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Deadfront Distribution Switchboards

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Foreword

This Standards Publication is intended to provide a basis of common understanding within the electrical community by aiding the user and specifier in selection and specification of deadfront distribution switchboards for specific applications by stating:

a. The general standards for deadfront switchboards including the types, insulating requirements, unusual service conditions, service equipment requirements, ampacity, and markings
b. Standard switchboard ratings including short circuit current ratings
c. Test procedures and tests for switchboard design and production
d. Manufacturing standards for switchboards
e. Switchboard application standards to provide proper selection of a switchboard and its components to ensure satisfactory service

PB 2-2001 completely revises and supersedes PB 2-1995.

These standards are periodically reviewed by the Panelboard and Distribution Board Section of NEMA for any revisions necessary to keep them up-to-date with advancing technology. User needs have been considered throughout the development of this publication. Proposed or recommended revisions should be submitted to:

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Rosslyn, VA 22209

This Standards Publication was developed by the Panelboard and Distribution Board product group of the LVDE Section. At the time it was approved, the Panelboard and Distribution Board Section was composed of the following members:

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Current Technology, Inc.—Richardson, TX
Eaton Corporation—Pittsburgh, PA
The Durham Company—Lebanon, MO
GE—Plainville, CT
Hubbell, Inc.—Bridgeport, CT
Industrial Electric Mfg., Inc.—Fremont, CA
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Penn Panel & Box Company—Collingdale, PA
Post Glover Resistors, Inc.—Erlanger, KY
The Pringle Electrical Mfg. Co.—Fort Washington, PA
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Section 1
GENERAL

1.1 SCOPE

This Standards Publication covers floor-mounted deadfront switchboards rated 6000 amperes or less, 600 volts or less, which consist of an enclosure, molded case circuit breakers, low-voltage power circuit breakers, fusible or non-fusible switches, instruments, metering equipment, monitoring equipment or control equipment, with associated interconnections and supporting structures. These units are used in the distribution of electricity for light, heat, and power.

1.2 REFERENCED STANDARDS

American National Standards Institute
1430 Broadway
New York, NY 10018

C12.11-1987 (R1993)	*Instrument Transformers for Metering Purposes, 15kV and Less*
ANSI/IEEE C37.13-1990	*Low-voltage AC Power Circuit Breakers Used in Enclosures*
C37.16-1997	*Low-voltage Power Circuit Breaker and AC Power Circuit Breaker Protectors—Preferred Ratings, Related Requirements and Application Recommendations*
C37.17-1997	*Trip Devices for AC and General Purpose DC Low-Voltage Power Circuit Breaker*
C37.50-1989 (R2000)	*Test Procedures for Low-voltage (AC) Power Circuit Breaker Used in Enclosures*
ANSI/NEMA Z535.4-1998	*Product Safety Signs and Labels*

Institute of Electrical and Electronics Engineers
445 Hoes Lane
Piscataway, NJ 08855-1331

IEEE 141-1993	*Electric Power Distribution for Industrial Plants*

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1300 North 17th Street
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AB 3-2001	*Molded Case Circuit Breakers and Their Application*
FU 1-1986 (R1996)	*Low Voltage Cartridge Fuses*
ICS 1-1993 (R2000)	*General Standards for Industrial Control and Systems*

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KS 1-2001 *Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)*

PB 1-2001 *Panelboards*

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

PB 2.2-1999 *Application Guide for Ground Fault Protective Devices for Equipment*

250-1997 *Enclosures for Electrical Equipment (1000 Volts Maximum*)

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269

NFPA 70-2002 *National Electrical Code*

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 248-1-2000 *Low-Voltage Fuses – Part 1: General Requirements*

UL 248-4-2000 *Low-Voltage Fuses – Part 4: Class CC Fuses*

UL 248-6-2000 *Low-Voltage Fuses – Part 6: Class H Non-Renewable Fuses*

UL 248-7-2000 *Low-Voltage Fuses – Part 7: Class H Renewable Fuses*

UL 248-8-2000 *Low-Voltage Fuses – Part 8: Class J Fuses*

UL 248-9-2000 *Low-Voltage fuses – Part 9: Class K Fuses*

UL 248-10-2000 *Low-Voltage Fuses – Part 10: Class L Fuses*

UL 248-11-2000 *Low-Voltage Fuses – Part 11: Plug Fuses*

UL 248-12-2000 *Low-Voltage Fuses – Part 12: Class R Fuses*

UL 248-14-2000 *Low-Voltage Fuses – Part 14: Supplemental Fuses*

UL 248-15-2000 *Low-Voltage Fuses – Part 15: Class T Fuses*

UL 489-1996 *Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures*

UL 891-1998 *Dead-Front Switchboards*

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1.3 DEFINITIONS

accessible (switchboards): Not permanently closed in by the section structure and capable of being inspected and maintained, through access plates or doors, without disturbing switchboard section structure.

This is not intended to imply that the switchboard should be maintained while energized. There is danger due to hazardous voltage and exposed electrical conductors which will result in electric shock, burn, or explosion. Before performing any maintenance operations, turn off all power supplying the switchboard. Check the voltage of all incoming line terminals to positively ascertain that the equipment is totally de-energized. Failure to do so will result in electric shock, severe personal injury or death.

accessible, front: An enclosure in which all bus and device connections are accessible from the front. If necessary, a limited number of devices shall be permitted to be removed to achieve this accessibility.

accessible, rear: An enclosure in which all incoming and outgoing cable or bus connections are accessible from the rear. Other connections shall be permitted to be front accessible.

ambient temperature: The temperature of the air or other medium where the equipment is to be used.

ampacity: The current in amperes a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

asymmetrical current: An alternating current having a waveform which is offset with respect to the zero axis due to a transient condition. The offset occurs at the initiation of a short circuit or other change in current. The offset usually decays quickly until steady-state conditions are reached and the current becomes symmetrical. Asymmetrical current is composed of the symmetrical and direct current components. It is expressed in rms total amperes or rms asymmetrical amperes at a specific time (normally $^{1}/_{2}$ cycle) after initiation of a short circuit or other change in current.

auxiliary section: A section other than the main, distribution, or combination section.

auxiliary switch: Switches which are mechanically operated by a main switching device for switching, interlocking, or other purposes. Auxiliary switch contacts shall be permitted to be designated as "a" or "b" as indicated below, but other contact arrangements shall be permitted to be used.

"a" contacts are open when the switching device contacts are open or tripped and closed when the switching device contacts are closed.

"b" contacts are closed when the switching device contacts are open or tripped and open when the switching device contacts are closed.

available short circuit current: The maximum current in rms symmetrical amperes which a circuit is capable of delivering to the line terminals of the equipment.

barrier: A partition for the insulation or isolation of electric circuits or electric arcs.

bonding: The permanent joining of metallic parts to form an electrically conductive path that will assure electrical continuity and the capacity to conduct safely any current likely to be imposed.

bonding jumper: A reliable conductor to assure the required electrical conductivity between metal parts required to be electrically connected.

bonding screw: A screw that is used as a bonding jumper or to attach a bonding jumper to a metal part of a grounding circuit.

branch circuit device: The final overcurrent device protecting a circuit.

bus: A conductor, or group of conductors, that serves as a common connection for two or more circuits.

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bus, branch: A bus that usually originates at a section bus and terminates in one or more overcurrent devices.

bus, ground: A bus to which the equipment grounding conductors from individual pieces of equipment are connected and which, in turn, is connected to the grounding electrode conductor at one point. It provides a continuous ground in multiple equipment sections through which it passes. (See Figures 1-1, 1-2, and 1-3)

bus, mimic: A single-line diagram on the face of the equipment showing the principal connections of a system.

bus, neutral: A bus having the appropriate number of terminals to provide for the connection of the neutral line and load conductors.

bus, section: A portion of a bus structure which serves one or more overcurrent devices in the switchboard section and comprises that part of the bus between the through bus and branch bus.

bus, splice: A bus that electrically connects switchboard sections.

bus, supply: The bus that conducts electric power from the source terminations to the main disconnect device(s).

bus structure: An assembly of bus conductors with associated connecting joints and insulating supports.

bus, through: A bus that extends through a switchboard section. It is sometimes called a horizontal, cross, or main bus.

circuit breaker: A device designed to open and close a circuit by non-automatic means, and to open the circuit automatically on a predetermined overcurrent, without damage to itself when properly applied within its rating.

circuit breaker, low voltage power:
A mechanical switching device, capable of making, carrying, and breaking currents under normal circuit conditions and also, making and carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit. Rated 1000 V ac or below, or 3000 V dc and below, but not including molded-case circuit breakers.

circuit breaker, molded case: A circuit breaker which is assembled as an integral unit in a supporting and enclosing housing of insulating material.

clearing I^2t: The measure of heat energy developed as a result of current flow between the time that current begins to flow and until the overcurrent protective device clears the circuit. "I^2" stands for the square of the effective (rms) let-through current and "t" stands for the time of current flow in seconds.

clearing time: The total time measured from the beginning of the specified overcurrent condition until the interruption of the circuit at rated voltage.

combination section: A switchboard section which performs the functions of both the distribution and main sections.

compartment: An area within the equipment that is constructed to isolate devices in that compartment from the surrounding area except for openings used for interconnections, control, or ventilation.

continuous current rating: The amount of current a conductor, a device or a piece of equipment can carry continuously for an indefinite period of time without exceeding its allowable temperature rise.

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continuous load: A load where the maximum current is expected to continue for three hours or more.

control wiring: The wiring for the circuit(s) of a piece of equipment that carries the electrical signals directing the performance of the devices in that equipment, but which does not carry power current.

current-limiting device: An overcurrent protective device that interrupts all available overcurrents within its interrupting rating and, within its current-limiting range, limits the clearing time at rated voltage to a time interval equal to or less than the first major current loop duration, and limits peak let-through current to a value less than the peak current that would be possible with the device replaced by a solid conductor of the same impedance.

current-limiting range: The range of an overcurrent protective device is that range of symmetrical rms available currents equal to and less than the interrupting rating of the device in which the total clearing time at rated voltage and frequency is less than $^{1}/_{2}$ cycle.

current rating: The designated maximum direct or alternating current in rms amperes at rated frequency that a device can carry continuously under specified conditions.

deadfront switchboard: A switchboard which has no exposed live parts on the front.

device: A component of an electrical system that is intended to carry or control, but not utilize, electrical energy.

dielectric withstand tests: Tests to determine the ability of the insulating materials and spacings to withstand overvoltages.

disconnecting means: A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

distribution section: A switchboard section having branch or feeder circuit switching and overcurrent protective devices.

drawout mounted device: An assembly of a device (circuit breaker or switch) together with a supporting structure constructed so that the device is supported and can be moved to either the main circuit connected or disconnected position without the necessity of removing connections or mounting supports. The structure includes both self-supporting circuit terminals and an interlocking means which permits movement of the device between the main circuit connected and disconnected positions only when the device contacts are in the open position.

enclosure: A surrounding case constructed to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection to the enclosed equipment against specified environmental conditions.

fixed-mounted device: See **stationary mounted device.**

frame size: Applies to a group of molded case circuit breakers that are physically interchangeable with each other. Frame size is expressed in amperes and corresponds to the largest ampere rating available in the group. Groups may or may not be physically interchangeable with each other whether furnished by one manufacturer or by various manufacturers.

fuse: A protective device which opens by the melting of a current-sensitive element during specified overcurrent conditions.

fusible switch: A switch in which one or more poles have a fuse in series in a composite unit.

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grounded: Connected to earth or to some conducting body that serves in place of the earth.

grounded conductor: A system or circuit conductor that is intentionally grounded.

ground-fault protector (GFP): A ground-fault protector is a device or system that provides protection for equipment (not for personnel) by opening the circuit in case of a predetermined ground-fault current. A ground-fault protector includes a ground-fault current sensing device and relaying equipment or a combination of ground-fault current sensing device and relaying equipment that will operate to cause a disconnecting means to function at a predetermined value of ground-fault current.

grounding conductor, equipment: The conductor used to connect noncurrent-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor, the grounding electrode conductor, or both, at the service equipment or at the source of a separately derived system.

grounding electrode conductor: The conductor used to connect the grounding electrode to the equipment grounding conductor, to the grounded conductor, or to both, of the circuit at the service equipment or at the source of a separately derived system.

group mounted device: See **panel mounted device**.

individually mounted device: A device which is not panel-mounted and which may or may not be enclosed in its own compartment.

insulation level: The insulation strength of a material expressed in terms of an rms withstand voltage.

interlock: An electrical or mechanical component actuated by the operation of a device or other means, with which it is directly associated to govern succeeding operations of the same or allied devices.

interrupting rating: The highest current at rated voltage that a device is intended to interrupt under standard test conditions.

isolated: Not accessible to personnel unless special means for access are used.

isolated device: A device which is segregated from other devices by metal or insulating barriers or enclosures and which is not readily accessible to personnel unless special means for access are used.

main section(s): A portion of a switchboard where the main or service disconnect device(s) is located. The section shall also be permitted to contain utility meters or other instruments. Incoming line conductors may be terminated in this section.

main device: A single device that disconnects all ungrounded conductors, other than control power conductors when used, from the supply bus. (See Figure 1-1)

neutral (assembly); solid neutral: An assembly consisting of an appropriate number of terminals to provide for the connection of the grounded (neutral) line and load conductors. When used as a component of service equipment, the neutral also includes: (1) a means for making the required bonding connection between the neutral and the enclosure; and (2) a terminal for the service grounding conductor (unless that terminal is located as in Fig. 1-2).

neutral conductor: A conductor that is connected to the midpoint of a three-wire single-phase system, the center point of a wye-connected three-phase system, or the midpoint of one side of a delta-connected three-phase system.

panel-mounted device: One of a closely grouped assembly of devices which is mounted on a common base or mounting surface utilizing panelboard type construction. The total combination is then mounted in a switchboard combination or distribution section.

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peak let-through current: The maximum instantaneous current through an overcurrent device during the total clearing time.

rating: A designated limit of operating characteristics based on definite conditions.

service equipment: The necessary equipment, usually consisting of a circuit breaker or switch and fuses, and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cutoff of the supply.

short circuit current rating: The maximum RMS prospective (available) current to which a device can be connected. The rating is expressed in amperes and volts.

stationary mounted device: A device which can be removed only by unbolting electrical connections and mounting supports.

switch: A device, manually operated, unless otherwise designated, for opening and closing or for changing the connection of a circuit.

switchboard: A large single panel, structural frame, or assembly of panels or structural frames on which may be mounted, on the face or back or both: switches, overcurrent, and other protective devices, buses, and instruments. Switchboards may be accessible from the rear as well as from the front and are not intended to be installed in cabinets.

switchboard section: A portion of a switchboard which is prevented by the structural framework from being physically separated into smaller units.

symmetrical current: Symmetrical current is alternating current having no offset or transient component and, therefore, having a wave form essentially symmetrical about the zero axis. Symmetrical current is expressed in terms of rms amperes.

temperature rise: The difference in temperature between the temperature of the part under consideration and the ambient temperature.

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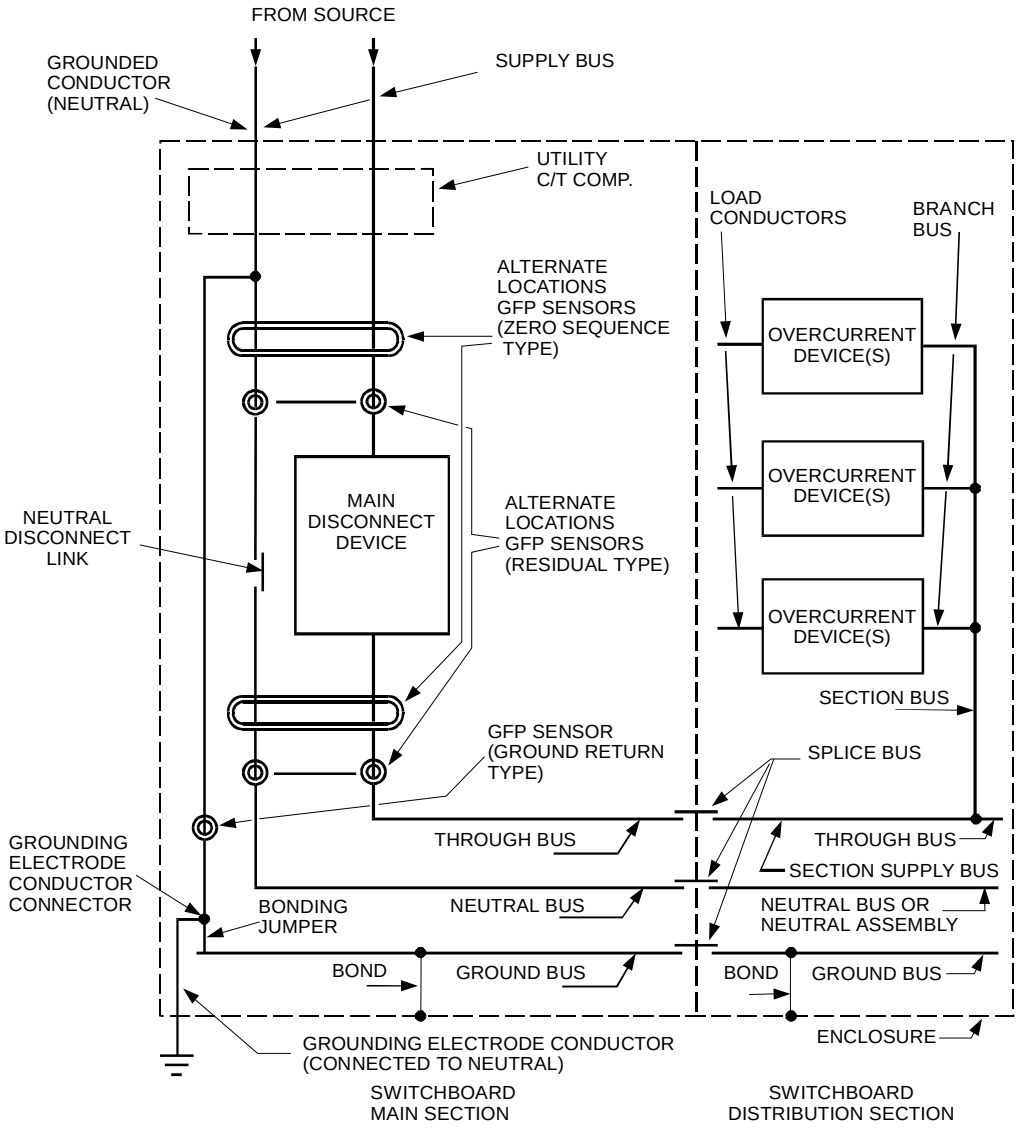


Figure 1-1
SERVICE EQUIPMENT-SYSTEM GROUND CONNECTED TO NEUTRAL
TYPICAL DEADFRONT SWITCHBOARD LAYOUT

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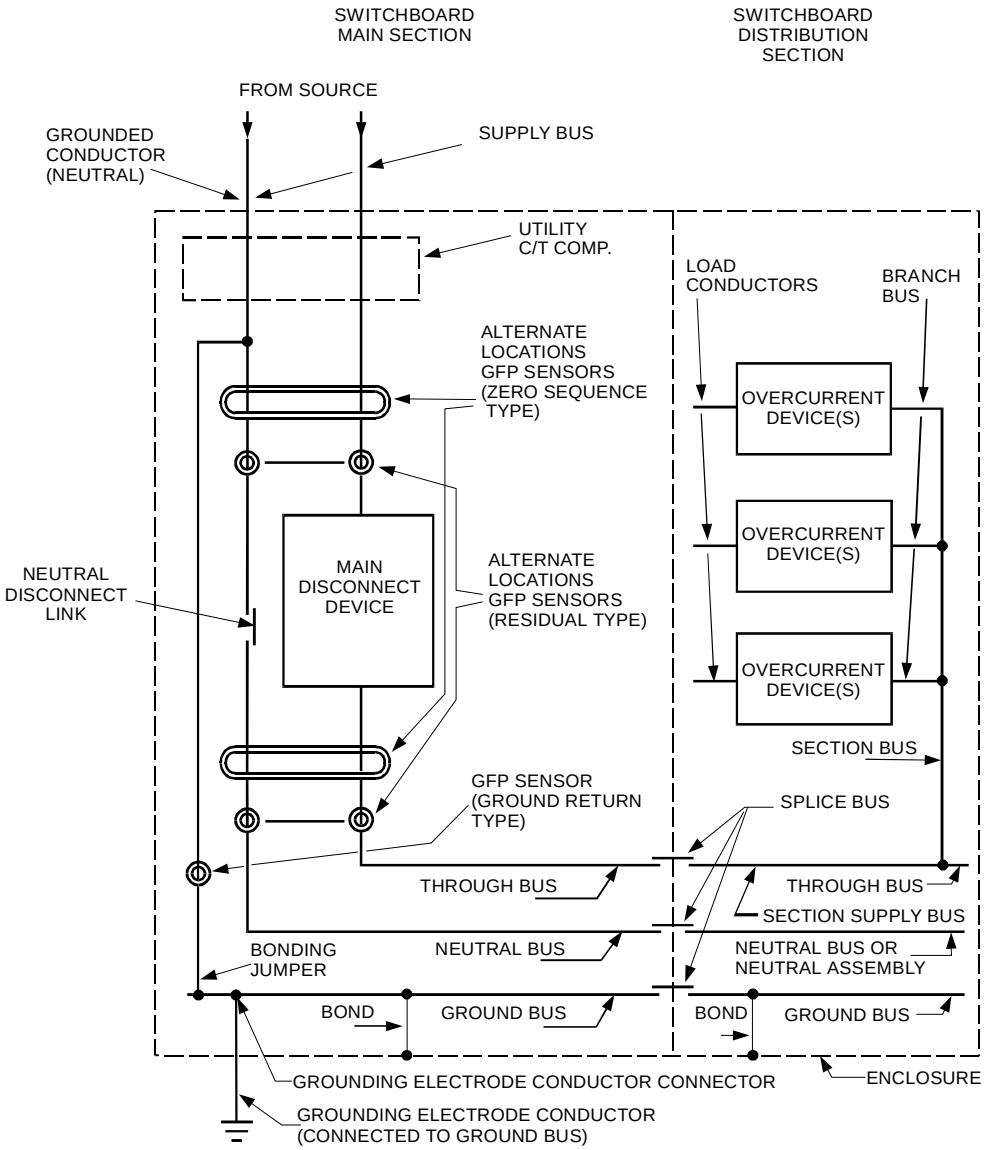


Figure 1-2
SERVICE EQUIPMENT-SYSTEM GROUND CONNECTED TO GROUND BUS
TYPICAL DEADFRONT SWITCHBOARD LAYOUT

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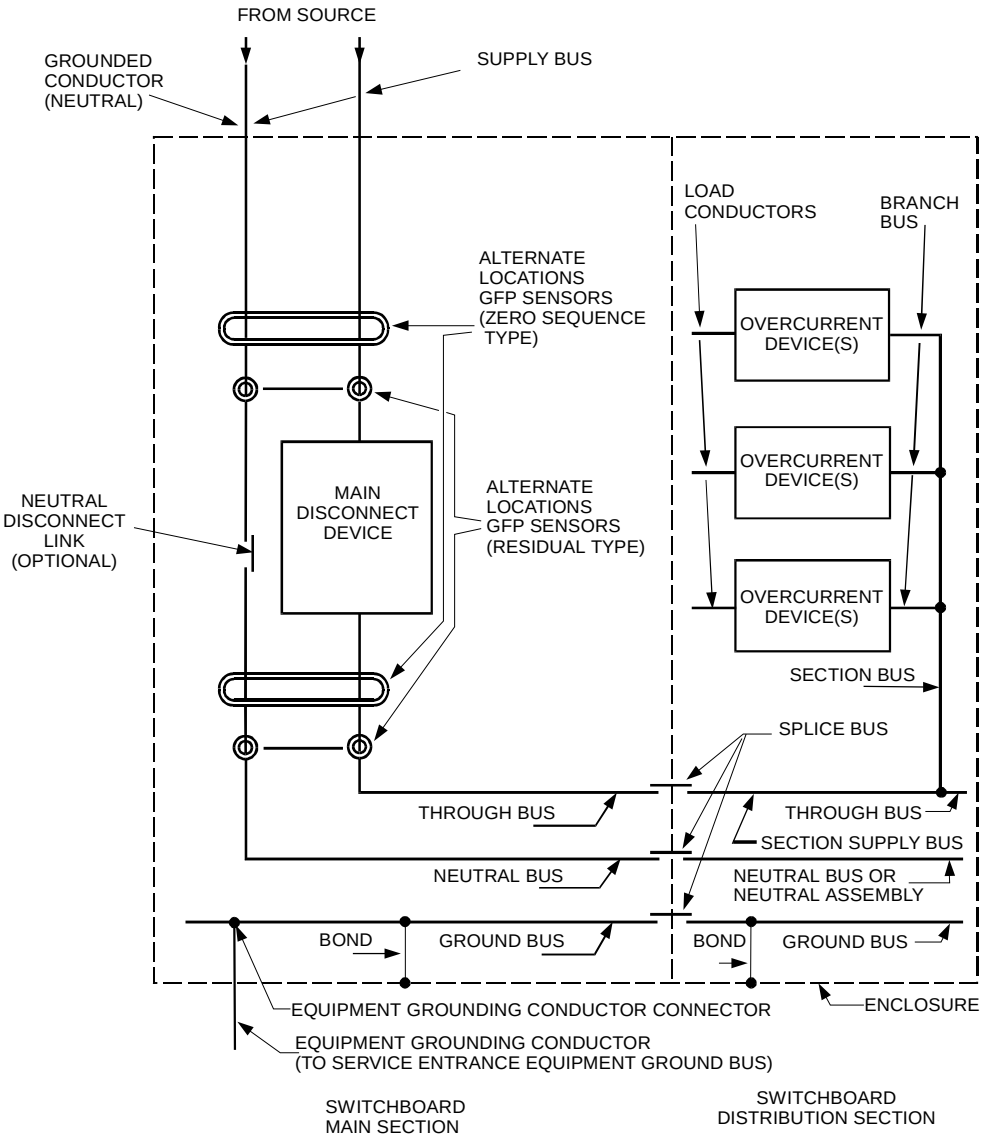


Figure 1-3
NON-SERVICE TYPICAL DEADFRONT SWITCHBOARD LAYOUT EQUIPMENT

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Section 2
CLASSIFICATIONS, CHARACTERISTICS, AND RATINGS

2.1 GENERAL STANDARDS

2.1.1 Arrangement

A switchboard consists of one or more main, distribution, combination, and auxiliary sections which are electrically and mechanically interconnected.

Devices shall be applied in accordance with the manufacturer's instructions.

Main disconnect devices may be individually mounted or can be an integral part of a panel mounted assembly.

2.1.2 Equipment Specification

In order to ensure that the proper switchboard is selected for a particular application, the user should provide the manufacturer with the following equipment specifications:

a. Rating of supply
    1. Voltage
    2. Number of phases
    3. Current in amperes
    4. Available short circuit-current at the line terminals of the switchboard in rms symmetrical amperes
    5. Frequency (if other than 60 Hz.)
b. Neutral ampacity as a percentage of the switchboard ampere rating
c. Cables
    1. Size
    2. Type
    3. Number
    4. Entry location (top or bottom)
d. Busway
    1. Entry location(s) and phase orientation
    2. Description
    3. Grounding method
e. Ground-fault protection
    1. System type
    2. Settings
f. Enclosure type
g. Main disconnect devices
    1. Type (circuit breaker, switch, etc.)
    2. Ampere rating
    3. Poles
    4. Quantity
h. Branch circuit devices
    1. Type (circuit breaker, switch, etc.)
    2. Ampere rating
    3. Poles
    4. Quantity
    5. Location or sequence of branch devices if specifically required

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i. Local requirements
   1. *National Electrical Code*
   2. Local electrical codes
   3. Utility codes
   4. Others
j. Intended application: service equipment, non-service equipment, separately derived system secondary, second building disconnect
k. Construction features
   1. Front accessible, rear accessible, front and side accessible, rear and side accessible, etc.
   2. Individually mounted
   3. Panel (Group) mounted
   4. Compartmented
l. Unusual service conditions (see 2.1.4)
m. Alignment of sections (if different depths)*
n. Where working access will be available (front, rear, side)

* Sections are aligned when their front or rear surfaces, or both, are in the same plane. This choice is important when sections vary in depth.

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Table 2-1
AMBIENT TEMPERATURE RANGES OF DEVICES COMMONLY MOUNTED IN SWITCHBOARDS

Device	Ambient Temperature Ranges	Reference Publications
Molded case circuit breakers	-5°C through + 40°C	UL 489
Enclosed switches	-30°C through + 40°C	NEMA KS 1
Low voltage cartridge fuses		UL 248-1 UL 248-4 UL 248-6 UL 248-7 UL 248-8 UL 248-9 UL 248-10 UL 248-11 UL 248-12 UL 248-14 UL 248-15 NEMA FU 1
Low voltage power circuit breakers	-30°C through + 40°C	ANSI C37
Electromagnetic and manual motor control at 6000 feet and less	+ 40°C maximum	NEMA ICS series

2.1.3 Usual Service Conditions

Switchboards conforming to this Standards Publication shall be suitable for operation:

a. When and where the ambient temperature is within the limits of devices mounted therein (see Table 2-1)
b. Where the altitude does not exceed 6600 feet (2000 meters)

2.1.4 Unusual Service Conditions

When unusual service conditions exist, such conditions should be brought to the manufacturer's attention when specifying the switchboard since additional construction or protection features may be required. Among such unusual conditions are unusual ambient temperatures, high humidity, high altitude, exposure to corrosive or explosive fumes, dust, vapors, abnormal vibration, mechanical shock, tilting or unusual operating duties.

2.1.5 Temperature Limits

2.1.5.1 Temperature Limits for Switchboards

The maximum allowable temperature limit for switchboards is based on an allowable temperature rise over a prescribed ambient temperature as described in UL 891.

2.1.5.2 Temperature Limits for Parts Subject to Contact by Personnel

A part handled by personnel or external surfaces accessible to personnel during the normal course of their duties shall not attain a total temperature higher than 60°C (140°F) if made of metal, or 85°C (185°F) if made of plastic.

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2.1.5.3 Temperature Limits for Parts Not Subject to Contact by Personnel

External surfaces which are not accessible to personnel during the normal course of their duties shall not attain a total temperature higher than 110°C (230°F).

2.2 RATING STANDARDS

2.2.1 General

The ratings of a switchboard are designations of operating limits under specified conditions of ambient temperature, temperature rise, and so forth.

Switchboards shall have the following ratings:

a. Voltage (See 2.2.2)
b. Short-circuit current (See 2.2.6 and 2.2.7)
c. Frequency (See 2.2.3)
d. Continuous current (See 2.2.4)
e. Insulation level (See 2.2.5).

2.2.2 Voltage Ratings

The voltage rating of a switchboard section or interior shall not be greater than 600 volts and is the maximum value for which the assembly has been evaluated. Common ratings are shown in Table 2-2.

2.2.3 Frequency Rating

The frequency rating of ac switchboards shall be either 50, 60, or 50/60 hertz unless otherwise specified.

2.2.4 Continuous Current Rating

2.2.4.1 Through Bus Rating

Common continuous current ratings of a switchboard through bus are 400, 600, 800, 1000, 1200, 1600, 2000, 2500, 3000, 3200, 4000, 5000, or 6000 amperes. Other ratings are not prohibited.

2.2.4.2 Section Supply Rating

A switchboard section shall be assigned a continuous current supply rating which does not exceed the ampacity of the bus or cable which supplies power to the section.

2.2.4.3 Section Rating

A switchboard section shall be assigned a continuous current section rating which does not exceed the ampacity of the section bus or section disconnect. If the ampacities of the several section bus bars in a section, including the neutral bus bar, are not identical, the section continuous current rating shall specify the ampacity of each section bus bar or terminal.

Exception: The continuous current section rating can exceed the rating of the section disconnect, when markings indicate that the assigned value is a maximum and make reference to the section disconnect.

2.2.5 Insulation Level Rating

The insulation level rating of switchboards having a given voltage rating shall be twice the rated voltage plus 1000 volts. DC switchboards shall be permitted to be tested with alternating current equivalent. See 2.2.2 for system voltages.

2.2.6 Basis of Short-Circuit Current Rating of Switchboards

The short-circuit current rating assigned to the switchboard shall not exceed the interrupting rating or short-circuit current rating of any component in the power circuit which is installed in its intended manner.

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Exception: A higher rating shall be permitted to be assigned to a switchboard for a specific combination of components provided that the series combination has passed short-circuit tests qualifying it for its assigned short-circuit current rating and the switchboard is suitably marked to identify the required upstream overcurrent protective device. In no case shall the short-circuit current rating exceed the interrupting rating of the first (upstream) overcurrent device in the specific combination.

The short-circuit current rating of a switchboard shall be in rms symmetrical amperes.

2.2.7 Short-Circuit Current Ratings of Switchboard Devices

2.2.7.1 Circuit Breakers

The short-circuit current rating of a circuit breaker used as a device in a switchboard shall be its interrupting rating of 5000; 7500; 10,000; 14,000; 18,000; 20,000; 22,000; 25,000; 30,000; 35,000; 42,000; 50,000; 65,000; 85,000; 100,000; 125,000; 150,000; or 200;000 rms symmetrical amperes. The manufacturer shall be consulted for interrupting current ratings at specific voltages.

2.2.7.2 Fusible Switches

The short-circuit current rating of a fusible switch as a device in a switchboard shall be the interrupting current rating of the installed fuses or the short-circuit current rating of the switch, whichever is smaller. The ratings of fuses and switches used in combination shall be 10,000; 25,000; 50,000; 100,000; or 200,000 rms symmetrical amperes.

2.2.7.3 Other Devices

The manufacturer should be consulted for rating information for other devices or combination of devices used in switchboards.

Table 2-2
COMMON VOLTAGE RATINGS OF SWITCHBOARDS

System		Voltage Ratings, Volts	
Number of Phases	Number of Wires	Alternating Current	Direct Current
1 (or direct current)	2	120, 240, 277	125, 250
1 (or direct current)	3	120/240, 208Y/120 480Y/277	125/250
3 (derived from 3-phase 4-wire system)	3	208Y/120, 220Y/127 440Y/254, 480Y/277	. . .
3	3	120, 240, 480, 600	. . .
3	4 wire delta with the neutral at midpoint of one phase	240/120	. . .
3	4 wire wye with neutral	208Y/120, 220Y/127 440Y/254, 480Y/277, or 600Y/347	. . .

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Section 3
PRODUCT MARKING

3.1 REQUIRED INFORMATION

Switchboards shall be clearly marked with the following information:

a. Manufacturer's name or trademark
b. Catalog number or type designation
c. Current rating
d. Voltage rating
e. Number of phases (if ac rated)
f. Short circuit current rating
g. Conductor temperature rating

3.2 LOCATION OF MARKINGS

To make persons aware of immediate or potential hazards in the application, installation, use, maintenance, or inspection of switchboards, each switchboard section shall be conspicuously marked on all sides having removable covers with a product safety label that complies with ANSI Z535. (See Figure 3-1.)

3.3 NATIONALLY RECOGNIZED STANDARDS OR APPLICABLE LAWS OR REGULATIONS

These requirements are not intended to rule out the use of other labels or markings which are required to comply with other nationally recognized standards or applicable laws or regulations, or which may be deemed necessary by the manufacturer.

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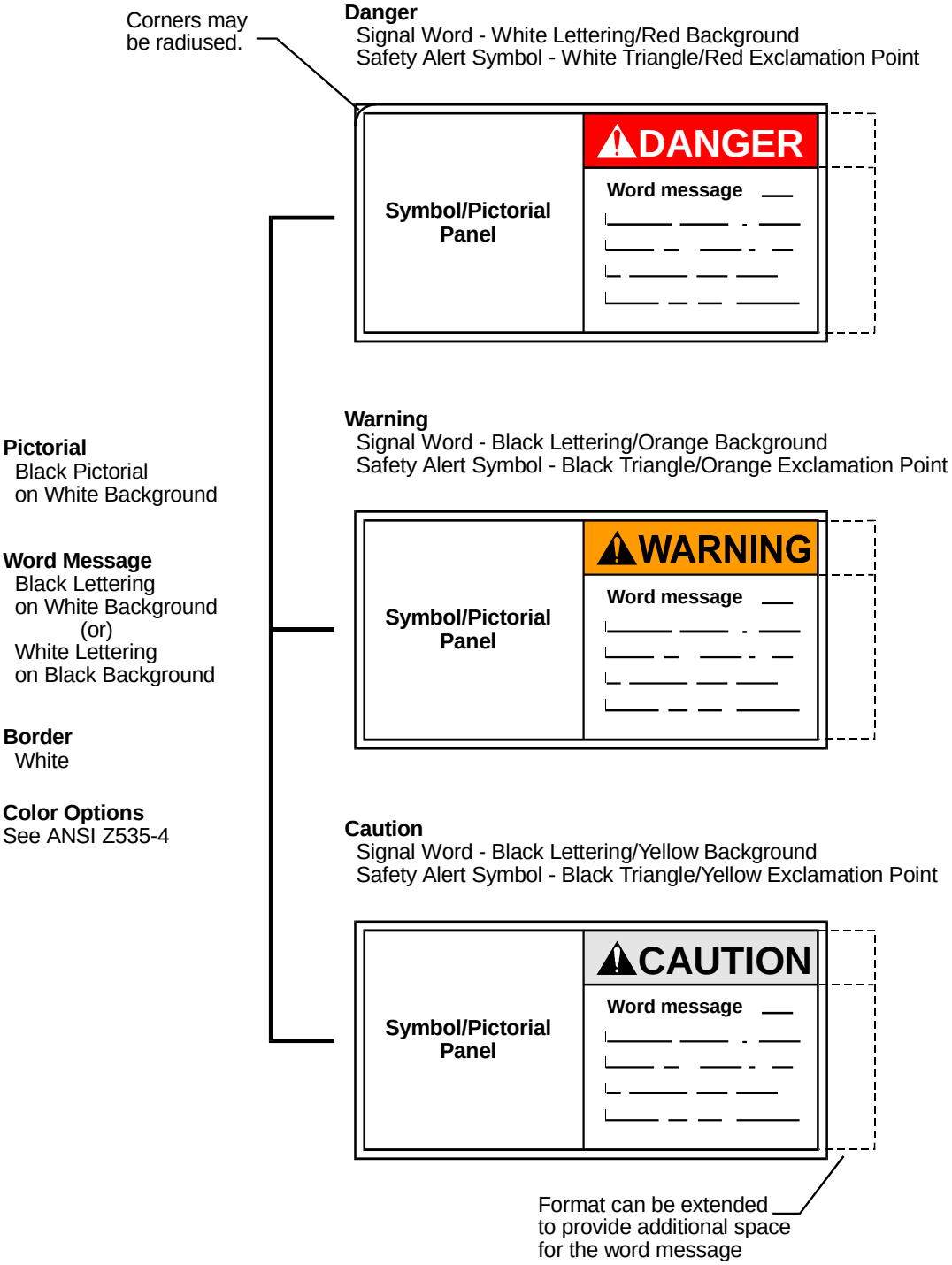


Figure 3-1
PRODUCT SAFETY LABEL

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Section 4
INSTALLATION, MAINTENANCE, AND STORAGE

See NEMA Publication PB 2.1 for installation, maintenance and storage instructions.

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Section 5
CONSTRUCTION

5.1 GENERAL

The construction of switchboard assemblies covered by this Standards Publication shall be in accordance with UL 891.

5.2 TYPE OF ENCLOSURE

Switchboards are typically provided with Type 1, 2, 3R, or 5 enclosures as specified in NEMA Publication 250.

5.2.1 Type 1

Enclosures constructed for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection against falling dirt.

5.2.2 Type 2

Enclosures constructed for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment, to provide a degree of protection against falling dirt, and to provide a degree of protection against dripping and light splashing of non-corrosive liquids.

5.2.3 Type 3R

Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, and snow; and that will be undamaged by the external formation of ice on the enclosure.

5.2.4 Type 5

Enclosures constructed for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt; against settling airborne dust, lint, fibers, and flyings; and to provide a degree of protection against dripping and light splashing of non-corrosive liquids.

5.3 HEIGHT OF INDOOR ENCLOSURES

The nominal installed maximum height of the enclosure is 90 in. (228.6 cm), excluding floor sills, lifting members, and pull boxes.

5.4 PHASE OR POLARITY ARRANGEMENTS

The phase arrangement on three-phase switchboard buses shall be A, B, C, from front to back, top to bottom, or left to right, as viewed from the front of the switchboard. On a 3-phase, 4-wire delta system, the B phase shall be that phase having the higher voltage to ground.

An exception to this arrangement shall be permitted in the case of equipment within the same switchboard as the metering equipment on 3-phase, 4-wire delta connected systems where the equipment shall be permitted to have the same phase configuration as the metering equipment.

The phase arrangement for a 240-volt, 3-phase, 3-wire switchboard section or interior for use on a grounded B phase system shall be permitted to be A, C, with the neutral assembly as the B phase.

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Other arrangements shall be permitted where a switchboard section or interior is manufactured for addition to existing installations and the arrangement of the bus bars is indicated by marking.

Unless otherwise specified, polarities on dc assembled switchboard buses shall be arranged positive, neutral, negative, front to back, top to bottom, or left to right as viewed from the front of the switchboard.

5.5 GROUNDING AND BONDING

Refer to UL 891 for grounding and bonding requirements for both single section and multi-section switchboards.

Grounding provisions shall be made for all drawout devices to ensure that they are grounded until all ungrounded electrical connections are disconnected by a safe distance.

When mounted on metal switchboard structures, metallic cases of instruments, instrument transformers, meters, relays, and similar devices shall be considered as being adequately grounded when secured by metal mounting screws having adequate provision for piercing the paint film.

5.6 UTILITY TRANSFORMER COMPARTMENT

Switchboard assemblies containing current transformer (CT) compartments for utility metering shall be arranged as specified by the utility, or as shown in Figure 5-1.

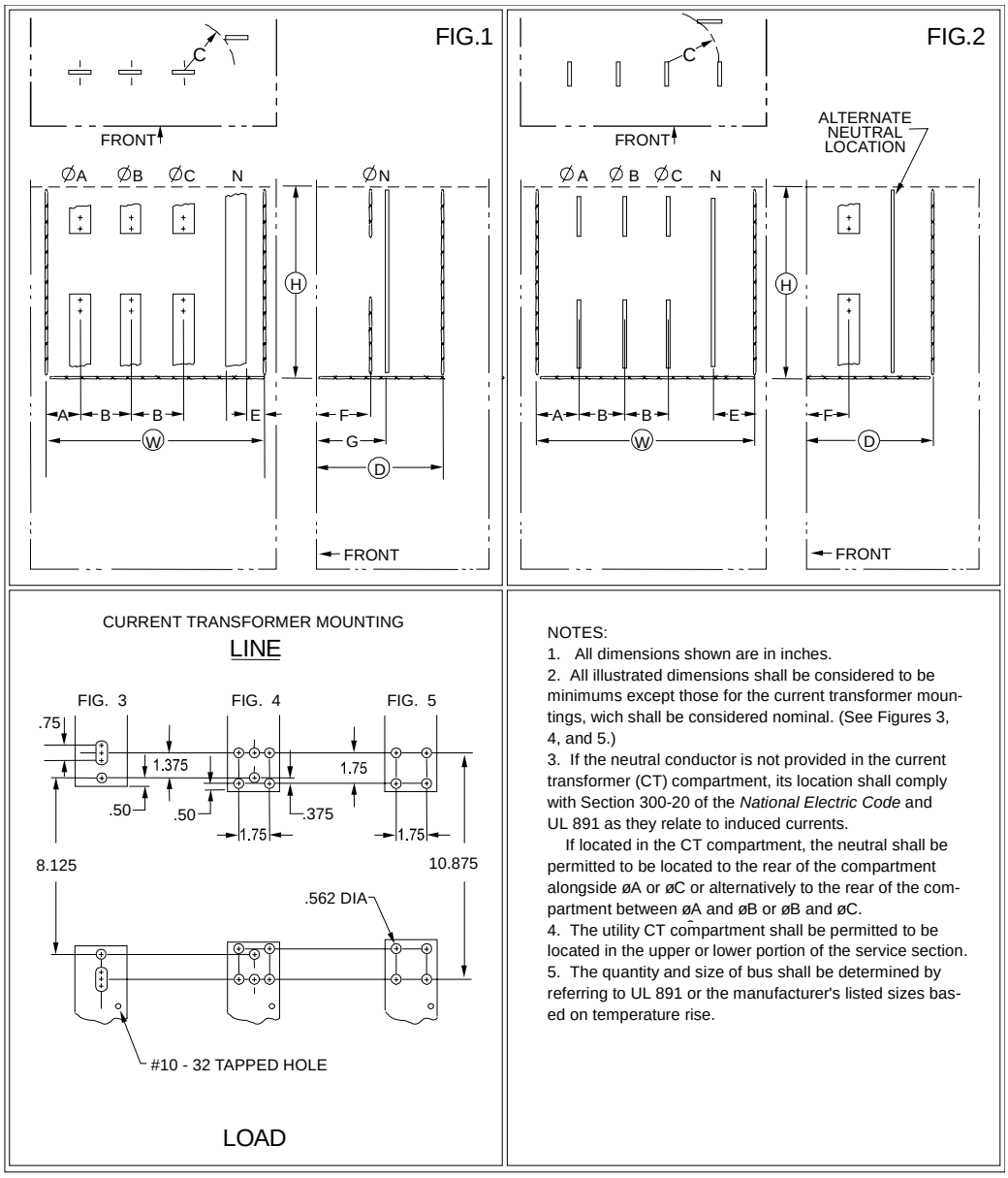
Mounting provisions shall be provided for the installation of either bar or window type transformers built to the specifications of ANSI C12.11.

The front of the CT compartment shall be accessible through a sealable hinged single or double door or removable cover.

Barriers constructed in accordance with the material and thickness requirements of UL 891 shall be installed, as required, to prevent access to the compartment through other than the sealable doors or covers.

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AMPS.	FIG.	COMPARTMENT			BUS DRILLING FIGURE	A	B	C	E	F	G
		(H)	(W)	(D)							
400 - 800	1	20	28	12	3	5	9	5	2	6	SEE NOTE 3
801 -1200	1 OR 2	20	28	12	4	5	9	5	2	6	
1201 - 2000	1 OR 2	20	28	12	5	6	9	6	2	6	
2001 - 3000	1 OR 2	20	30	12	5	6.5	9	6.5	2	6.188	
3001 - 4000	1 OR 2	20	35	16	5	7	9	7	2	6.188	

Figure 5-1
UTILITY CURRENT TRANSFORMERS COMPARTMENTS

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Section 6
TEST STANDARDS

6.1 CLASSIFICATION OF TESTS

6.1.1 Design Tests

Design tests are those which are made to determine the adequacy of the design of a particular type, style or model of switchboard assembly to meet its assigned ratings and to operate satisfactorily under normal service application conditions or under special application conditions if specified. Design tests are made only on representative new switchboard assemblies to substantiate ratings assigned to all other assemblies of a similar design and are not expected to be repeated under normal production.

Design tests for a switchboard shall include the following:

a. Temperature Rise Tests (See 6.1.1.1.)
b. Short-circuit Current Test (See 6.1.1.2.)
c. Enclosure Tests (See 6.1.1.3.)
d. Dielectric Test (See 6.1.1.4.)

6.1.1.1 Temperature Rise Tests

A temperature rise test shall be made unless the bus bars are of a size sufficient to provide a current density not more than that permitted by UL 891. However, regardless of bus size, a temperature rise test shall be made if a switchboard uses one or more switches, fuseholders, or circuit breakers having plug-in connections to the bus bars.

When temperature rise tests are made, they shall be conducted in accordance with requirements of UL 891.

For ratings above 4000 amperes, bus bar sizes are subject to special considerations such as bus density, construction, bus location, spacing between bars, structure, frame material, and ventilation.

6.1.1.2 Short-Circuit Test

Short-circuit current tests shall be conducted according to the requirements of UL 891.

The short-circuit current rating of a switchboard shall be determined by test of representative through section and branch bus configurations, and cable arrangements and connections, which are integral to the switchboard assembly.

Tests shall be run to determine the adequacy of the bracing for different methods of routing incoming conductors, such as bus extensions, busways, or cables, which are an integral part of the switchboard assembly.

Short-circuit current ratings shall be given in rms symmetrical amperes at the corresponding voltage. (See 2.2.7.)

6.1.1.3 Enclosure Tests

Switchboard enclosures shall be tested to the applicable requirements of NEMA 250, as amended by specific requirements in UL 891.

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6.1.1.4 Dielectric Tests

6.1.1.4.1 Test Voltage and Points of Application

A switchboard shall withstand for 1 minute without breakdown the application of a 60-hertz sinusoidal potential of 1000 volts plus twice rated voltage:

a. Between live metal parts and dead metal parts with all switching devices closed
b. Between live metal parts of opposite polarity with all switching devices closed

Overcurrent devices such as fuses, trip units of circuit breaker frames designed for use with interchangeable trip units, and so forth shall be in place wherever provisions are made for their use. A transformer, coil, or other device normally connected between lines of opposite polarity shall be disconnected from one side of the line during the test specified in item b.

6.1.1.4.2 Testing Transformer and Duration Application

The test potential shall be supplied from a suitable 500 volt-ampere or larger testing transformer, the output voltage of which can be adjusted. The applied potential shall be increased gradually from zero until the required test value is reached and shall be held at that level for one minute.

A smaller transformer shall be permitted to be used if the transformer is provided with a suitable voltmeter to directly measure the applied output potential.

6.1.2 Production Tests

Production tests are those which are made on completed switchboard assemblies or component parts to check the quality and uniformity of the workmanship and materials used in the manufacture of switchboards.

Production tests for a switchboard shall include:

a. 60-hertz dielectric tests (See 6.1.2.1.)
b. Mechanical operation tests (See 6.1.2.2.)
c. Grounding of instrument transformer cases test (See 6.1.2.3.)
d. Electrical operation and control wiring tests (See 6.1.2.4.)
e. Ground-fault sensing equipment test (See 6.1.2.5.)

6.1.2.1 Dielectric Tests

For production tests, repeat the dielectric tests described in 6.1.1.4, or as an alternate to applying a 60-hertz sinusoidal potential of 1000 volts plus twice rated voltage for 1 minute, 120 percent of the above test potential shall be applied for 1 second.

If a switchboard section involves a meter or meters, such instruments shall be disconnected from the circuit during the test. The meter or meters shall then be tested separately by applying for 1 minute a 60-hertz essentially sinusoidal potential between live parts and dead-metal parts. The test potential shall be 1000 volts in the case of an ammeter, and 1000 volts plus twice the rated voltage in the case of a voltmeter, wattmeter or other instrument.

6.1.2.2 Mechanical Operation Tests

Mechanical tests shall be performed to ensure that removable unit operating mechanisms, mechanical interlocks, and so forth, function properly and that removable units which are intended to be interchangeable are interchangeable.

6.1.2.3 Grounding of Instrument Transformer Cases Test

The continuity of the grounding of metallic instrument transformer cases or frames shall be checked with a low potential source (10 volts or less) using bells, buzzers, or lights.

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6.1.2.4 Electrical Operation and Control Wiring Tests

6.1.2.4.1 Control Wiring Continuity

The correctness of the control wiring of a switchboard assembly shall be verified by either:

a. Actual electrical operation of the component control devices
b. Individual circuit continuity checks with electrical circuit testers

6.1.2.4.2 Control Wiring Insulation Test

A 1500-volt, 60-hertz test voltage shall be applied from live metal parts to dead-metal parts in the control circuit after all circuit grounds have been disconnected. All circuits shall be wired together with small bare copper wire in order to short circuit voltage sensitive components such as coil windings and solid-state electronic devices.

6.1.2.4.3 Polarity Tests

Tests shall be made to ensure that instrument transformers are correctly connected for polarity.

Analog type instruments shall be tested to ensure that pointers move in the proper direction.

Meters and relays shall be tested to ensure that their polarity will not cause improper functioning.

6.1.2.4.4 Sequence Tests

Switchboard assemblies involving the sequential operation of devices shall be tested to ensure that these devices function properly and in their intended order.

The sequence test need not be made on remote equipment controlling or controlled by the switchboard assembly.

6.1.2.5 Ground-Fault Sensing Equipment Test

Switchboards containing ground-fault sensing equipment shall be tested in accordance with UL 891.

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Section 7
APPLICATION STANDARDS

7.1 SELECTION OF APPARATUS

Switchboards should be properly selected to ensure satisfactory service. Switchboards conforming to these standards are suitable for operation in accordance with their ratings under usual service conditions. (See 2.1.3.) Where switchboards are subjected to unusual service conditions, (See 2.1.4.) the manufacturer should be consulted.

7.2 VOLTAGE RATINGS

The nominal voltage of the system to which a switchboard is connected shall not exceed the voltage rating of the switchboard. (See 2.2.2.)

7.3 CONTINUOUS CURRENT-CARRYING RATINGS

7.3.1 Switchboards Without Main Overcurrent Protective Devices (Main Lug Switchboard)

The total continuous load current on a switchboard shall not exceed the section supply rating of the main section. (See 2.2.4.2.)

7.3.2 Main Overcurrent Protective Device in a Switchboard

The total continuous load current on a main overcurrent protective device shall not exceed 80 percent of its ampere rating unless the device is rated for continuous operation at 100 percent of its ampere rating.

7.3.3 Branch-Circuit Overcurrent Protective Device in a Switchboard

The total continuous load current on a branch circuit overcurrent protective device shall not exceed 80 percent of its ampere rating unless the device is rated for continuous operation at 100 percent of its ampere rating.

7.4 DETERMINATION OF SECTION BUS AND THROUGH BUS AMPACITY IN A MULTISECTION SWITCHBOARD

The user is best qualified to specify the ampacity of section and through buses based on the nature and demand factor of the loads to be served by each section.

7.4.1 Calculation of Section Bus Ampacity

In the absence of a specified ampacity from the user, the section bus furnished by the manufacturer shall not be less than the percentage of the sum of the ratings for the number of branch circuit overcurrent protective devices provided as specified in Table 7-1.

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Table 7-1
MINIMUM AMPACITY OF SECTION BUS*

Number of Branch Circuit Overcurrent-Protective Devices Supplied	Percent of the Sum of the Ratings
1	100
2–3	80
4–6	70
7–12	60
over 12	50

* A switchboard that is designed for a specific installation where the loading is known may have section bus with less than this minimum ampacity.

In determining ampacity, the sum is based on 100 percent of the current rating of the branch circuit device. In the case of fusible devices, the fuse clip rating shall be used, and in the case of interchangeable trip breakers the frame size shall be used.

If provision is made for the future installation of one or more specific branch-circuit units, the section bus ampacity shall be calculated with the current values for these units added to those for the units which are factory-installed.

If space is provided for an unspecified future use, the calculated ampacity required of the section bus shall be increased by the multiplying factor specified in the following Table 7-2.

Caution: This calculated section rating may not be sufficient for all combinations of units which may be installed in the spare space.

Table 7-2
MULTIPLYING FACTOR FOR BUS AMPACITIES

Unspecified Space in Percent of Total Section Space	Multiplying Factor
0–10	1.00
11–25	1.25
26–40	1.50
41–60	1.75
over 60	2.00

The section bus ampacity shall in no case be required to be greater than:

a. The supply rating of the switchboard section
b. The rating of an overcurrent device protecting the bus as a main or submain

When the calculated minimum ampacity is higher than that of a standard section rating, the next larger standard section bus shall be used.

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7.4.2 Calculation of Through Bus Ampacity

The minimum ampacity of the through bus furnished by the manufacturer shall be based on the following:

a. A through bus which feeds one switchboard section shall have a minimum ampacity equal to the section bus rating of that section.

b. A through bus which feeds two or more switchboard sections shall have a minimum ampacity of 80 percent of the numerical sum of the section bus ratings when calculated in accordance with 7.4.1.

c. If the user's specification requires provision for the addition of switchboard section(s) in the future, the expected section bus rating(s) shall be added to the ratings of those sections which are factory-installed, and the through bus shall have an ampacity not less than 80 percent of that total.

d. The through bus ampacity shall in no case be required to be greater than:

   1. The supply rating of the switchboard
   2. The rating of an overcurrent device protecting the bus as a main or submain.

e. Through or splice bus bars which extend beyond the point where the section bus bars are connected may have reduced ampacity, but not less than the supply rating of the next section of the group. The through bus ampacity shall in no case be less than 33.3 percent of:

   1. The supply rating of the switchboard
   2. The rating of an overcurrent device protecting the bus as a main or submain.

f. When the calculated minimum ampacity of the through bus is higher than a standard through bus rating, the next larger standard through bus shall be used.

7.5 FREQUENCY RATING

The frequency rating for ac switchboard assemblies is usually 50, 60, or 50/60 hertz. For applications at other frequencies, consult the manufacturer.

7.6 SHORT-CIRCUIT CURRENT RATING

7.6.1 Application on System

A Switchboard shall be applied only on a system having an available short-circuit current not greater than the short-circuit current rating of the switchboard. (See 2.2.7 for short-circuit current ratings and 6.1.1.2 for short-circuit test procedure.)

7.6.2 Current-Limiting Devices

Where current-limiting devices are used to meet specific short-circuit current ratings, these means shall either be as an integral or external part of the switchboard, or provision shall be made to allow for the integral or external installation of specific current-limiting means upon installation of the switchboard.

7.6.3 Calculation

IEEE Publication No. Std. 141 contains detailed information for the calculation of short-circuit currents. Information on such calculations and tables showing the short-circuit current available at various distances from transformers may also be found in NEMA Standards Publication AB 3. However, it is important that the actual system data be compared with the values assumed in formulating the tables to determine the reliability of the results. Transformer impedance values are particularly important.

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7.6.4 Examples for Application–Determination of Switchboard Short-Circuit Current Rating (See Figure 7-1.)

Example 1. Assume:

a. 50,000 rms symmetrical amperes short-circuit current available at the line terminals of the switchboard supply bus at the rated voltage

b. The individual overcurrent devices and their branch buses have short-circuit current ratings of 50,000 rms symmetrical amperes at the voltage rating of the system

c. The through bus and section bus have short-circuit current ratings of 65,000 rms symmetrical amperes

d. The main device has a short-circuit current rating of 75,000 rms symmetrical amperes

e. The supply bus has a short-circuit current rating of 75,000 rms symmetrical amperes

Since the individual overcurrent devices have the lowest short-circuit current rating, the short-circuit current rating of the assembled sections would be 50,000 rms symmetrical amperes, and the switchboard would be satisfactory for application on a system having an available short-circuit current up to 50,000 amperes

Example 2. Assume:

a. 50,000 rms symmetrical amperes short-circuit current available at the line terminals of the switchboard supply bus at rated voltage

b. The individual overcurrent devices and their branch bus have short-circuit current ratings of 40,000 rms symmetrical amperes at the voltage rating of the system

c. The through bus and section bus have short-circuit current ratings of 65,000 rms symmetrical amperes

d. The main device has a short-circuit current rating of 75,000 rms symmetrical amperes

e. The supply bus has a short-circuit current rating of 75,000 rms symmetrical ampere

The short-circuit current rating of the assembled sections would be 40,000 rms symmetrical amperes, the same as the individual overcurrent devices. The switchboard would be unsatisfactory for application on a system having an available short-circuit current of 50,000 amperes. As the individual overcurrent devices and their branch bus are the only elements in the system not having sufficient short-circuit capacity, the switchboard could be made suitable for this application by replacing these devices and the bus with devices and bus having a short-circuit current rating of a least 50,000 rms symmetrical amperes.

Example 3. Assume:

a. The diagram shown in Figure 7-1 and assumptions a, b, and c as stated in example 2

b. Assume the rms symmetrical available short-circuit current at the line terminals of the main device is raised from 50,000 amperes to 65,000 amperes

The switchboard is not satisfactory for use with this system. However, this situation could be corrected by:

a. Installing a switchboard with all devices and bus having a short-circuit current rating of at least 65,000 rms symmetrical amperes

b. Protecting the switchboard on the line side of the branch bus with a main device which has been series combination tested and marked with the branch devices at 65,000A rms minimum available

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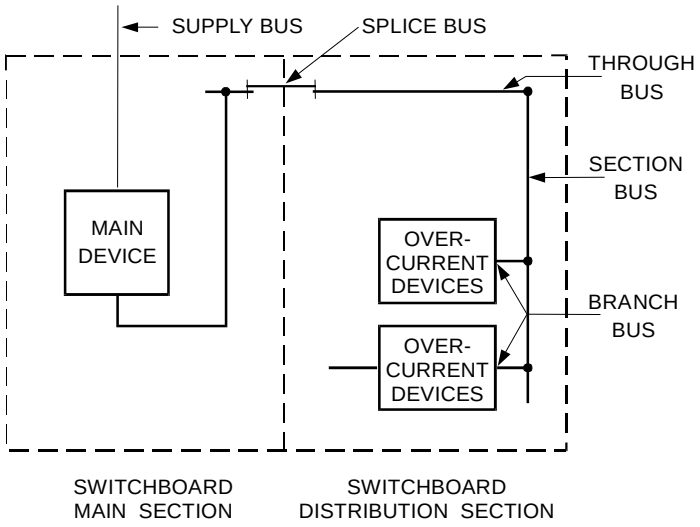


Figure 7-1
SWITCHBOARD DIAGRAM

7.7 LOCATION, INSTALLATION, OPERATION, AND MAINTENANCE

In addition to the proper design and manufacture of switchboards, their successful operation is dependent upon proper handling, location, installation, operation, and maintenance. For detailed information on these application topics, refer to NEMA Standards Publication No. PB 2.1. Some installation guidelines, pertaining specifically to planning of the switchboard location are more appropriately covered in this Standards Publication, and are listed as follows:

a. Locate the switchboard so that it is not exposed to physical damage or unqualified personnel

b. Locate the switchboard well away from combustible materials

c. Unless specifically designed for the purpose, do not install switchboards where unusual service conditions exist. (See 2.1.4.) To avoid nuisance circuit breaker tripping or fuse blowing, locate the switchboard so that normal ambient temperatures do not exceed 40°C (104°F)

d. In a wet location or outside of a building, use a Type 3R enclosure or provide the switchboard with means to prevent moisture or water from entering and accumulating within the enclosure

e. Position the switchboard (not rear accessible) so there is clearance between it and adjacent walls, minimum of 1/2 inch for indoor and 6 inches for outdoor or wet locations

f. When selecting a location, sufficient access and working space should be provided around the switchboard. Refer to Section 110-26 of *the National Electrical Code* for detailed requirements

g. Provide adequate lighting for all working spaces around the switchboard

h. Floor area or foundation should be of adequate strength to support the weight of the switchboard. It should be as smooth and level as possible

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7.8 GROUND-FAULT PROTECTION

Ground-fault protection (GFP) is recommended to minimize damage in the event of a short-circuit to ground having sufficiently low magnitude so that the overcurrent protective device would normally not trip or would require an extended time to trip. See UL 891 and the National Electrical Code for minimum requirements and NEMA Standards Publication PB 2.2 for additional information.

Switchboard ground-fault protectors are generally of three types:

a. Zero Sequence Type—An individual sensor that vectorially sums current flow through all of the phase conductors and neutral conductors (if any). Any resulting current is directly proportional to the ground-fault current in the system.

b. Residual Type—Separate individual sensors vectorially sum the current flow through each phase conductor and neutral conductor (if any). Any resulting current is directly proportional to the ground-fault current in the system.

c. Ground Return Type—An individual sensor monitors the current in the grounding conductor only. This type of application is used with a single main device service switchboard only. To comply with the activating ground current and operating time requirements of the *National Electric Code,* all ground connections must be on the load side of the sensor. No ground connections are permitted integral or external to the switchboard on the line side of the sensor.

To minimize the amount of switchboard bus unprotected by ground-fault protection, single-ended switchboards should have a single main and double ended switchboards should be limited to two mains. Construction of this type limits the number of operations necessary to de-energize the switchboard.

Consideration should be given to providing ground-fault protection for individual feeder or branch circuits. Protectors which open only a main device may cause loss of power on circuits other than those circuits experiencing the ground-fault. When there is no main protective device that can operate to open all ungrounded supply conductors, the switchboard bus is not protected from ground-faults. The specifying engineer should be consulted as to the type of ground-fault protection required and the recommended settings for a particular installation.

7.9 CORNER-GROUNDED (GROUNDED B PHASE) THREE-PHASE DELTA APPLICATIONS

Two-pole circuit breakers intended to be installed on corner-grounded (grounded B phase) delta systems to supply three-phase loads shall be marked 1 phase – 3 phase.

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