 megohm, the equipment can be re-energized.

8. Recommended Torque Values

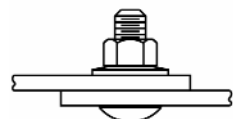
If the switchboard manufacturer does not provide specific torque recommendations, use the following as a guide.

Hardware Description	Torque Value
1/2 inch	780-900 lb-in (88-102 N*m)

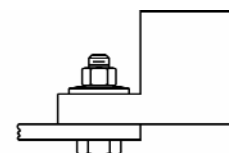


Carriage Bolt
Hex Nut
Conical Washer

Hardware Description	Torque Value
1/4 inch	50-75 lb-in (6-8 N*m)
5/16 inch	80-125 lb-in (9-14 N*m)
3/8 inch	175-225 lb-in (20-25 N*m)
1/2 inch	250-350 lb-in (28-40 N*m)

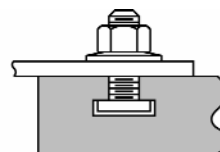


Carriage Bolt
Conical Washer Assembly
(Keps Nut)



Hex Head Bolt
Conical Washer Assembly
(Keps Nut)

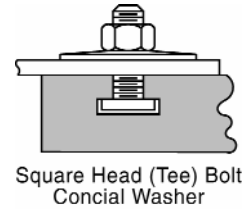
Hardware Description	Torque Value
3/8 inch	175-225 lb-in (20-25 N*m)
1/2 inch	250-350 lb-in (28-40 N*m)



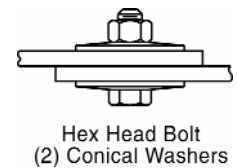
Square Head (Tee) Bolt
Conical Washer Assembly
(Keps Nut)

Recommended Torque Values

Hardware Description	Torque Value	
	Conical Washer OD	Square Head (Tee) Bolt Conical Washer
3/8 inch	0.87 inches (22 mm)	250-280 lb-in (28-32 N*m)
	1 inch (25 mm)	130-150 lb-in (15-17 N*m)
1/2 inch	1.25 inches (32 mm) 2.25 inches (57 mm)	450-550 lb-in (51-62 N*m)



Hardware Description	Torque Value	
	Conical Washer OD	Hex Head Bolt (2) Conical Washers
5/16 inch	0.90 inches (23 mm)	145-260 lb-in (16-29 N*m)
3/8 inch	0.87 inches (22 mm)	250-280 lb-in (28-32 N*m)
	1 inch (25 mm)	130-150 lb-in (15-17 N*m)
1/2 inch	1.25 inches (32 mm) 2.25 inches (57 mm) 3.00 inches (76 mm)	780-900 lb-in (88-102 N*m)



9. Switchboard Insulation Resistance Chart

NOTE: The use of a AC dielectric tester for testing the switchboard is not recommended. Use an insulation resistance tester with a capacity of 500-1000 Vdc.

	Phase-to-Phase			Phase-to-Ground			Neutral-to-Ground
Date	All Disconnects Open						
	A-B	B-C	C-A	A-GND	B-GND	C-GND	N-GND
	Phase-to-Phase			Phase-to-Ground			Neutral-to-Ground
Date	All Disconnects Closed						
	A-B	B-C	C-A	A-GND	B-GND	C-GND	N-GND

10. Operations and Maintenance Documents

This *Recommended Practice* refers to manufacturer's packing label warnings (2.1a), instruction manuals, literature, drawings (Section 3), recorded values of tests (4.2, 7.3.2, 9), and set values of adjustable trips

(4.4 and 4.5a, 4.5d). This material, plus as-built drawings, should be assembled, identified and delivered to the owner of the facility at the completion of the installation.



(This appendix is not part of the standard)

Appendix A: Reference Standards

This publication, when used in conjunction with the National Electrical Code and switchboard manufacturers' literature, provides sufficient information to install and maintain deadfront switchboards operating at 600 volts and less. The following publications may also provide useful information:

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209
(703) 841-3200
(703) 841-3300 Fax

NEMA PB 2.1-1996, *General Instructions for Proper Handling, Installation, Operation, and Maintenance of Deadfront Distribution Switchboards Rated 600 Volts or Less*

NEMA PB 2.2-1988 (R1994), *Application Guide for Ground-Fault Protective Devices For Equipment*

NEMA AB 4-1996, *Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications*

National Fire Protection Association
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
(617) 770-3000
(617) 770-3500 Fax

ANSI/NFPA 70-1999, *National Electrical Code*

ANSI/NFPA 70B-1998, *Electrical Equipment Maintenance*

InterNational Electrical Testing Association
106 Stone Street
P.O. Box 687
Morrison, CO 80465
(303) 697-8441
(303) 697-8431 Fax

NETA ATS-1995, *Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*

NETA MTS-1993, *Maintenance Testing Specifications for Electrical Power Distribution*



National Electrical
Contractors Association
3 Bethesda Metro Center
Suite 1100
Bethesda, MD 20814
301-657-3110
fax: 301-215-4500
www.neca-neis.org

Standards & Safety
Index: NECA 409-2002
2.5K/11-02

