UL 67

STANDARD FOR SAFETY

Panelboards

UL Standard for Safety for Panelboards, UL 67

Thirteenth Edition, Dated May 15, 2018

SUMMARY OF TOPICS:

This revision of ANSI/UL 67 dated August 1, 2024, includes Updating Energy Management System Requirements; 6.6.12, 34.1.28, 34.16.7 and Section 34.20.

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated March 1, 2024 and June 7, 2024.

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Standard for Panelboards

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The most recent designation of ANSI/UL 67 as an American National Standard (ANSI) occurred on August 1, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

The Department of Defense (DoD) has adopted UL 67 on June 18, 1990. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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PANELBOARDS FOR MARINE USE

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INTRODUCTION

1 Scope

1.1 These requirements cover panelboards to be employed in accordance with the National Electrical Code, NFPA 70.

1.2 These requirements cover panelboards intended to provide the primary function of control and protection of electrical circuits.

1.3 These requirements do not cover:

a) Distribution equipment which sole function is the automatic or nonautomatic transferring of one or more load conductor connections from one power source to another. Reference the Standard for Transfer Switch Equipment, UL 1008.

b) Factory wired assemblies of industrial control equipment intended to control industrial processes. Reference the Standard for Industrial Control Panels, UL 508A.

c) Distribution equipment containing only one circuit subdivision, unless also provided with a meter socket. See 6.5.1. Reference the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489.

d) Distribution equipment intended to serve as a means for distributing power required to operate mobile or temporarily installed equipment. Reference the Standard for Power Outlets, UL 231.

e) Factory wired assemblies of controllers, timers, temperature regulating equipment and such, intended for control of equipment for use with swimming pools, hot tubs, and/or spas. Reference the Standard for Electric Spas, Equipment Assemblies, and Associated Equipment, UL 1563.

f) Factory wired assemblies intended for the control of Architectural and Floating Fountains. Reference the Standards for Motor-Operated Water Pumps, UL 778, Underwater Luminaires and Submersible Junction Boxes, UL 676 and Industrial Control Panels, UL 508A.

g) Portable power distribution equipment. Reference the Standard for Portable Power-Distribution Equipment, UL 1640.

h) Panelboards with converter and/or inverter functions, intended for use as distribution equipment in recreational vehicles. Reference the Standard for Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts, UL 458.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

2.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

2.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

2.5 A component not marked with a short-circuit current rating is considered rated for use in a circuit having a maximum available fault current as shown in Table 2.1.

Table 2.1
Assumed maximum short-circuit current rating for unmarked components

Components				Short circuit current rating, kA
1.	Circuit Breaker (Including GFCI Type)			5
2.	Clock-Operated Switch			5
3.	Fuseholder			10
4.	Plug Fuse			10
5.	Industrial Control Equipment:			
	a.	Auxiliary Devices		5
	b.	Switches		5
6.	Meter Socket Base			10
7.	Motor Controller, rated in horsepower (kW)			
	a.	1.5 – 50	(1.1 – 37.3)	5
	b.	51 – 200	(38 – 149)	10
	c.	201 – 400	(150 – 298)	18
	d.	401 – 600	(299 – 447)	30
	e.	601 – 900	(448 – 671)	42
	f.	901 – 1600	(672 – 1193)	85
8.	Photoelectric Switches			5
9.	Receptacle (GFCI Type)			2[a]
10.	Receptacle (other than GFCI Type)			10
11.	Snap Switch			5
12.	Terminal Block			10
13.	Thermostat			5
14.	Direct Connected Meters			b

[a] The short-circuit current available in a 120 volt secondary circuit of a transformer rated 5 kilovolt-amperes or less is considered to be 2 kiloamperes or less.

[b] See 2.7.

2.6 The short-circuit current available in the secondary circuit of a transformer rated 10 kilovolt-amperes or less is considered to be 5000 amperes or less.

2.7 For other than a plug-in watt-hour meter, a current-sensing meter in a panelboard shall be a type that has been subjected to a 60 hertz rms short-circuit current of 12,000 amperes for four electrical cycles, and a peak current of 30,000 amperes for one-half electrical cycle, and shall be provided with overcurrent protection as described in 25.8.5.2. A plug-in watt-hour meter intended to be plugged into a meter socket base is not considered to be a part of the meter center.

Exception No. 1: A meter need not have been tested nor provided with overcurrent protection if it is intended for use with a current transformer.

Exception No. 2: A meter need not have been tested nor provided with overcurrent protection if it is used across a shunt that has been subjected to a short-circuit test as specified in Section 25, Short-Circuit Current Test.

Exception No. 3: A meter need not have been subjected to a peak current of 30,000 amperes nor provided with overcurrent protection if the short-circuit current rating of the panelboard or the available fault current of the circuit at the meter is 14,000 amperes or less.

Exception No. 4: The four electrical cycle test may be reduced to 10,000 amperes if the short-circuit current rating of the panelboard is 10,000 amperes or less.

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4 Undated References

4.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

5 Glossary

5.1 For the purpose of this standard, the following definitions apply.

5.1A ACCESSORIES – A device or devices that perform a secondary function of the panelboard.

5.2 AMBIENT TEMPERATURE – The temperature of the surrounding medium that comes in contact with the panelboard. For an enclosed panelboard, it is the temperature of the medium outside the enclosure.

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

5.4 AVAILABLE SHORT-CIRCUIT CURRENT – That current which would flow in a circuit if a short-circuit of negligible impedance were to occur at a given point.

5.5 BARRIER – A partition for the insulation or isolation of electric circuits or electric arcs.

5.6 BONDING – The permanent joining of metallic parts to form an electrical conductive path that ensures electrical continuity and the capacity to conduct safely any current likely to be imposed.

5.7 BONDING JUMPER – A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected.

5.8 BONDING SCREW – A screw that is used as a bonding jumper.

5.9 BUS – A conductor, or group of conductors, that serves as a common connection for two or more circuits.

5.10 CABINET – An enclosure designed for either surface mounting or flush mounting and is provided with a frame, mat, or trim in which a swinging door or doors are or can be hung.

5.11 CARTRIDGE FUSE – A fuse consisting of a current-responsive element inside a fuse body with contacts on both ends.

5.12 CIRCUIT BREAKER – A device designed to open and close a circuit by nonautomatic means, and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.

5.13 *Deleted*

5.14 CONTINUOUS DUTY – Operation at a substantially constant load for an indefinitely long time.

5.15 *Deleted*

5.16 CURRENT RATING – The designated maximum direct current or alternating current (RMS Amperes at rated frequency) that a device can carry continuously under specified conditions.

5.17 CUTOUT BOX – An enclosure designed for surface mounting that has swinging doors or covers secured directly to and telescoping with the walls of the enclosure.

5.18 DEADFRONT – A barrier that prevents live parts from being exposed to a person on the operating side of the panelboard.

5.19 DEADFRONT SHIELD – A barrier that is used behind a door to cover wiring spaces and uninsulated live parts that would otherwise be exposed to a person when the door is open.

5.20 DEVICE – A unit of an electrical system that is intended to carry or control, but not utilize, electrical energy.

5.21 DIELECTRIC WITHSTAND TESTS – Tests to determine the ability of the insulating materials and spacings to withstand overvoltages.

5.22 DOUBLE-LUG PANELBOARD – A panelboard that has two sets of main line terminals, each set having sufficient current-carrying capacity to supply the panelboard, see Figure 5.1 and Figure 5.2.

Figure 5.1

Subfeed lugs connected to incoming line terminals

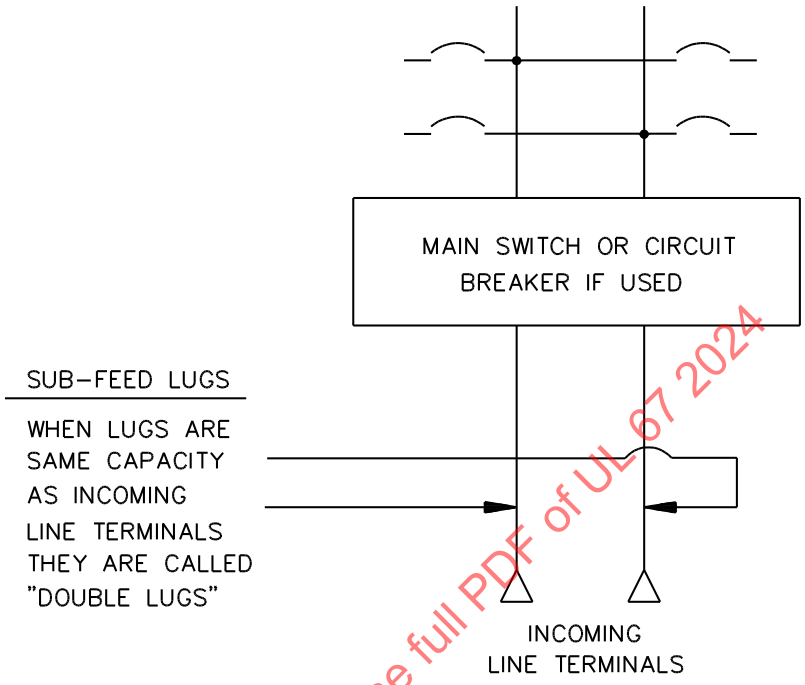

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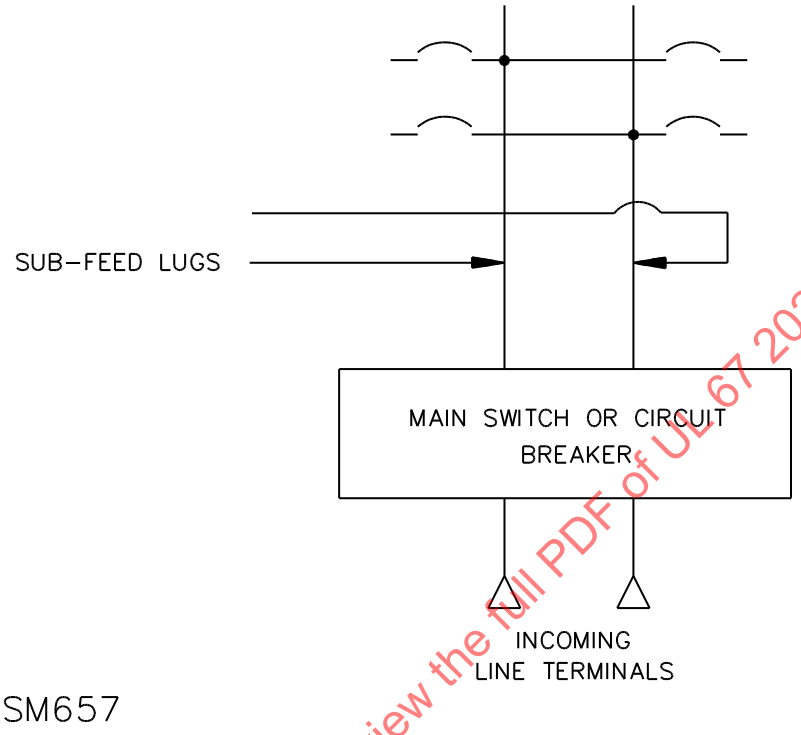
Figure 5.2

Subfeed lugs connected to bus bars protected by an overcurrent protective device in the panelboard



5.23 DUMMY FUSE (TEST LINK) – A current-carrying part made of copper and having dimensions such that it will fit its fuse-mounting means with the same conditions of pressure, contact, and cross-sectional areas as are obtained on terminals of the fuse that it is intended to replace. A dummy fuse shall not be a protective device.

5.24 ENCLOSED PANELBOARD – An assembly of buses and connections, overcurrent devices, and control apparatus with or without switches, or other equipment, installed in a suitable cabinet, cutout box, or enclosure suitable for a panelboard application.

5.25 ENCLOSED RECREATIONAL VEHICLE (RV) PANELBOARD – An enclosed panelboard intended to be installed in a recreational vehicle (RV) in accordance with Article 551 of the National Electrical Code, NFPA 70.

5.26 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.

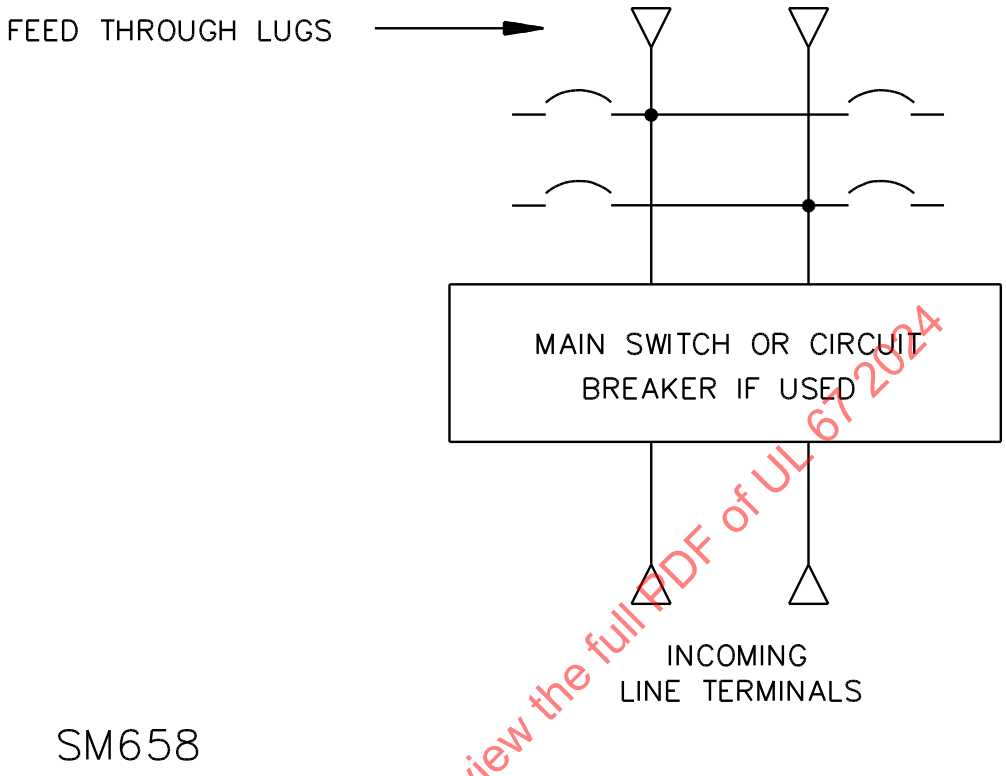
5.26A ENERGY MANAGEMENT SYSTEM (EMS) – A system that controls an electrical load, a power production source, or an energy storage system.

Note: A “Power Control System” is considered a type of Energy Management System.

5.27 FEED-THROUGH LUG – A terminal that is connected to a main bus bar at the end opposite from the incoming line terminal or main device, if used, and that is provided for connection to an outgoing wire or cable, see Figure 5.3.

Figure 5.3

Feed through lugs for a separate circuit external to the panelboard



5.28 FILLER PLATE – A plate intended to close an opening that would otherwise be closed by the subsequent installation of a circuit breaker or other device.

5.29 FLUSH-MOUNTED (TYPE) – A device designed to be set into and secured to a flat surface, with a minimal front projection.

5.30 FRAME SIZE – A term applied to a group of molded case circuit breakers of similar physical configuration. Frame size is expressed in amperes and corresponds to the largest ampere rating available in the group. The same frame size designation may be applied to more than one group of circuit breakers.

5.31 FUSE – A non-resettable protective device which opens a circuit during specified overcurrent conditions by means of a current responsive element or elements.

5.32 FUSE CLIPS – The contacts of the fuseholder that support the fuse and connect the fuse terminals with the circuit.

5.33 FUSIBLE SWITCH – A switch in which one or more poles have a fuse in series in a composite unit.

5.34 FUSEHOLDER – An assembly of a base, fuse clips, and necessary insulation for the mounting and connecting of a fuse into a circuit.

5.35 GROUNDED CONDUCTOR – A system or circuit conductor that is intentionally grounded.

5.36 GROUND-FAULT CIRCUIT INTERRUPTER (GFCI) – A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established for a Class A device.

5.37 GROUND-FAULT PROTECTION OF EQUIPMENT – A system intended to provide protection of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device.

5.38 GUTTER TAP LUG – A terminal that is located in a wiring gutter of a panelboard and that is provided for:

a) The connection of an incoming or an outgoing conductor, or a panelboard main; or

b) The connection of two sets of outgoing conductors to a branch or other outgoing circuit, see Figure 5.4 and Figure 5.5.

A lug connecting an outgoing conductor is also considered to be a subfeed lug, see 5.61(a).

Figure 5.4

Gutter tap lugs connected to panelboard mains

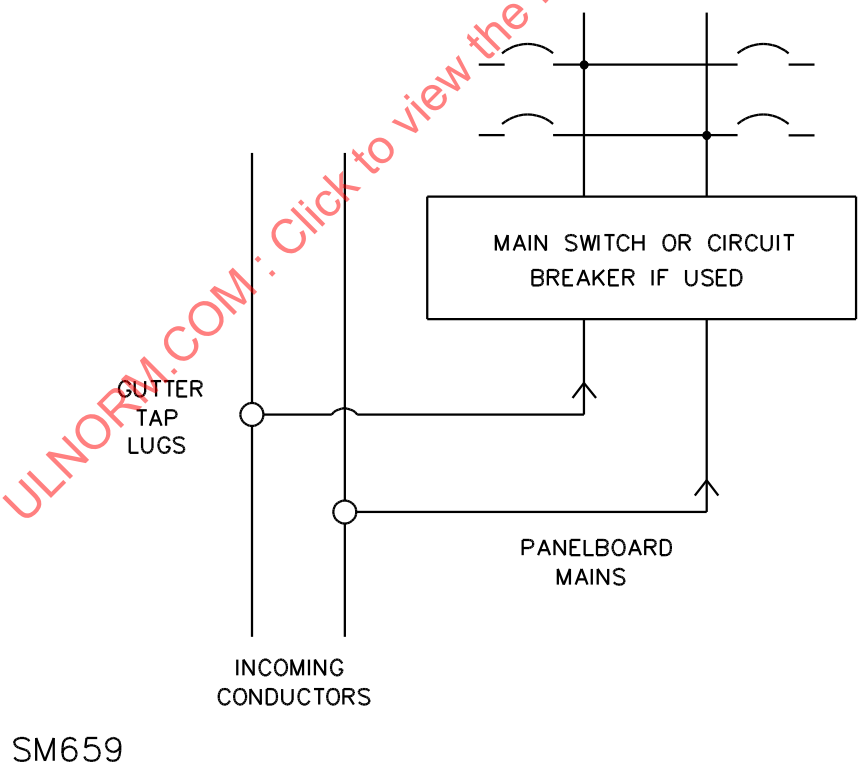
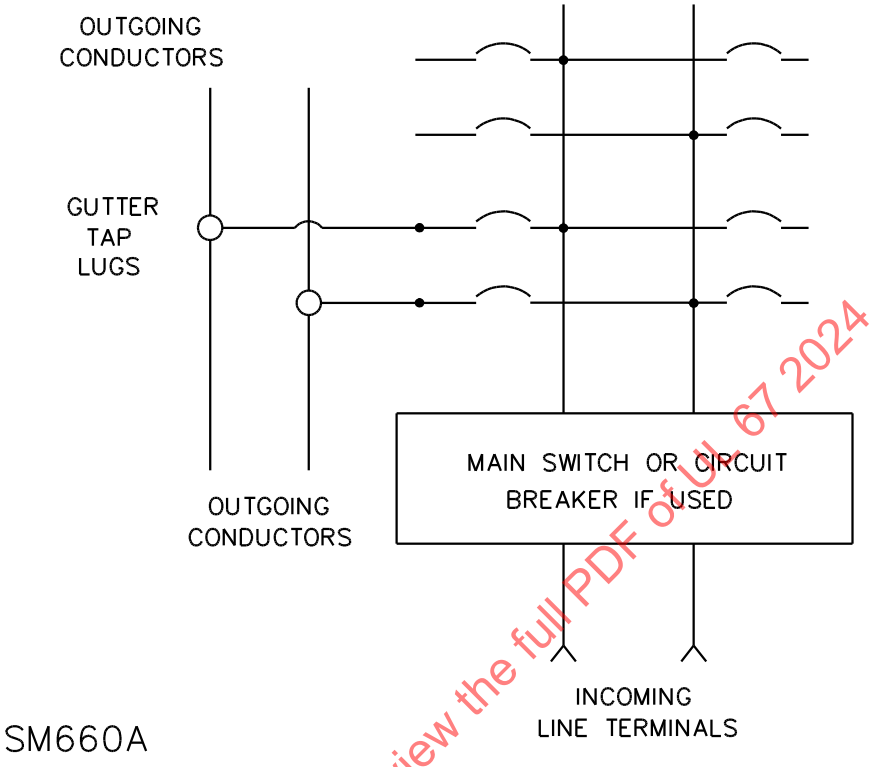


Figure 5.5

Gutter tap lugs connected to a branch circuit



5.39 I^2t (AMPERE SQUARED SECONDS) – An expression related to the circuit energy as a result of current flow. "I^2t" is a common expression for the circuit energy between the initiation of the fault current and the clearing of the circuit. "I" is the value of current, expressed in amperes, and "t" is the duration of current flow, expressed in seconds. For AC applications, the value of current is to be the rms value.

5.40 INTERLOCK – An electrical or mechanical component actuated by the operation of a device with which it is directly associated to govern succeeding operations of the same or allied devices.

5.41 INTERRUPTING RATING – The highest current at rated voltage that a device is intended to interrupt under standard test conditions.

5.42 KNOCKOUT – A portion of the wall of an enclosure so fashioned that it is capable of being readily removed by a hammer, screw driver, and pliers at the time of installation in order to provide an opening or hole for the attachment of a raceway, cable, or fitting.

5.43 *Deleted*

5.44 LUG – A terminal that is provided for the connection of a wire or a cable to a panelboard or for a wire or cable connection between component parts of a panelboard.

5.45 MAIN – A device that is provided for the connection of an incoming line conductor.

5.46 MAIN TERMINAL – A terminal that is provided for the connection of an incoming line conductor.

5.47 MAINS (MAIN TERMINALS) – The terminals, or main device, provided for the connection of the main incoming line conductors.

5.47A METER CENTER (METERING CENTERS) – A panelboard or enclosed panelboard that contains one or more meter sockets.

5.48 NEUTRAL (ASSEMBLY); SOLID NEUTRAL – An assembly consisting of enough 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 the following:

a) A means for making the required bonding connection between the neutral and the enclosure; and

b) A terminal for the grounding electrode conductor.

5.49 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.

Note: The neutral conductor is the grounded conductor.

5.50 OVERCURRENT PROTECTIVE DEVICE – An individual fuse or circuit breaker pole.

5.51 PANELBOARD – A single panel or a group of panel units designed for assembly in the form of a single panel; includes buses, automatic overcurrent devices, and may be equipped with switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front, or placed in an enclosure.

Note: A Panelboard may also be referred to as a “panelboard interior.”

5.51A PANELBOARD KIT – A panelboard shipped from the manufacturer in the form of a single field-assembled kit; designed to be installed in a cabinet, enclosure, or cutout box.

5.52 PEAK LET-THROUGH CURRENT (AC) – The maximum instantaneous current through an overcurrent device during the total clearing time.

5.53 PLUG FUSE – A screw-in type fuse for use in an Edison base type fuseholder.

5.54 *Deleted*

5.55 PRESSURE WIRE CONNECTOR – A reusable connector into which the conductor (wire) is secured by mechanical pressure applied by an integral screw, cone, or other mechanical parts.

5.56 PULLOUT SWITCH – A switch, enclosed or non-enclosed, that is operated to open a circuit by manually separating the movable contact from the stationary contact, and is operated to close a circuit by manually reconnecting the movable contact and the stationary contact.

5.57 RATING – A designated limit of operating characteristics based on defined conditions.

5.58 SERVICE – The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

5.59 SERVICE EQUIPMENT – The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s), and their accessories, connected to the load end of service conductors to a

building or other structure, or an otherwise designated area, and intended to constitute the main control and cutoff of the supply.

5.60 SHORT-CIRCUIT CURRENT RATING (EQUIPMENT) – The maximum available current to which a device can be connected. The rating is expressed in amperes and volts. Ratings based on AC are rms values.

5.61 SUBFEED LUG – A terminal that is provided for the connection of a wire or a cable:

a) To a bus bar that is connected directly to the panelboard main incoming line terminal, see Figure 5.1; or

b) To a bus bar fed by an overcurrent protective device in the panelboard, see Figure 5.2.

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

5.63 SYMMETRICAL CURRENT – 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 A.

5.64 VENTILATED – So constructed as to provide a means to permit circulation of external air through the enclosure to remove excess heat, fumes, and vapors.

CONSTRUCTION

6 General

6.1 All panelboards

6.1.1 A panelboard shall employ materials throughout that are acceptable for the particular use, and shall be made and finished with the degree of uniformity and grade of workmanship practicable in a well-equipped factory.

6.2 Equipment on supply side of disconnect

6.2.1 Only the following equipment shall be permitted to be connected to the supply side of the service disconnecting means:

a) Meters, meter sockets, or meter disconnect switches nominally rated not in excess of 1000 volts;

b) Instrument transformers (current and potential), high-impedance shunts and Type 1 surge-protective devices;

c) Load management devices if overcurrent protection is provided;

d) Taps for load management devices, optional standby power systems, and fire and sprinkler alarms;

e) Control circuits of power operable service disconnecting means including control circuits of optional standby power systems, if overcurrent protection and disconnecting means are provided; and

f) Ground-fault protection systems or Type 2 surge-protective devices, if overcurrent protection and disconnecting means are provided.

g) Taps for interconnected electric power production sources, such as solar photovoltaic, wind, or fuel cell systems.

6.2.2 For the purpose of determining the number of disconnects as required in 6.4.2 and 6.4.2A, disconnects on the supply side of the service disconnecting means, as permitted in 6.2.1, shall not be counted as a service disconnect. Disconnects and overcurrent protection on the supply side of the service disconnecting means that comply with (a), (b), and (c) below may be located behind a deadfront or screwed-on cover, if:

a) The disconnect or overcurrent protective device is installed as part of the equipment;

b) The circuit being controlled is contained within the panelboard enclosure; and

c) The panelboard is marked in accordance with 34.9.10.

6.2.3 *Deleted*

6.3 Distribution equipment

6.3.1 A panelboard may be designed for mounting on a mounting post or pedestal for distribution equipment.

6.4 Service equipment

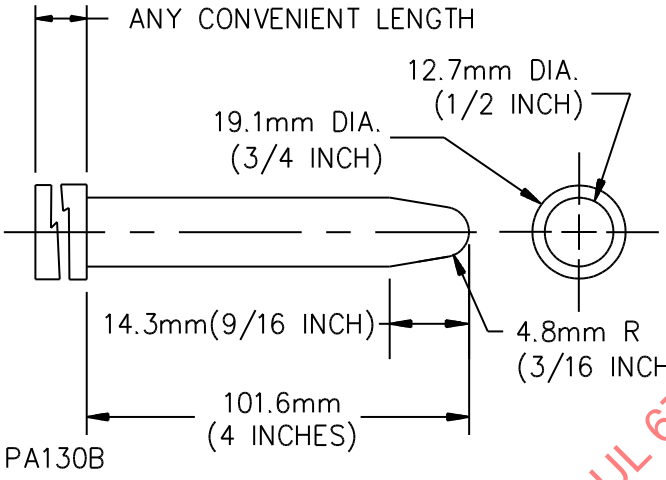
6.4.1 A panelboard intended for use as service equipment shall comply with the applicable requirements in the Reference Standard for Service Equipment, UL 869A.

6.4.2 Panelboards other than meter centers constructed in accordance with 6.4.2A, are limited to a single service disconnect in each enclosure and shall be constructed such that, with the service disconnect in the off position, ungrounded uninsulated live parts on the supply side of the service disconnect are protected against inadvertent contact by persons while servicing any field connected load terminal, including a neutral load terminal, a branch circuit equipment grounding terminal, or the neutral disconnect link. Inadvertent contact is determined by use of the probe illustrated in Figure 6.1. If restriction to the line-side of the service disconnect is dependent on the installation of field installed service conductors, conductors sized in accordance with 12.1.10 shall be installed in the terminals when determining exposure to inadvertent contact. All live parts of the line side service terminal, including the connector body and pressure screw shall be evaluated.

Note: In accordance with the Standard for Electrical Safety in the Workplace, NFPA 70E, an electrically safe work condition should be established and verified prior to working on electrical equipment. Accessibility requirements do not endorse working on energized electrical equipment.

Figure 6.1

Straight probe



6.4.2A Meter centers shall be permitted to have two to six service disconnects in each enclosure, provided that each service disconnecting means:

a) Is located within a separate compartment, with a separate door or cover, that complies with enclosure requirements in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50 and

b) Complies with the accessibility requirements in 6.4.2.

Operating handles and/or handle escutcheons are permitted to protrude beyond compartment walls.

6.4.3 Metal barriers provided to limit exposure to inadvertent contact shall:

a) Have a thickness not less than 0.032 inch (0.81 mm) if uncoated, not less than 0.034 inch (0.86 mm) if galvanized, and not less than 0.050 inch (1.27 mm) if aluminum.

b) Be constructed so that it can be readily removed or repositioned, and then re-installed, without the likelihood of contacting bare live parts or damage the insulation of any insulated live part.

Exception: Factory installed barriers that limit access to factory installed wiring and terminations are not required to be constructed so that they can be removed or repositioned.

6.4.4 Nonmetallic barriers provided to limit exposure to inadvertent contact shall:

a) Comply with requirements in 16.3.3 for barriers used in conjunction with a minimum air space of 0.013 inch (0.33 mm).

b) Be constructed so that it can be readily removed or repositioned, and then re-installed, to allow access to the terminal for servicing.

Exception: Factory installed barriers that limit access to factory installed wiring and terminations are not required to be constructed so that they can be removed or repositioned.

6.4.5 Panelboards marked “Suitable for use as service equipment” and

a) Constructed in accordance with 6.8.3.2 and designed for use interchangeably either with main-terminal or a single service disconnect only, or

b) Provided with a single service disconnect,

shall be permitted to provide the protection from inadvertent contact in 6.4.2 in a field installable kit when marked in accordance with 34.12.12. See also 34.9.11.

6.5 Branch circuits

6.5.1 A panelboard shall have more than one circuit subdivision. Terminals for a feed-through circuit are considered to be a circuit subdivision.

Exception: A meter center may have only one load circuit.

6.5.2 *Deleted*

6.5.3 *Deleted*

6.5.4 *Deleted*

6.5.5 *Deleted*

6.6 Electrical connections

6.6.1 Other than as noted in 6.6.3 and Panelboard kit, 6.9, all electrical connections between switches, fuseholders, circuit breakers, and the like shall be complete so that only line, load, metering, and control circuits need be connected when a panelboard is installed.

6.6.2 *Deleted*

6.6.3 A panelboard may be shipped from the factory without branch-circuit bus bars mounted in place if the branch-circuit bus bars are provided as a field installable kit. See 6.8.3.3 and 11.2.7.

6.6.4 *Deleted*

6.6.5 If a panelboard is acceptable for use with or without a neutral bus bar, the neutral bus bar need not be mounted in place when the panelboard is shipped from the factory if the neutral bus bar is provided as a field installable kit. See 6.8.3.4.

6.6.6 Separate wires or bus bars may be provided for making the connection:

a) To or from a fusible switch or circuit breaker that will control a section of a panelboard, or

b) To associated equipment.

One end of such a wire or bus bar may be connected in place when the panelboard is shipped from the factory. See 11.2.4 and 34.12.10.

6.6.7 If one end of the separate wire mentioned in 6.6.6 is not connected when the panelboard is shipped, the loose end shall be secured so that damage to itself and to the panelboard during shipment is not likely to occur. If the load end of the wire is not connected to the panelboard when shipped, it shall be:

a) Secured to an insulating base that is acceptable for supporting uninsulated live parts, or

b) Completely covered, including the cut end, with acceptable insulation.

6.6.8 A back-fed unit – such as a circuit breaker, a fused switch, or a main terminal kit – that uses a friction or plug-on bus bar connection shall not be used to terminate the field installed ungrounded supply conductors.

Exception: A back-fed unit provided with an additional fastener that requires other than a pull to release the unit from its mounting position on the panel (such as a hold-down kit for a back-fed main circuit breaker) may be used to terminate field installed ungrounded supply conductors. See 34.1.17 and 34.12.1.

6.6.9 Panelboards for use in accordance with Article 702 of the National Electrical Code, ANSI/NFPA 70, shall have both main disconnect units comply with 6.6.8 or its exception.

6.6.10 The operating mechanism in a panelboard used as transfer equipment in accordance with Article 702 of the National Electrical Code, ANSI/NFPA 70, shall be interlocked to prevent simultaneous connection to both the normal and alternate sources of supply. The interlock shall be installed as part of the panelboard assembly in the factory or provisions made for its field installation. The panelboard or field installed kit shall be marked in accordance with 34.1.27 or 34.12.18.

6.6.11 Panelboards intended for interconnection with one or more electric power production sources operating in parallel with a primary source(s) of electricity, in accordance with Article 705 of the National Electrical Code, NFPA 70, shall be permitted to have provisions for connection(s) as noted in (a) and (b). See 34.16 for marking requirements.

a) Supply Side Connection – Panelboards intended for use in applications where the non-primary sources are connected on the supply side of the service disconnecting means, see 6.2.1(g), shall comply with the following:

1) The current rating of the panelboard or ampacity of the bus bars (see 31.1) shall not be exceeded based on the sum of sources being determined by one of the following methods:

i) The sum of the continuous current output ratings of all supply side overcurrent devices connected to non-primary parallel power sources.

ii) The sum of all connected non-primary parallel power sources is limited by the current setpoint of an EMS complying with 6.6.12.

2) If connections are provided to interconnect power production sources, those connections shall accommodate conductors no smaller than 6 AWG copper or 4 AWG aluminum.

b) Load Side Connection – Panelboards intended for use in applications where the non-primary sources are connected on the load side of the service disconnecting means shall be permitted to have one or more load side disconnects for the interconnection of parallel power sources if the current rating of the panelboard or ampacity of the bus bars (see 31.1) is not exceeded, based on the sum of source and/or loads that can be simultaneously energized, as determined by one of the following methods:

1) The sum of the continuous current output ratings of all overcurrent devices connected to primary and non-primary parallel power sources

2) The sum of all connected loads that can be simultaneously energized, or primary and non-primary parallel power sources, is limited by the current setpoint of an EMS complying with 6.6.12

Exception: The total rating of all overcurrent devices supplying the panelboard may be up to 120% of the rating of the panelboard if the overcurrent device(s) intended for use with interconnected

parallel power sources are positioned at the opposite end from the main input, or if the connections are at either end of a center-fed panelboard.

6.6.12 When used to limit current to comply with 6.6.11, to provide load management of EVSE, or for load calculations, a Power Control System (PCS) shall comply with the Outline of Investigation for Power Control Systems, UL 3141. Markings, as specified in 34.20, shall be provided when a panelboard includes an EMS, components of an EMS, or instructions to install an EMS, to limit current.

6.6.13 Panelboards intended to provide uninterruptible power supply to control circuitry shall be marked in accordance with 34.17.1.

6.7 Field installable equipment

6.7 revised and relocated as 6.8

6.7.1 *Deleted*

6.7.2 *Deleted*

6.7.3 *Deleted*

6.7.4 *Deleted*

6.8 Field installable accessories and equipment

6.8.1 General

6.8.1.1 Field Installable accessories and equipment shall comply with all applicable requirements of this standard.

6.8.1.2 The installation shall not require the use of other than normally available tools, such as screwdrivers, pliers and wrenches, unless such a tool and instructions for its use are furnished with the equipment or accessory.

6.8.1.3 Panelboards, field installable accessories and equipment shall comply with the marking requirements of 34.12, Field-installed equipment.

6.8.2 Field installable accessories

6.8.2.1 A panelboard may have provision for field-installed accessories provided the following conditions are met:

a) The panelboard is acceptable for use with or without the accessory.

b) Instructions for the installation and operation are provided with each accessory.

c) A barrier that is necessary because spacings would otherwise be less than required is securely attached at the factory to either the panelboard, or to the accessory to be installed.

d) The accessory is an essentially complete unit and does not require assembly in the field.

e) The installation of the accessory does not expose uninsulated or mechanical functional parts that would not be exposed during the replacement of overcurrent protective devices.

f) Means for mounting the accessory require no drilling, cutting, or filing of holes.

Exception: Drilling, cutting, or filing is acceptable in the panelboard enclosure if:

a) Such openings are indicated by drill points or breakouts on the enclosure. Drill points may be applied at the factory, by a template provided with the field-installed accessory, or other equivalent means, such that the location to be drilled can be determined by the installer; and

b) It is possible to accomplish the drilling or cutting in a manner so that debris inside the panelboard enclosure does not accumulate.

6.8.2.2 Requirements for wiring space, wiring gutters, and wire bending space in Section 17 do not apply to the evaluation of field installed accessories. See marking requirement in 34.12.19.

6.8.3 Field installable equipment

6.8.3.1 Pressure terminal connectors for line or load field connections that are available from the equipment manufacturer in the form of a field installable terminal kit, or as one or more terminal connectors specified for field installation on the equipment, shall comply with the following (reference 12.1.1, Exception No. 2):

a) Fastening devices, such as studs, nuts, bolts, spring and flat washers, as required for an effective installation shall either be provided as part of the component terminal kit or be mounted on or separately packaged with the equipment.

b) The installation of the terminal kit shall not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location. The means for securing the terminal connector shall be readily accessible for tightening before and after installation of conductors.

c) If the pressure terminal connector specified in (a) requires the use of a special tool for securing the conductor, any necessary instructions shall be included in the component terminal kit package or with the equipment.

d) Installation of the pressure terminal connectors in the intended manner shall result in a product that meets the requirements in this standard.

e) The equipment shall be marked in accordance with 34.12, Field-installed equipment.

6.8.3.2 The main terminals may be in the form of a main-terminal kit if the panelboard is specifically designed for use interchangeably either with those terminals or with a main circuit breaker or switch. A main-terminal kit may consist of individual terminals or may be an assembly consisting of:

a) Terminals;

b) Bus bars that provide connections between those terminals and the main bus bars of the panelboard; and

c) A mounting means for those components.

The kit may be connected to the main bus bars by either bolting or plugging in. The kit shall be marked in accordance with 34.12.11.

6.8.3.3 A panelboard shipped from the factory without branch-circuit bus bars mounted in place as permitted in 6.6.3 shall have all barriers needed to comply with the spacing requirements in Section 16,

Spacings, permanently attached to the panelboard or the field-installed branch-circuit bus bars. See also 11.2.7. The panelboard shall be marked in accordance with 34.12.4.

6.8.3.4 A panelboard shipped from the factory without a neutral bus bar as permitted in 6.6.5 shall comply with the following:

a) The panelboard and the neutral bus bar shall be marked in accordance with 34.12.6, and

b) The neutral bus bar shall be shipped completely assembled so that field assembly of barriers or other parts, other than terminals or the mounting of a separate cover after the neutral is wired in the field, is not necessary.

6.9 Panelboard kit

6.9.1 Panelboards may be provided in the form of a field-assembled kit provided the following conditions are met:

a) All components or sub-assemblies necessary to complete the construction of the panelboard shall be included as part of the panelboard kit when shipped from the factory.

Exception: Bus bars, as permitted in Exception Nos. 1, 2, and 3 to (e), may be provided separately when marked in accordance with 34.12.

b) Assembly shall not require the use of other than normally available tools, such as screwdrivers, pliers, and wrenches, unless such tools and instructions for its use are furnished with the kit.

c) Barriers that are needed to comply with spacing requirements in Spacings, Section 16, shall be securely attached at the factory to parts of the assembly that include the energized parts that require the use of the barriers. See 16.3.4.

d) Assembly shall not require drilling or cutting of parts of the assembly.

Note: This does not apply to the mounting of the panelboard into the cabinet, enclosure, or cutout box.

e) All energized bus bars shall be mounted to one subassembly of the kit with interconnections completely assembled so that interconnections of the bus bars are not required in the field. Also refer to 11.2.4 – 11.2.9 for additional bus bar support requirements.

Exception No. 1: Branch-circuit bus bars, as permitted in 6.6.3.

Exception No. 2: Neutral bus bars, as permitted in 6.6.5.

Exception No. 3: Bus bars to a fusible switch, circuit breaker, or associated equipment, as permitted in 6.6.6.

f) Panelboard kits are marked in accordance with 34.19.

g) Panelboard kits are provided with installation instructions in accordance with 37.1.

7 Enclosure

7.1 General

7.1.1 A panelboard shall be constructed for use in a switchboard, cabinet, or cutout box. An enclosed panelboard shall be provided with an enclosure complying with the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50, except for modification and additional requirements as specifically described in the standard.

7.1.2 A single-threaded nut designed to slip over the edge of sheet metal to receive a retaining screw may be used to secure a deadfront to supports, a unit such as a switch or circuit breaker to a mounting panel, a mounting pan to an enclosure, or a cover or a front to an enclosure if:

a) The nut is protected against corrosion by enameling, galvanizing, sherardizing, plating, or other equivalent means.

b) The threads do not strip when a torque of 30 pound-inches (3.4 N·m) is applied.

7.1.3 A Panelboard enclosure shall be sufficiently deep to allow the door or doors to be closed with any switches in either the open or the closed position.

7.1.3.1 The enclosure shall be constructed so that all doors accessing equipment that is likely to require examination, adjustment, servicing, or maintenance while energized shall open to a minimum of 90 degrees from the closed position.

7.1.4 A meter center shall have an opening to accommodate a watt-hour meter. The metal from which it is cut shall comply with the Standard for Meter Sockets, UL 414.

7.1.5 *Deleted*

7.1.6 For enclosed recreation vehicle (RV) panelboards, that portion of the enclosure associated with the low voltage compartment, may comply with the enclosure requirements in the Standard for Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts, UL 458. Unless the line voltage and low voltage compartment of the assembly are separated by a barrier that complies with enclosure requirements in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50, the overall assembly shall be mounted in an enclosure which complies with the requirements of UL 50.

7.2 Component arrangement

7.2.1 A fuse puller and a pull-out switch incorporating a fuseholder employed in a panelboard shall have no live parts exposed when the device is in the closed position, and cartridge-fuse clips in such a device shall be dead when accessible for the inspection or replacement of fuses.

7.2.2 The setting, adjustment, or manual operation of a clock-operated switch or similar device by an operator shall not result in exposure of wiring, other than that directly connected to the switch or device, or exposure to unintentional contact with live parts.

7.2.3 A meter-socket base shall be mounted independently of the cover unless it is intended to be used with a current transformer.

7.2.4 The enclosure of a meter socket shall house completely all live parts with an appropriate meter mounted in position.

7.2.5 In a meter socket, all bare live parts shall be recessed:

a) Not less than 1/2 inch (12.7 mm) behind the plane of the outer edge of the meter-mounting rim, or behind the plane of the meter-mounting hole if a mounting rim is not provided.

b) Behind the plane of the cover, unless a barrier or the like is provided so that the cover may be removed without the likelihood of its contacting a bare live part.

7.3 Ventilating openings

7.3.1 General

7.3.1.1 Ventilating openings shall only be permitted on enclosed panelboards rated 400 amperes or more. When provided, ventilating openings shall be located as follows:

a) In an enclosure intended for surface mounting only – permitted in the front, side, top or bottom walls only,

b) In an enclosure not intended for surface mounting only – permitted in the front only.

7.3.1.2 Ventilating openings shall be guarded so that there will be no direct access to a live part.

7.3.1.3 Guarding as required by 7.3.1.2 may be accomplished by:

a) Screened or louvered openings with internal barriers,

b) Hoods or stacks with labyrinth air passages.

7.3.2 Barriers

7.3.2.1 A ventilating opening in the top of the enclosure shall be covered by a hood or protective shield spaced above the opening to prevent the entry of foreign material.

7.3.3 Size, location, and covering or screening

7.3.3.1 A ventilating opening – slot, louver, or the like – shall be protected by one or more baffles, barriers, or other obstructions of such dimensions and locations that any access path to a live part requires at least two changes in direction from a straight line. If the minor dimension of a ventilating opening is larger than 1/4 inch (6.4 mm) it shall be protected by a screen having a minor dimension no larger than 1/4 inch.

7.3.3.2 A louver shall not be more than 12 inches (305 mm) long.

7.3.3.3 The size, shape, and location of a screened or otherwise covered opening shall be such that it will not unduly weaken the overall enclosure.

7.3.3.4 The area of all openings cut or formed from the enclosure metal shall not exceed 25 percent of the area of the wall in which the openings are located.

Exception: The 25 percent area limitation may be exceeded if reinforcing means, such as stiffeners, are employed and the enclosure complies with the requirement in 7.3.3.3.

7.3.3.5 The area of an opening covered by a louvered, perforated, or expanded metal panel that is thinner than the enclosure shall not exceed 200 square inches (1290 cm^2). The area of an opening covered by 0.053 inch (1.35 mm) thick or thinner – 0.056 inch (1.42 mm) if zinc coated – steel panel or by a screen of 14 AWG (2.1 mm^2) or smaller steel wire shall not exceed 80 square inches (516 cm^2).

7.3.3.6 The wires of a screen shall not be smaller than 16 AWG (1.3 mm^2) and the openings shall not exceed 1/4 inch (6.4 mm) in any dimension. A supplementary screen having smaller openings may be provided, but is not to be considered in evaluating the primary screen.

7.3.3.7 Perforated sheet steel and sheet-steel expanded mesh shall not be less than 0.042 inch (1.07 mm) thick – 0.045 inch (1.14 mm) thick if zinc coated – for mesh openings or perforations 1/2 square inch (3.2 cm^2) or less in area; and shall not be less than 0.080 inch (2.03 mm) thick – 0.084 inch (2.13 mm) thick if zinc coated – for larger openings.

Exception: Perforated sheet metal or expanded metal mesh not less than 0.020 inch (0.51 mm) thick – 0.023 inch (0.58 mm) thick if zinc coated – may be employed for a guard or enclosure, the indentation of which will not alter the clearance between uninsulated live parts and grounded metal so as to adversely affect performance or reduce spacings below the minimum acceptable values specified in Table 16.1.

7.3.4 Rainproof and raintight

7.3.4.1 An enclosed panelboard without ventilating openings may be designated as Type 3, 3S, 4, 4X, 6, or 6P if it complies with the applicable requirements in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

7.3.4.2 An enclosed panelboard, with or without ventilation openings, may be designated as Type 3R or 3RX if it complies with the applicable requirements in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, and with the requirements in Section 22, Rain Test.

8 Bases and Supports – Insulating Material

8.1 An insulating material used for direct or indirect support of an uninsulated live part shall provide the level of performance specified in Table 8.1 for direct support and Table 8.2 for indirect support of a live part.

Exception: An insulating material may be accepted based on the end-product tests specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Table 8.1
Maximum performance level category (PLC) for direct support insulating material

Test specified[a]	Flammability rating of material[a,d]		
	V-0	V-1	V-2
High voltage Arc Tracking Rate (HVTR)	1[b]	1[b]	1[b]
Comparative Tracking Index (CTI) Under Moist Conditions	3[c,e]	3[c,e]	3[c,e]
High Current Arc Ignition (HAI)	3	2	2
Hot Wire Ignition (HWI)	4	3	2

[a] CTI, HAI, HVTR, and HWI are determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. Flammability ratings are determined in accordance with the Standard for Tests For Flammability of Plastic Materials For Parts in Device and Appliances, UL 94.

[b] This requirement is only applicable to a component having spacings less than 1/2 inch over surface as covered by Table 16.3.

[c] A material having a comparative tracking index PLC of 4 may be used if the voltage involved is 250 volts or less.

[d] A material having a HB flame rating is not acceptable in any case.

[e] Phenolics having a comparative tracking index PLC of 4 are acceptable if the voltage involved is 600 volts or less.

Table 8.2
Maximum performance level category (PLC) for indirect support insulating material

Test specified[a]	Flammability rating of material[a]			
	V-0	V-1	V-2	HB
High Current Arc Ignition (HAI)[b]	3	2	2	1
NOTE – If the spacing between the indirect support material and the live part is less than 1/32 inch (either through air or over surface) the material shall be considered as providing direct support and shall comply with Table 8.1.				
[a] See note a to Table 8.1. [b] If the end product through air spacing between the indirect support material and the live part is 1/16 inch or greater, but less than 1/2 inch, then consideration can be given to conducting the High Current Arc Ignition Test at the end product spacing. If the through air spacing is 1/2 inch or greater, then this requirement is not applicable.				

8.2 Thermoplastic insulating materials used for direct or indirect support of uninsulated live parts shall be subjected to the Mold Stress Relief Test, Section 24.

8.3 Slate, porcelain, and soapstone are acceptable materials for the support of an uninsulated live part. A base of slate or porcelain shall not be less than 1/2 inch (12.7 mm) thick.

8.4 Other than as indicated in 8.5, a live screwhead, a rivet, or a nut on the underside of a base designed for surface mounting shall be countersunk not less than 1/8 inch (3.2 mm) in the clear, and covered to a depth of not less than 1/8 inch (3.2 mm) with a waterproof, insulating sealing compound.

8.5 If the screw or nut mentioned in 8.4 is reliably prevented from loosening by being staked or upset, by a lock washer, or by other means, it may be insulated from the mounting surface by a material other than a sealing compound or by providing a spacing from the mounting surface not less than that specified in Table 16.1.

8.6 In a panelboard that has been found to be acceptable without a temperature test and in a panelboard incorporating fuseholders, the sealing compound mentioned in 8.4 shall not soften at a temperature of 90°C (194°F).

8.7 A determination of the softening point of a sealing compound as noted in footnote c to Table 21.1, is to be made in accordance with the test for softening point by ring and ball apparatus described in the Standard for Polymeric Materials – Short Term Property Evaluation, UL 746A.

Exception: A test is not required for a thermosetting material.

9 Covers, Barriers, and Partitions

9.1 General

9.1.1 A panelboard having a wiring gutter, wiring space, or termination area shall be provided with a cover, barrier, or partition extending around or from the side or sides of all bases or groups of bases of switches, fuseholders, or circuit breakers within the enclosure. Such a cover, barrier, or partition shall be firmly secured in position and shall fit closely with the bases of devices within the enclosure and with the door, frame, or side walls so as to enclose the wiring space, wiring gutter, or termination area and the wires stowed within it. A cover shall be provided to enclose a wiring space, wiring gutter, or termination area that would otherwise be exposed when a door giving access to a switch or fuse is open. See 17.2.2.1.

9.1.2 With reference to the requirement in the second sentence in 9.1.1, a cover, barrier, partition, or dead-front shield in a panelboard intended for use in an enclosure with no dimension more than 40 inches

(1016 mm) and no area more than 1000 square inches (64.5 square decimeters) is considered to fit closely with:

a) The bases of devices if the gap at any point is not more than 1/8 inch (3.2 mm) with the cover, barrier, partition or dead-front shield and the devices assembled in any normal position; and

b) The front of the enclosure if the gap between the front and the return flange of a dead-front shield is not more than 3/16 inch (4.8 mm) with the panelboard properly positioned in the enclosure.

9.1.3 A panelboard shall be deadfront unless it is intended for use where it will be accessible only to qualified persons. See 34.1.6.

9.1.4 A barrier shall be provided between the installed wires and any part in the panelboard that may involve arcing in its operation. A barrier that is necessary for compliance with 17.2.2.1 is to be of such construction and so located that normally placed wires in a wiring gutter will be prevented from contacting an uninsulated live part. A barrier is not required to discourage the improper running of wires in a space intended for field addition of units, a space that contains uninsulated live parts, or both, if there are other spaces obviously intended for the placement of wiring and of adequate size for the wires.

9.1.5 A barrier shall be provided between bus bars and wiring and terminal spaces if the presence of the bus bars is not obvious when viewed from the front of the installed panelboard with the deadfront removed if it is removed for wiring and all units are in place.

Exception: The barrier may be omitted if the bus bars are recessed at least 1 inch (25.4 mm) back from the edge adjacent to the spaces of the installed main or branch-circuit units.

9.1.6 The illustrations and descriptions in Figure 9.1 indicate the locations where barriers are required.

Figure 9.1

Typical layouts of components, compartments, spaces, and barriers

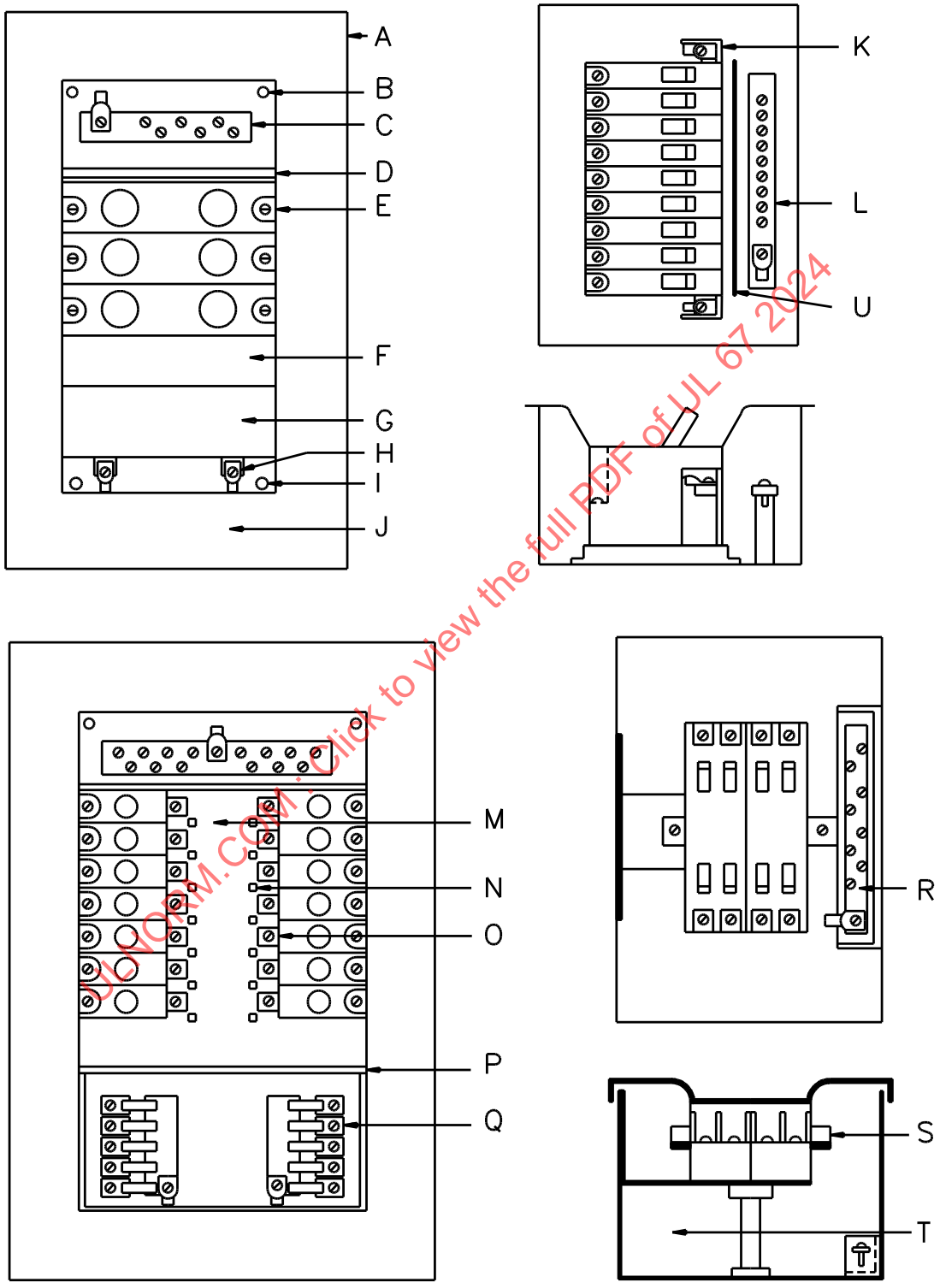


Figure 9.1 (cont'd)

Notes for Figure 9.1

A – Cabinet or cutout box.

B – Barrier separating neutral termination area from compartment containing arcing parts; barriers separating bus bars from a neutral terminal space or wiring spaces if neutral is not provided. See 9.1.5.

C – Recessed branch-circuit terminals.

D – Space available for one or more additional units, containing uninsulated bus bars. Side barriers are not required to prevent wires from being run over the bus bars if there is adequate wiring space elsewhere, and if the bus bars are located in relation to the adjacent wiring space so that wires placed in the wiring space in a normal manner will not come in contact with them.

E – Completely segregated main switch.

F – Main-termination area.

G – Barrier posts for main termination area. Posts must extend within 1/8 inch of dead-front shield.

H – Wire-bending space between any wire connector and the wall or barrier toward which it is directed or through which the connected conductor may normally pass.

I – Main terminal in gutter recessed between closely fitting walls.

J – Wiring gutter containing wires from meters.

K – Barriers creating termination area.

L – Terminals feeding branch-circuit units.

M – Barriers completely separating meter-fuse compartment from wiring spaces. Individual openings in barriers are provided opposite each terminal.

N – Meter-fuse compartment with terminals for wires leading to meters.

O – Main terminals in side wiring space that will contain not more than eight wires, excluding main feeders, if one or more of these wires may be of a polarity opposite to that of the terminal.

P – Back wiring space.

Q – Barrier separating bus bars from wiring spaces. See 9.1.5.

9.1.7 Other than as indicated in 9.1.8 and 9.1.11, a metal barrier shall have a thickness not less than 0.053 inch (1.35 mm) if uncoated sheet steel, not less than 0.056 inch (1.42 mm) if galvanized sheet steel, and not less than 0.075 inch (1.91 mm) if aluminum.

9.1.8 A metal barrier may be of a thickness less than that specified in 9.1.7 if its strength and rigidity is not less than that of a flat sheet of the same metal having the same dimensions as the barrier and of the specified thickness.

9.1.9 A barrier of slate or marble shall not be less than 1/2 inch (12.7 mm) thick. Except as indicated in 9.1.10, a nonmetallic barrier other than slate, marble, or similar material shall not be less than 1/4 inch (6.4 mm) thick and shall be supported to provide the necessary strength and rigidity.

9.1.10 The thickness of a nonmetallic barrier other than slate, marble, or similar material, may be less than 1/4 inch (6.4 mm) if the barrier is located so that it will not be subject to mechanical abuse during installation and is located and supported so that it will have the necessary mechanical strength and rigidity. See 16.3, Barriers and liners.

9.1.11 A dead-front shield shall have a thickness not less than 0.032 inch (0.81 mm) if uncoated, not less than 0.034 inch (0.86 mm) if galvanized, and not less than 0.050 inch (1.27 mm) if aluminum.

9.1.12 In a dead-front panelboard that has a dead-front shield with a metal thickness in accordance with 9.1.11 and that also has a door as integral parts of the cover, the door may have a thickness less than the requirement of the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50, but not less than 0.032 inch (0.81 mm) if uncoated steel, not less than 0.034 inch (0.86 mm) if galvanized steel, and not less than 0.050 inch (1.29 mm) if aluminum.

9.1.12.1 Formed hinges may be utilized for doors with edges longer than 24 inches (610 mm) or having an area more than 360 in^2 (232,300 mm^2) when:

a) With an edge longer than 24 inches (610 mm) on the side that is hinged and on the side opposite the hinged side, but not on the edges adjacent to the side with the formed hinge;

b) Having an area more than 360 in^2 (232,300 mm^2); and

c) Weighing 6.825 lbs. (3.1 kg) or less for doors made of steel or 3.35 lbs. (1.5 kg) or less for doors made of aluminum.

Note: Weight of the doors corresponds to the maximum weights for doors manufactured in accordance with the requirements and limitations in door sizes that may utilize formed hinges in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50. For the purposes of this requirement, steel is assumed a weight of 0.283 lbs/in^3, and aluminum is assumed a weight of 0.098 lbs/in^3).

9.1.13 A dead-front shield shall be supported independently of any support that will be provided by units that may be field-installed. It shall be constructed so that it can be readily installed and removed without the likelihood of contacting a bare live part or damage the insulation of any insulated live part inside the enclosure.

9.1.14 With reference to the requirement in 9.1.13, a dead-front shield is considered to be likely to fall backward into the panelboard interior unless it is reliably supported during removal until it can be extracted directly from the enclosure without a further sliding or twisting motion.

9.1.15 In a panelboard of the dead-front type employing insulating material as a covering or protection of uninsulated live parts, the head of a screw or rivet that engages the mounting strap of a switch, or that may become live through malfunction or breakdown of the switch, shall be located or protected by countersinking or the equivalent so that it will not be exposed to unintentional contact from the front of the device.

9.2 Bushings

9.2.1 An opening in a metal barrier through which a factory-installed wire or cable or a field-installed wire may pass shall be provided with a bushing or shall be formed so that insulated conductors will not come in contact with sharp edges.

9.2.2 A bushing employed at the opening mentioned in 9.2.1 may be of glass, porcelain, hard fiber, phenolic composition, or cold-molded composition. A metal eyelet or grommet having a smooth, rounded surface on which the wire or cable may bear is acceptable in place of a bushing. A bushing of rubber, neoprene, polyvinyl chloride, or of hot-molded shellac-and-tar composition is not acceptable.

9.2.3 The bushing may be of material other than those mentioned in 9.2.2 if it has been investigated and found to be acceptable for the purpose.

10 Filler Plates

10.1 A filler plate as discussed in 10.2 – 10.10 is a plate intended to close an opening that would otherwise be closed by subsequent installation of a circuit breaker or other device. A breakout is not considered to be a filler plate. See 34.14.1 and 34.14.2.

10.2 If one or more openings are not closed when the panelboard is installed, filler plates complying with the requirements in 10.3 – 10.10 shall be available. If one or more branch-circuit units are factory installed, filler plates closing the remaining openings for field installation of such units shall be factory installed.

10.3 A sheet-steel filler plate shall have an average thickness not less than 0.056 inch (1.42 mm) if galvanized or 0.053 inch (1.35 mm) if uncoated.

Exception: The average thickness may be not less than 0.034 inch (0.86 mm) if galvanized or 0.032 inch (0.81 mm) if uncoated, if the plate is not larger than 1 inch by 3 inches (25.4 mm by 76.2 mm) or it is employed behind a door or a cover.

10.4 A filler plate of insulating material shall:

a) Be of material that is acceptable for the indirect support of uninsulated live parts, in accordance with 8.1 and 8.3;

b) Not be less than 3/32 inch (2.4 mm) thick at any point;

c) Other than as noted in 10.5, have one dimension – length or width – not larger than 3 inches (76.2 mm) and have the other dimension not larger than 1 inch (25.4 mm); and

d) Be located a minimum of 1/32 inch (0.8 mm) from a live part. Also see Note to Table 8.2.

10.5 A filler plate may have dimensions larger than those specified in 10.4(c) if it has been investigated and found to be acceptable for the purpose.

10.6 Other than as noted in 10.7, screws shall be employed for securing a filler plate in place.

10.7 Means other than screws for securing a filler plate may be employed if the plate, when secured in place, will not be dislodged as a result of normal use but may be readily removed if desired.

10.8 A filler plate shall:

a) Be of such size and shape that it will extend at least 1/32 inch (0.8 mm) on all sides beyond the opening that it is intended to close (See 10.1 and 10.9);

b) Have a 1/4 inch (6.4 mm) or wider right-angle flange or the equivalent around its perimeter that, except at the ends of a row of units, will closely abut a similar flange or the equivalent around the edge of the opening that the plate is intended to close; or

c) Overlap as specified in 10.8(a) on one, two, or three sides and shall have a flange or the equivalent as described in 10.8(b) on the remaining side or sides.

10.9 A filler plate shall close the opening to at least the same extent as the unit, such as a switch or circuit breaker, in place of which the filler plate is mounted.

10.10 The amount of overlap at a formed ear intended to secure a filler plate in place is not specified, but with the plate in place a resulting opening at such point shall not be longer than the thickness of the cabinet front or the dead-front shield.

11 Current-Carrying Parts

11.1 General

11.1.1 A current-carrying part shall be of silver, a silver alloy, copper, a copper alloy, aluminum, an aluminum alloy, or other metal investigated and found to be acceptable for the application, and shall be rigid.

11.1.2 Iron or steel shall not be used for a part that is depended upon to carry current.

11.1.3 Plated steel screws, nuts, and studs may be used to secure pressure wire connectors and bus bars. A No. 10 and larger plated-steel wire-binding screw may be used at a terminal, in connection with a nonferrous terminal plate. Bolts, washers, and nuts at the hinges of knife switches are considered to be parts that are not depended upon to carry current.

11.1.4 Copper and brass are not acceptable for plating wire-binding screws, nuts, and stud terminals, but a plating of cadmium, zinc, tin, or silver is acceptable.

11.1.5 Each bus bar shall be plated at each joint with tin, silver, nickel, or cadmium.

Exception No. 1: Welded or brazed joints need not be plated.

Exception No. 2: Copper bus bars need not be plated if the current at the joints is 600 amperes or less.

Exception No. 3: Other coatings may be used for aluminum bus bars if investigated for the application in accordance with the requirements in 21.1.1 and 21.6.1.

11.1.6 Among the factors taken into consideration when the acceptability of other coatings as mentioned in Exception No. 3 to 11.1.5 is being determined are its adherence to aluminum and resistance to corrosive environment. These factors are considered with respect to conductivity and thermal aging.

11.1.7 Each riveted connection involving current-carrying parts shall have a spring washer at one end and either a spring washer or a flat washer at the other end.

Exception No. 1: A construction that has been tested in accordance with 21.5.1.

Exception No. 2: A connection rated 225 amperes or less employing copper bus bars only.

11.1.8 A spring washer shall be used at one end of a bolt securing current-carrying parts together.

Exception No. 1: A construction that has been tested in accordance with 21.5.1.

Exception No. 2: A spring washer may be replaced with a split ring lock washer and flat washer if each aluminum bus in the joint has a tensile yield strength of at least 20,000 pounds per square inch (138 MPa).

Exception No. 3: A flat washer, a split-ring lock washer, or a bolthead that complies with 11.1.10(b) may be used in place of a spring washer if the joint does not include any aluminum or if aluminum bolts are used with aluminum bus bars.

Exception No. 4: A type of fastening equivalent to that used for evaluating the suitability of a wire connector used as a component in accordance with the requirements for wire connectors.

Exception No. 5: A spring washer is not required at a bolted contact of an aluminum alloy conductor used in the grounding circuit for an application such as the service-grounding electrode, a neutral-bonding conductor, or an equipment-grounding conductor.

11.1.9 A spring washer as mentioned in 11.1.7 and 11.1.8 shall:

a) Be a dished washer of stainless, or hardened and tempered steel,

b) Have an outer diameter not less than 150 percent of the bolt diameter and a thickness not less than one-eighth of the bolt diameter, and

c) Be dished not less than 3-1/2 percent of the bolt diameter.

11.1.10 A flat washer as mentioned in 11.1.7 and 11.1.8 shall have:

a) A thickness at least one-sixth the diameter of the rivet shank or bolt, and

b) An outer diameter at least 150 percent of that of the rivet shank or bolt, but not less than the outer diameter of the spring washer.

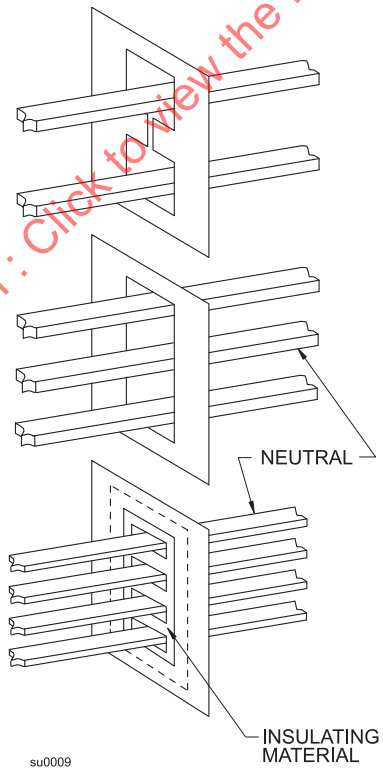
11.1.11 All conductors of an alternating-current circuit that pass through a wall or partition of metal having magnetic properties, including the neutral, shall be run through the same opening.

Exception: Internal wiring of panelboards subjected to the Temperature Test, Section 21, with temperatures recorded in the area of the metal wall or partition to determine compliance with Table 21.1, are not required to include all conductors in the same opening.

11.1.12 With reference to the requirement in 11.1.11, and to Figure 11.1, the conductors may pass through individual openings in a wall or partition if the openings are connected by slots cut in the metal wall. The conductors may be run through individual openings in an insulating block used to cover an opening in the metal wall sufficiently large for all the conductors of the circuit if no metal bracket, brace, or the like, is placed across the insulating material between the conductors.

Figure 11.1

Conductors through openings



11.2 Bus bars, supports

11.2.1 A bus bar or uninsulated live part, other than a pressure wire connector as mentioned in 16.1.15, shall be reliably secured so that ordinary vibration will not loosen the securing means, and shall be prevented from turning or shifting in position if any spacings less than half those specified in Table 16.1 would result from such turning or shifting. A bus bar provided with one or more insulators that must be

removed when the unit is installed shall be prevented from any turning or shifting that would result in spacings less than half those specified in Table 16.1 with all insulators in place, or that would result in a spacing less than 1/8 inch (3.2 mm) for any voltage up to 250 volts, or 1/4 inch (6.4 mm) for any voltage from 251 to 1000 volts, with any insulators omitted.

11.2.2 A neutral bus bar shall be mounted on an insulating base that complies with the requirements in 8.1.

Exception: A neutral need not be mounted on an insulating base when the panelboard is marked to indicate that it is suitable only for use as service equipment in accordance with 34.9.1.

11.2.3 A bolted connection between two bus bars or between a bus bar and another current-carrying part shall not depend on polymeric insulation to maintain the clamping force unless investigated for such use as specified in 21.7.1, and shall not depend on thermoplastic material in any case.

Exception: This requirement does not apply to a joint intended to carry 30 amperes or less, or to a meter socket base.

11.2.4 A bus bar shall be supported independently of any switch, circuit breaker, or the like that is connected to it unless such switch, or the like is reliably supported independently of the bus bar and is factory-installed.

11.2.5 The phase arrangement of main and submain bus bars in a 3-phase panelboard, not including the connections to metering equipment , shall be A, B, C, from front to back, top to bottom, or left to right as viewed from the front of the panelboard. The neutral in a 3-phase, 4-wire panelboard may be in any location in the sequence (for example: A, N, B, C) if it is identified as such by a marking on the neutral or on a wiring diagram. The B-phase shall be that phase having the higher voltage to ground on 3-phase, 4-wire, delta-connected systems (see 34.4.4 and 34.4.5).

Exception No. 1: Other bus bar arrangements may be used for a panelboard manufactured for an existing installation if the arrangement of the bus bars is indicated by marking.

Exception No. 2: The phase arrangement in a 240-volt, 3-phase, 3-wire panelboard intended for use on a grounded B-phase system is to be A, C with the neutral as the B-phase.

Exception No. 3: Other bus bar arrangements may be used for a panelboard if access to the bus bars is limited or field connection of cables is not required, and the arrangement of bus bars is indicated by marking.

Exception No. 4: A meter center intended for 3-phase, 4-wire delta connected systems only may have the same phase configuration as the metering equipment (C-phase at the higher voltage to ground). See 34.4.5.

Exception No. 5: A meter center having a combination voltage rating that includes a 3-phase, 4-wire delta system rating, may be marked to show the C-phase at the higher voltage to ground.

11.2.6 If a branch bus bar is not prevented from turning by being secured to a circuit breaker, a switch, a fuseholder, or the like when the panelboard is shipped from the factory:

a) The branch bus bar shall be prevented from turning. Friction alone is not acceptable for this purpose; or

b) Any part of the branch bus bar to which spacings may be reduced to values less than the minimum acceptable if the bus bar rotates shall be insulated. The insulation shall be securely held in place.

11.2.7 A panelboard in which branch bus bars may be mounted in the field – see 6.6.3 – shall be such that reliable support will be provided for such bus bars. A base for supporting a bus bar shall be assembled in place in the panelboard before it is shipped from the factory. See 34.12.4.

11.2.8 Friction between surfaces is not acceptable as a means to prevent turning or shifting of an uninsulated live part. Turning or shifting may be prevented by the use of two screws or rivets, by noncircular shoulders or mortises, by a dowel pin, lug, or offset, by a connecting strap or clip fitted into an adjacent part, or by an equivalent method. No reliance is to be placed on a single branch circuit fuseholder, circuit breaker or switch unit for preventing turning of the branch bus bar feeding such unit, if such turning would reduce spacings to less than those specified in 11.2.1 or Table 16.1.

11.2.9 In determining the adequacy of means to prevent turning or shifting in regard to 11.2.8, any screw or nut is to be loosened and retightened finger-tight without a tool. The bus bar is then to be pushed to the extent limited by the screws or other means and the resulting spacings measured.

11.2.10 If a branch-circuit unit, such as a circuit breaker, switch unit, or plug fuseholder, rated 600 amperes or less is removable from the front of the panel, the replacement or removal of such unit shall not result in the likelihood of a short circuit from turning or dropping of parts.

11.2.11 Bolts, nuts, or washers used in securing a branch circuit unit are not considered likely to fall if they are visible and readily reached. A branch bus bar will usually be considered likely to fall if the same bolts that secure the branch-circuit unit to the branch bus bar also serve to secure the branch bus bar to the bus bar on its line side.

11.2.12 If parts are held together by screws, a threaded part shall not have fewer than two full, clean-cut threads. If the screw does not extend all the way through a threaded part, the taper or lead thread and the first full thread are to be disregarded in determining the number of threads engaged.

11.3 Ampacity General

11.3.1 Except as indicated in 11.3.2, a panelboard shall comply with the requirements specified in Section 21, Temperature Test. See 12.1.10.

11.3.2 A panelboard rated 400 amperes or less with aluminum bus bars or 1600 amperes or less with copper bus bars need not be subjected to the tests in Section 21, Temperature Test, if it complies with all of the following:

a) A factory- or field-installed insulated conductor connected between parts of a panelboard shall have an ampacity not less than the maximum current rating of the circuit in which it is connected, in accordance with Table 11.1.

b) Other than as noted in 11.3.3, 11.3.4, and 11.3.5 the current density shall not be more than:

1) One thousand amperes per square inch (155 A/cm^2) of cross section for solid copper.

2) Seven hundred fifty amperes per square inch (116 A/cm^2) of cross section for solid aluminum having a conductivity of at least 55 percent that of the International Annealed Copper Standard.

3) Two hundred amperes per square inch (31 A/cm^2) of contact area at bolted contacts between copper or aluminum bus bars and connecting straps or connectors. In determining

the contact area of a bolted or riveted connection, no additions or subtractions shall be made for the area of screws, bolts, or rivets.

4) Seventy-five amperes per square inch (11.6 A/cm^2) of contact area at contact surfaces of copper switch blades and jaws.

c) The panelboard shall not be rated for a frequency of more than 60 hertz.

d) The panelboard is rated 110 amperes or less or having any circuits rated 110 amperes or less and is marked to indicate use of 60°C conductors only for circuits rated 110 amperes or less and 75°C conductors for circuits rated more than 110 amperes. See 12.1.10(c).

Table 11.1
Ampacities of insulated conductors

Wire size,		Temperature rating of conductor			
		60°C (140°F)		75°C (167°F)	
AWG or kcmil	mm^2	Copper	Aluminum	Copper	Aluminum
14	2.1	20 (15)[a]	–	20 (15)[a]	–
12	3.3	25 (20)[a]	20 (15)[a]	25 (20)[a]	20 (15)[a]
10	5.3	30	25	35 (30)[a]	30 (25)[a]
8	8.4	40	30	50[b]	40[b]
6	13.3	55	40	65[b]	50[b]
4	21.2	70	55	85[b] (100)[c]	65[b]
3	26.7	85	65	100[b] (110)[c]	75[b]
2	33.6	95	75	115[b] (125)[c]	90[b] (100)[c]
1	42.4	110	85	130[b] (150)[c]	100[b] (110)[c]
1/0	53.5	d	d	150 (175)[c]	120 (125)[c]
2/0	67.4	d	d	175 (200)[c]	135 (150)[c]
3/0	85.0	d	d	200 (225)[c]	155 (175)[c]
4/0	107.2	d	d	230 (250)[c]	180 (200)[c]
250	127	d	d	255 (300)[c]	205 (225)[c]
300	152	d	d	285	230 (250)[c]
350	177	d	d	310 (350)[c]	250 (300)[c]
400	203	d	d	335 (400)[c]	270
500	253	d	d	380	310 (350)[c]
600	304	d	d	420	340 (400)[c]
700	355	d	d	460	375
750	380	d	d	475	385
800	405	d	d	490	395
900	456	d	d	520	425
1000	506	d	d	545	445
1250	633	d	d	590	485

Table 11.1 Continued on Next Page

Table 11.1 Continued

Wire size,		Temperature rating of conductor			
		60°C (140°F)		75°C (167°F)	
AWG or kcmil	mm²	Copper	Aluminum	Copper	Aluminum
1500	760	d	d	625	520
1750	887	d	d	650	545
2000	1013	d	d	665	560

NOTES

1 For a multiple conductor connector at a terminal, the ampacity value is to be multiplied by the number of conductors that the terminal is capable of accommodating [1/0 AWG (53.5 mm²) and larger].

2 These values of ampacity apply only when a maximum of 3 current carrying conductors are to be field installed in a single conduit. When four or more conductors other than a grounding conductor or a neutral that carries the unbalanced current from other conductors of the same circuit are to be installed in conduit, the allowable ampacity of each of these conductors is reduced as shown in the following table. These reduced values do not apply to internal wiring of a panelboard unless enclosed in conduit.

Number of Conductors	Percent of Value in Table
4 – 6	80
7 – 9	70
10 – 20	50
21 – 30	45
31 – 40	40
41 or more	35

[a] Values in parentheses are to be used if wire is connected to an overcurrent protective device. The other values are applicable in accordance with 11.3.2.

[b] The ampacity of these sizes shall be the same as for 60°C (140°F) wire when connected to a molded case circuit breaker unless the breaker is marked 75°C (167°F).

[c] The values in parentheses are capable of being used at the main terminals of a single-phase, 3-wire, panelboard intended for use as residential service equipment, when the panelboard is marked in accordance with 34.1.14.

[d] For wire sizes 1/0 AWG and larger, it is assumed that wire with at least a 75°C temperature rating is being used.

11.3.3 The limitations on current density mentioned in 11.3.2(b) do not apply:

a) To a connecting strap, bus bar, or the like comprising a part of a circuit breaker, switch, or fuseholder employed in the panelboard.

b) To a part of a strap, bus bar, jumper, and the like, adjacent to and connected to a terminal of a switch, circuit breaker, or fuseholder – but for not more than 1 inch (25.4 mm) from the terminal – if a reduced cross section in that part is necessary because the terminal is recessed or barriers are adjacent to it.

c) At a connector if the entire normal contact surface is in contact with the bus bar, terminal, or other surface to which it is connected. The normal contact surface of a pressure wire connector is considered to be that area resulting when two identical connectors are positioned back-to-back with the major axes of the wire barrels at 90 degrees or 180 degrees from each other, whichever position results in the smaller contact surface.

d) At the connection of a bus bar to a terminal of a switch, circuit breaker, or fuseholder if the contact area at the point at which the bus bar is connected to such a terminal is:

1) The full contact area available on the circuit breaker, switch, or fuseholder, or

2) Not less than the contact area between the terminal and the pressure wire connector normally supplied with such a unit.

11.3.4 The cross section of a bus as covered in 11.3.2(b) may be reduced by not more than 5 percent due to rounding, shaping, or dimensional tolerances.

11.3.5 Part of the bus material may be removed for slots or holes – whether used or not – provided the remaining material at any cross section along the length of the bus bar has at least 70 percent of the required ampacity and the remaining metal in any 6 inch (152.4 mm) length of bus is at least 93 percent of the metal of a bus having the required ampacity in accordance with 11.3.2(b); for example, a 1 inch (25.4 mm) wide bus may have 9/32 inch (7.1 mm) holes on 1 inch centers or a 4 inch (101.6 mm) wide bus may have 13/32 inch (10.4 mm) wide slots 3.2 inch (80.9 mm) long every 6 inches.

11.3.6 Table 11.2 gives the ampacities of some of the more common sizes of copper bus bars.

Table 11.2
Ampacities of common size copper bus bar

Width of bus bar,		Bus-bar thickness, inches (mm)											
inches	(mm)	3/64 (1.2)	0.051 (1.30)	1/16 (1.6)	0.064 (1.63)	5/64 (2.0)	0.081 (2.06)	3/32 (2.4)	1/8 (3.2)	5/32 (4.0)	3/16 (4.8)	7/32 (5.6)	1/4 (6.4)
3/8	(9.5)	18	19	23	24	29	30	35	47	59	70	82	94
7/16	(11.1)	21	22	27	28	34	35	41	55	68	82	96	109
1/2	(12.7)	23	26	31	32	39	41	47	63	78	94	109	125
9/16	(14.3)	26	29	35	36	44	46	53	70	88	105	123	141
5/8	(15.9)	29	32	39	40	49	51	59	78	98	117	137	156
11/16	(17.5)	32	35	43	44	54	56	64	86	108	129	150	172
3/4	(19.1)	35	38	47	48	59	61	70	94	117	141	164	188
7/8	(22.2)	41	45	55	56	68	71	82	109	137	164	191	219
1	(25.4)	47	51	63	64	78	81	94	125	156	188	219	250
1-1/8	(28.6)	53	57	70	72	88	91	105	141	176	211	246	281
1-1/4	(31.8)	59	64	78	80	98	101	117	156	195	234	273	313
1-3/8	(34.9)	64	70	86	88	102	111	129	172	205	258	301	344
1-1/2	(38.1)	70	77	94	96	117	122	141	188	235	281	328	375
1-3/4	(44.5)	82	89	109	112	137	142	164	219	273	328	383	438
2	(50.8)	94	102	125	128	156	162	188	250	313	375	438	500
2-1/4	(57.2)	105	115	141	144	176	182	211	281	352	422	492	563
2-1/2	(63.5)	117	128	156	160	185	203	234	313	391	469	547	625

11.4 Main unit ratings

11.4.1 The current rating of a main switch, a main fuseholder, and a main circuit breaker – trip-unit rating of a breaker having interchangeable trip units – shall be in accordance with Table 11.3.

Table 11.3
Main switch, fuseholder, and circuit breaker ratings

Rated ampacity of main bus bar	Maximum main switch and fuseholder rating, amperes	Maximum main circuit breaker rating, amperes
0 – 30	30	30
31 – 40	60	40
41 – 50	60	50
51 – 60	60	60
61 – 70	100	70
71 – 90	100	90
91 – 100	100	100
101 – 125	200	125
126 – 150	200	150
151 – 175	200	175
176 – 200	200	200
201 – 225	400	225
226 – 250	400	250
251 – 275	400	275
276 – 300	400	300
301 – 350	400	350
351 – 400	400	400
401 – 450	600	450
451 – 500	600	500
501 – 600	600	600

11.5 Neutral

11.5.1 The neutral bus bar shall have an ampacity not less than that of the other bus bars, except that the neutral in a 3-wire d-c or single-phase a-c panelboard or in a 3-phase, 4-wire panelboard, rated more than 200 amperes, shall not have an ampacity less than 200 amperes. See 34.1.12.

11.5.2 A neutral bus bar intended for use in a panelboard with increased neutral ampacity shall have an ampacity of 125%, 150%, 175%, or 200% of the other phase bus bars.

11.5.3 When the main neutral terminal is located at the electrical center of the neutral bus bar, the ampacity of each half of the bus bar shall not be less than half the value specified in 11.5.1. The electrical center is identified as the point at which the neutral current to one side of the bus bar is equal to that to the other side, taking into consideration the total number of terminals located on the neutral bus bar and the current associated with each.

11.5.4 The ampacity of a section of a neutral bus bar that consists of two or more sections shall not be less than the greater of the following:

a) The ampacity required for the part of the neutral current that is expected to flow in that section taking into consideration the relationship between:

1) The number of terminals in that section and the current associated with each, and

2) The total number of terminals in the entire neutral and the currents associated with each.

b) The ampacity required for the current associated with the largest ampacity terminal located in that section.

11.5.5 With reference to 11.5.3 and 11.5.4, the neutral current associated with a given terminal is determined in accordance with Table 11.1, based on the wire of maximum size for which the terminal is capable of supporting; except that the assumed size of wire is not determined to be larger than that required to provide an ampacity not less than the maximum current rating of any overcurrent-protective device to be used in the panelboard. A terminal employing a wire-binding screw is identified as a 30 ampere terminal.

11.5.6 When the service phase conductors are paralleled, the size of the neutral conductor shall be based on the equivalent area of the parallel conductors.

Exception: The neutral conductor shall not be required to be larger than the largest ungrounded service conductor or equivalent area for parallel conductors.

11.6 Fuseholders and circuit breakers

11.6.1 Other than as indicated in 34.1.9, a wire or bus bar leading to a fuseholder shall have an ampacity not less than the maximum current rating of any fuse that the fuseholder will accommodate.

11.6.2 A wire or bus bar leading to a noninterchangeable-trip circuit breaker shall have an ampacity not less than the current rating of the breaker, and not less than 20 amperes in any case. See 34.1.10.

11.6.3 A wire or bus bar leading to an adjustable trip circuit breaker shall have an ampacity not less than the maximum current rating of the adjustable trip circuit breaker, and not less than 20 amperes in any case. See 34.1.10.

11.6.4 Other than as indicated in 34.1.9, a wire or bus bar leading to a circuit-breaker frame designed for use with interchangeable-trip units shall have an ampacity not less than the maximum current rating of the frame.

12 Wiring Terminals

12.1 General

12.1.1 A terminal, such as a pressure wire connector or wire-binding screw, shall be provided for connection of each conductor intended to be field-installed in the panelboard and shall be the same type as used during the short-circuit test. Connections may be provided for cord-connected equipment, see Cord-Connectors, Section 13. See 18.2, Equipment-grounding terminals.

Exception No. 1: Terminals are not required in a panelboard intended for connection to bus bars.

Exception No. 2: Terminals are not required to be factory installed in the panelboard if component terminal kits are available from the equipment manufacturer or one or more acceptable pressure terminal connectors are specified for field installation on the equipment, and the construction complies with requirements in 6.8.3.1.

Exception No. 3: An alternative wire connector, such as crimp for crimp, mechanical for mechanical, or crimp for mechanical that complies with the Standard for Wire Connectors, UL 486A-486B, may be used in a panelboard without conducting a short-circuit test under the following conditions:

a) The short-circuit current rating of the panelboard is less than 100,000 amperes, or 100,000 amperes maximum if the panelboard is protected by an overcurrent protective device, and

b) The panelboard short-circuit current rating divided by the number of conductors per phase results in a current of 50,000 amperes per conductor or less.

Exception No. 4: An alternative wire connector, such as crimp for crimp, mechanical for mechanical, or crimp for mechanical that complies with UL 486A-486B, may be used in a panelboard under the following conditions:

a) The short-circuit current rating of the panelboard is less than 100,000 amperes, or 100,000 amperes maximum if the panelboard is protected by an overcurrent protective device, and

b) The panelboard short-circuit current rating per conductor is greater than 50,000 amperes without conducting a short-circuit test provided that:

1) The number of conductors per leg is equal to or greater than the number of conductors as tested, and

2) The average pullout force – in accordance with UL 486A-486B – of three samples of the alternative wire connector is equal to or greater than the average pullout force of three samples of the wire connector used in the short-circuit test.

12.1.2 A wire-binding screw is acceptable for securing a 10 AWG (5.3 mm^2) or smaller conductor only.

12.1.3 A pressure wire connector shall be mechanically secured.

12.1.4 A pressure wire connector provided with or specified for use with a panelboard shall comply with the Standard for Wire Connectors, UL 486A-486B, or the Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E.

12.1.5 The tightening torque for a field-wiring terminal shall be as specified by the panelboard manufacturer and shall be marked as required by 34.5.1. The specified tightening torque shall not be less than 90 percent and not more than 100 percent of the value employed in the static heating test as specified in the Standard for Wire Connectors, UL 486A-486B, or the Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E, for that wire size corresponding to the ampere rating of the panelboard. See 23.1.

Exception: Torque value may be less than 90 percent if the connector is investigated in accordance with the lesser assigned torque value in UL 486A-486B, or UL 486E.

12.1.6 A main terminal shall be capable of securing the smallest conductor, or group of conductors in multiple, of standard size having an ampacity adequate for the rated current of the panelboard as determined in accordance with 12.1.10. See 12.1.11.

12.1.7 A panelboard with increased neutral ampacity shall have a neutral terminal rated for conductors sized for the ampacity of the neutral bus. See 11.5.2.

12.1.8 A terminal for a branch-circuit conductor shall be capable of securing the smallest conductor, or group of conductors in multiple, of standard size having an ampacity adequate for the application, as determined in accordance with 12.1.9 and 12.1.10. See 12.1.11.

12.1.9 With reference to 12.1.8, it is assumed that the ampacity of a wire or wires to be connected to a terminal of:

a) A fuseholder is any value within the range of current ratings of fuse that the fuseholder will accommodate;

b) A circuit breaker capable of accommodating interchangeable trip units of different current ratings is acceptable for the rating of the installed trip unit;

c) A circuit breaker not capable of accommodating interchangeable trip units of different ratings is acceptable for the current rating of the breaker.

12.1.10 The sizes of field installed conductors having ampacities as noted in 12.1.6 and 12.1.8 shall be determined from Table 11.1 based on:

a) The use of aluminum wire at all terminals identified on a wiring diagram or the like as being acceptable for use with such wire, except those terminals identified for use with copper wire only. See 34.2.3 – 34.2.7.

b) The use of wire rated 75°C (167°F) for all wire sizes 1/0 AWG and larger.

c) The use of wire rated 60°C (140°F) for all wire sizes 1 AWG and smaller, except the conductor size shall be based on the use of wire rated 75°C if:

1) The panelboard has been subjected to the temperature test using 75°C wire and is marked for 75°C field-installed wire at any terminals in accordance with 34.3.1, or

2) The panelboard is intended for use as residential service equipment as mentioned in note c to Table 11.1. See 34.1.14.

12.1.11 The requirements in 12.1.6 and 12.1.8 do not preclude use of a connector that will also accommodate a wire or wires of a size or sizes different from that specified in those paragraphs.

12.1.12 In an application in which conductors are used in multiple, the connectors shall be of the same type; that is, if mechanical set-screw connectors are used, all connectors in the arrangement shall be of the mechanical setscrew type.

12.1.13 Aluminum wire, insulated or uninsulated, used for internal wiring interconnections between current-carrying parts shall be terminated at each end by a method acceptable for the combination of the metals involved at the connection point.

12.1.14 A pressure wire connector used as a terminating device for factory or field-installed aluminum wire, shall be acceptable for use with aluminum under the condition involved, such as temperature, heat cycling or the like.

12.1.15 Separate feed-through terminals intended for connecting a single feed-through circuit and tap conductors to a panelboard – see 12.1.16, 17.2.2.3, 17.2.3.4, 34.3.3, 34.12.11, and 34.12.13 – shall provide terminals for tap conductors of ampacity not less than the current rating of the panelboard.

12.1.16 Separate feed-through terminals or a terminal assembly– terminals, compartment barriers, and the like – may be in the form of a kit if the kit complies with 6.8.3.1. See 17.2.2.3, 17.2.3.4, and 34.12.11 – 34.12.14.

12.2 Screw terminals

12.2.1 A wire-binding screw or stud of a wiring terminal shall not have more than 32 threads per inch (25.4 mm) and shall not be smaller than No. 10, except that a No. 8 copper-alloy machine screw may be used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) conductor. The terminal shall be provided with upturned lugs, a cupped washer, or the equivalent capable of retaining a 14 AWG solid conductor even though the screw or nut becomes slightly loose.

12.2.2 Except as noted in 12.2.5, a terminal plate for a wire-binding screw shall not be less than 0.050 inch (1.27 mm) thick.

12.2.3 There shall not be fewer than two full threads in the metal terminal plate.

12.2.4 A terminal plate may have the metal extruded at the tapped hole to provide at least two full threads, if the thickness of the unextruded metal is not less than the pitch of the thread.

12.2.5 A terminal plate not less than 0.030 inch (0.76 mm) thick may be used if the tapped threads have equivalent mechanical strength.

12.2.6 The point of attachment of a pressure wire connector or wire-binding-screw terminal shall not overhang its support unless the construction has the necessary mechanical strength to maintain the spacings required by 16.1.4.

12.2.7 In certain panelboards the points of attachment of pressure wire connectors overhang the support, usually in the molded-unit type in which bus bars are fastened at either end and extend beyond the support. These bus bars are used as main-line terminals or as neutral terminals with numerous branch-circuit binding-screw connections in addition to the main-neutral-supply lugs. These designs are capable of being used when the bus bars supporting the terminals and the pressure wire connectors have the required strength and rigidity to prevent deformation. Performance criteria for these requirements shall be in compliance with Section 23, Strength of Insulating Base and Support Test.

12.2.8 A terminal of a switch or circuit breaker that has an ampacity acceptable for the current-carrying parts shall be firmly and securely connected directly to a bus bar by a screw, stud and nut, or an equivalent fastening means.

12.2.9 If its terminal is not directly connected by a screw threaded into the bus bar, a circuit breaker or switch shall be secured independently of its terminal connection.

12.2.10 An individual terminal shall be provided for the connection of each branch-circuit neutral conductor.

12.2.11 The number of individual branch-circuit neutral terminals shall not be less than 75 percent of the total number of individual fuseholder or circuit-breaker poles capable of being installed in the panelboard.

Exception: The number of terminals may be less than 75 percent, but not less than 50 percent, if marked in accordance with 34.4.6.

12.2.12 A wiring terminal shall be located so that:

a) It will be accessible for examination, and

b) Connections may be tightened or branch-circuit wires removed without loosening any screws that secure a bus bar, switch, circuit breaker, fuseholder, or the like.

With reference to (a), a construction is acceptable even though it may be necessary to remove a circuit-breaker cover, trim, or the like to make a connection accessible.

12.2.13 Load terminals, including neutral load terminals, shall be located so that:

a) It will not be necessary to reach across or beyond an uninsulated ungrounded line bus in order to make a load connection, and

b) A tool 10 inches (254 mm) long or less used to tighten a load connection will not contact a live part that is not obvious from the front of the panelboard.

The requirement in (b) shall be determined with branch units connected.

12.2.14 Using normally available tools, it shall be possible to retighten the conductor securing means of a mechanical setscrew connector without removing the connector from the terminal plate or bus and without removing any conductor from the connector.

12.2.15 A terminal located in the fuse cavity of an Edison-base plug fuseholder is not considered accessible as it is expected that a nonremovable Type S fuseholder adapter will be installed.

13 Cord-Connectors

13.1 General

13.1.1 If provided with connections for cord-connected equipment, connectors shall comply with Section 13, Cord-Connectors.

13.1.2 Connections for cord-connected equipment shall be located so that neither the connector mounted in an input or output connector, nor the flexible cord attached to the connector, will be likely to interfere with the operation of any switch or circuit breaker handle.

13.1.3 An opening through which field installed wiring may pass shall be provided with a bushing or shall be formed so that there are no sharp edges with which conductors may come in contact.

13.1.4 All field wiring conductors of an alternating-current circuit that pass through a wall or partition of metal having magnetic properties, including the neutral, shall be run through the same opening. See 11.1.12.

13.1.5 An integral multiple pole connector shall have sufficient number of poles to accommodate the ground, neutral, and all ungrounded supply conductors in one connector. When single pole separable connectors are provided, there shall be a sufficient number to accommodate the ground, neutral, and all ungrounded supply conductors, and these connectors shall be grouped together.

13.1.6 An integral multiple pole connector shall be of a design such that the ground connection is the first connection made when inserting a connector, and is the last connection to be opened when removing the connector.

13.1.7 Multipole inlets rated below 200 A shall be suitable for connection and disconnection under load.

13.2 Input connections

13.2.1 The requirements in 13.2 are applicable to panelboards provided with an integral multiple pole inlet or with single pole separable connectors for cord connection to a portable generator.

13.2.2 An integral multiple pole inlet or single pole separable connector shall be of a construction with male phase and neutral mating contacts, and shall have a rating no less than the rating of the overcurrent device to which it is connected.

13.2.3 Inlets shall be arranged such that the current carrying parts of the inlet are energized only when a mating attachment connector is connected to the inlet.

13.2.4 Panelboards with an inlet shall be rated for outdoor use in wet locations and shall comply with the requirements for Type 3, 3R, 3S, 4, or 4X enclosures, as detailed in Section 7, Enclosure, with the cord connector installed as well as with the connector removed.

13.2.5 Single pole separable connectors shall be mechanically interlocked in such a manner that plugs must be connected in the following sequence and disconnected in the reverse order:

a) Equipment-grounding conductor connection;

b) Grounded circuit conductor connection; and

c) Ungrounded conductor connection.

Exception: Panelboards with separable single pole connectors rated above 200 A need not comply with 13.2.5 when marked in accordance with 34.18.1 and 34.18.2.

13.2.6 Panelboards with a multiple pole inlet or with single pole separable connectors shall additionally comply with construction requirements in 14.8, Panelboards with integral inlet, and marking requirements in 34.18, Panelboard with provisions for cord connections.

13.3 Output connections

13.3.1 General

13.3.1.1 The requirements in 13.3 are applicable to panelboards provided with an integral multiple pole outlet (receptacle) or with single pole separable outlets for cord connection to portable equipment.

13.3.1.2 A receptacle shall be rated for the voltage involved and shall be of the type having a terminal intended for use only with an equipment grounding conductor.

13.3.2 Multiple pole outlets (receptacles)

13.3.2.1 A receptacle shall be rated for the voltage involved and shall be of the type having a terminal intended for use only with an equipment grounding conductor.

13.3.2.2 Overcurrent protection for a receptacle branch circuit shall be provided within the panelboard.

13.3.2.3 A receptacle installed on an branch circuit shall have an ampere rating of not less than that of the branch circuit.

Exception: Where connected to a branch circuit supplying two or more receptacles, receptacle ratings shall comply with the values listed in Table 13.1.

Table 13.1
Receptacle ratings (two or more receptacles in branch circuit)

Branch circuit rating, A	Receptacle rating, A
15	Not over 15
20	15 or 20
30	30

Table 13.1 Continued on Next Page

Table 13.1 Continued

Branch circuit rating, A	Receptacle rating, A
40	40 or 50
50 and higher	Receptacle rating shall not be less than the branch circuit rating

13.3.2.4 After installation a receptacle face shall project a minimum of 0.015 inch (0.38 mm) from the faceplate or surrounding cover. A faceplate shall be installed so as to seat against a mounting surface.

Exception: The receptacle face shall be flush with, or project from, a faceplate or surrounding cover of insulating material.

13.3.2.5 Class A ground-fault circuit interrupter protection shall be provided for all 125-volt and less, single-phase, 15- or 20-ampere receptacles used in a panelboard marked as having a Type 3R enclosure or other Type designation intended for outdoor use.

13.3.2.6 All 15- and 20-ampere, 125- and 250-volt nonlocking receptacles used in a panelboard marked as having a Type 3R enclosure or other Type designation intended for outdoor use shall be rated as "weather-resistant" type.

13.3.3 Single pole separable outlets

13.3.3.1 A single pole separable connector shall be of a construction with female phase and neutral mating contacts, and shall have a rating no less than the rating of the overcurrent device to which it is connected.

13.3.3.2 Single pole separable connectors shall be mechanically interlocked in such a manner that plugs must be connected in the following sequence and disconnected in the reverse order:

a) Equipment-grounding conductor connection;

b) Grounded circuit conductor connection; and

c) Ungrounded conductor connection.

Exception: Panelboards with separable single pole connectors rated above 200 A need not comply with 13.3.3.2 when marked in accordance with 34.18.1 and 34.18.2.

14 Switches, Circuit Breakers, and Overcurrent-Protective Devices

14.1 General

14.1.1 A circuit breaker and a switch shall be mounted in a position, and shall be connected in a manner, with reference to line and load terminals, for which the device is acceptable.

14.1.2 An accessible means shall be provided in the panelboard so that each branch circuit can be independently de-energized. A switch, a plug fuse or other device incorporating a screw shell and a circuit breaker are acceptable as such means.

14.1.3 If a circuit breaker or switch is operated such that movement of the operating handle is vertical between the on and off positions resulting in one position being above the other position, then the upper position shall be the on position. A switch having more than one on position, such as a transfer switch or a

double throw switch, need not comply with this requirement. This requirement does not apply to operating handles that operate rotationally and is to be applied with the panelboard installed in the intended position.

14.1.4 An interchangeable circuit-breaker trip unit need not be factory-installed if it can be mounted in place without disassembly of any electrical connection.

14.1.5 A switch or circuit breaker provided to control a main, feeder, or branch circuit shall be capable of external manual operation under rated load conditions. Operating mechanisms of switches and circuit breakers located behind doors or covers shall be considered capable of external manual operation so long as the mechanism may be accessed without the use of a tool. Provisions for locking a cover are not to be considered as restricting access for external operation. An electrically operated switch or circuit breaker need not be capable of being externally operable by hand to the closed position.

14.2 Ratings

14.2.1 A switching device shall have a current and voltage rating not less than the ratings of the circuit that it controls.

14.2.2 An overcurrent protective device connected to the high leg (higher voltage to ground) of a 240/120-volt, 3-phase, 4-wire delta system shall be rated at least 240 volts. See 34.4.5.

14.2.3 A 2-pole circuit breaker, used in a panelboard marked for use on a corner-grounded delta system, shall be marked "1Ø – 3Ø."

14.2.4 The current rating of a main or branch-circuit switch shall not be less than the rating of the associated fuseholder.

14.3 Main and main-disconnect switches and circuit breakers

14.3.1 Except as indicated in 34.9.1, a panelboard is not required to be provided with or have provision for a main or main disconnects.

14.3.2 *Deleted*

14.3.3 *Deleted*

14.4 Switches

14.4.1 A switching mechanism shall be constructed so that there will be no undue mechanical stress on the switch parts.

14.4.2 Screws and nuts that attach operating parts to movable members shall be staked, upset, or otherwise locked in position to prevent loosening.

14.4.3 An operating handle of conductive material shall have provision for grounding or shall be effectively insulated. If the enclosure of a switching unit is of metal, grounding may be accomplished by having the operating handle of conductive material in electrical connection with the enclosure.

14.4.4 A 120-volt circuit in series with a 60-watt test lamp is to be used to determine whether a panelboard complies with the grounding requirement in 14.4.3.

14.4.5 A switching mechanism shall have a definite off position. See 34.7.1.

14.4.6 A single-throw knife switch shall be mounted so that gravity will not tend to close it, and shall be connected so that the blade or blades will be dead when the switch is open. A double-throw switch mounted so that gravity will tend to close it shall be provided with means to hold it in the off position.

14.4.7 Other than as noted in 14.4.8, a switch shall be provided on the supply side of each cartridge fuseholder such that each individual circuit can be independently disconnected from the source of supply.

14.4.8 The disconnecting means mentioned in 14.4.7 need not be provided if the panelboard is marked as described in 34.1.6.

14.4.9 In a panelboard employing a main section and one or more subsections in the same compartment, flexible leads, including insulated wire, shall not be used to connect the main section to a disconnect in a subsection unless:

a) Such leads are not located in the wiring gutter and

b) The disconnect, if removed, cannot inadvertently be incorrectly reinstalled in the main section so as to cause a short circuit.

14.5 Overcurrent protective devices

14.5.1 Each branch circuit shall be provided with overcurrent protection.

14.5.2 An overcurrent device shall not be connected in the permanently grounded wire of any circuit unless opening of the overcurrent device simultaneously opens all the conductors in that circuit.

14.6 Lighting and appliance panelboards

14.6.1 *Deleted*

14.6.2 *Deleted*

14.6.3 *Deleted*

14.6.4 *Deleted*

14.6.5 *Deleted*

14.6.6 *Deleted*

14.6.7 *Deleted*

14.6.8 *Deleted*

14.6.9 *Deleted*

14.6.10 *Deleted*

14.6.11 *Deleted*

14.7 Fuseholders

14.7.1 A fuseholder shall be of the plug or cartridge or special purpose type and shall comply with the requirements in Appendix A. Fuseholders of the special purpose fuse type shall also comply with the requirements in 14.7.3.

14.7.2 A main or branch-circuit fuseholder shall be connected in the circuit on the load side of a switch, if any.

14.7.3 Special purpose fuseholders may be used if evaluated for use with specific special purpose fuses, which are suitably rated for use as branch circuit, feeder, or service overcurrent protection. When used, special purpose fuseholders shall:

a) Be non-interchangeable with fuses of incompatible ratings. This requires that the fuseholder be of a design so that it will be difficult to install a fuse of any given class into a fuseholder that is designed for a current lower, or voltage higher, than that of the fuse intended for use with the fuseholder, and

b) Be marked for use with the specific special purpose fuses for which it is intended to be used.

14.8 Panelboards with integral inlet

14.8.1 Panelboards with an inlet shall be provided with branch circuit protection for the circuits supplied through the inlet. The rating of the branch circuit protection shall not be greater than the rating of the inlet.

15 Ground-Fault Protection

15.1 A panelboard marked for use as service equipment for 3-phase, 4-wire solidly grounded wye-connected services rated in excess of 150 volts to ground, but not exceeding 1000 volts phase-to-phase, shall be provided with ground-fault protection for each service disconnecting means rated 1000 amperes or more. The ground-fault sensing and relaying equipment provided shall operate to cause the service disconnecting means to open all ungrounded conductors of the faulted circuit. The maximum setting of the ground-fault protection shall be 1200 amperes.

Exception No. 1: If each service disconnecting means rated 1000 amperes or more is provided with a shunt trip that is acceptable for use with ground-fault protection, the ground-fault sensors or relaying equipment or both may be in a separate enclosure if the combination has been found acceptable and the panelboard is marked as required by 34.10.5.

Exception No. 2: Ground-fault protection need not be provided for a panelboard marked in accordance with 34.10.1.

15.2 Compliance with the requirements specified in 15.1 anticipates that each service disconnect device to which the requirement applies is provided with automatic tripping means for actuation by ground-fault sensing and relaying equipment that may, although not required, be a part of the service disconnect device.

15.3 Ground-fault sensing and relaying equipment that is not a part of the disconnect device shall be mounted in the panelboard enclosure and be connected to the disconnect device and power source, if any. The rating of the disconnect device control circuit shall be compatible with that of the sensing and relaying components.

Exception: As provided in Exception No. 1 to 15.1.

15.4 If ground-fault protection is provided, though not required by 15.1, it shall comply with the requirements for the installation of ground-fault protection equipment as specified in these requirements.

15.5 A ground-fault-protection system described as a zero-sequence type that employs a sensing element that encircles the neutral conductor, if any, and all ungrounded conductors of the protected circuit shall be installed in such a manner that the sensing element is located on the load side of any grounding or bonding connection to the neutral. It may be on the line or load connection to the neutral. It may be on the line or load side of the disconnecting device for the protected circuit.

15.6 A ground-fault-protection system described as the residual type that combines the outputs of separate sensing elements for the neutral, if any, and each ungrounded conductor shall be installed in such a manner that the neutral sensing element is located on the load side of any grounding or bonding connection to the neutral. The ungrounded conductor sensors may be on the line or load side of the disconnecting device for the protected circuits.

15.7 A ground-fault-protection system described as the ground-return type that employs a single sensing element to detect the actual fault current shall be installed in such a manner that the sensing element detects any current that flows in the grounding-electrode conductor, the main bonding jumper, and any other grounding connections within the equipment that may be made to the neutral. This will require that, except for these connections, the neutral be insulated from the noncurrent-carrying metal as covered in 16.1.17.

15.8 If the design of ground-fault-sensing and relaying equipment is such that a reset operation is required to restore the equipment to functional status following operation due to a ground fault or test, the design shall prevent closing and maintaining contact of the disconnecting device to be controlled by the ground-fault sensing and relaying equipment until the reset operation is performed.

Exception: The reset means may be incorporated in the disconnect device.

15.9 Overcurrent protection is not required for the operating coil of a fused power-circuit device or the shunt trip coil of a circuit breaker or switch used with ground-fault protection where the coil is connected to the load side of the controlled switch or circuit breaker as covered in 15.10.

15.10 The primary of a ground-fault protection control-circuit transformer may be connected on the line or load side of the main disconnect. The primary of the control-circuit transformer shall be connected to two line-voltage parts – not line and neutral. When connected to the line side of the main, a fused disconnect switch or circuit breaker suitable for service equipment and providing overcurrent protection shall be installed ahead of the transformer or control circuit or both. Overcurrent protection is not required for the control-circuit when wired to the load side of the main disconnect unless the control-circuit wiring leaves the enclosure.

15.11 The secondary circuit of a control-power transformer shall be grounded under any of the following conditions if the circuit extends or may extend beyond the equipment in which the transformer is mounted:

a) The secondary is less than 50 volts and the transformer supply is over 150 volts to ground or the transformer supply at any voltage is ungrounded.

b) The secondary is 50 volts or greater and the secondary circuit can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts.

15.12 If a transformer secondary is required to be grounded in accordance with 15.11, a main bonding jumper shall be factory connected to the transformer secondary and to the enclosure or ground bus. The size of the main bonding jumper shall be as specified in Table 18.1 based on the transformer-secondary-current rating. A grounding-electrode conductor connector sized in accordance with Table 18.1 shall be provided on the neutral or on the ground bus.

15.13 In equipment incorporating ground-fault protection of the ground-return type as described in 15.7, the main bonding jumper shall be factory connected to the neutral bus and to the enclosure or the ground bus.

15.14 A panelboard having ground-fault protection shall be subjected to a factory ground-fault-protection test as described in Section 29, Ground-Fault Protection Test, and shall be marked as specified in 34.10.2 – 34.10.5.

16 Spacings

16.1 General

16.1.1 There shall be a spacing of not less than 1 inch (25.4 mm) between any uninsulated live part and the door, except as noted in 16.1.2.

16.1.2 The spacing mentioned in 16.1.1 may be not less than 1/2 inch (12.7 mm) if the potential involved is 250 volts or less and:

a) The door has an average thickness of not less than 0.093 inch (2.36 mm) if uncoated sheet steel, and 0.097 inch (2.46 mm) if galvanized sheet steel, except as noted in 16.1.3, or the door is lined with acceptable insulating material, such as fiber not less than 1/32 inch (0.8 mm) thick or phenolic composition; or

b) The spacing is between the screw shell of a plug fuseholder and the door.

16.1.3 The door need not have the thickness specified in 16.1.2(a) if it has been found to have strength and rigidity not less than that of a flat door of the same overall length and width, consisting of steel of the specified thickness.

16.1.4 Except as noted in 16.1.1, 16.1.6 – 16.1.11, and 16.2.1 the spacings in a panelboard shall be as specified in Table 16.1.

Table 16.1
Spacings

Voltage involved	Minimum spacing, inch (mm)					
	Between uninsulated live parts of opposite polarity				Through air or over surface[b] between uninsulated live parts and grounded dead metal	
	Through air		Over surface[a,b]			
125 or less	1/2	(12.7)	3/4	(19.1)	1/2	(12.7)
126 – 250	3/4	(19.1)	1-1/4	(31.8)	1/2	(12.7)
251 – 600	1	(25.4)	2	(50.8)	1[c]	(25.4)
601 – 1000	1	(25.4)	2	(50.8)	1[c]	(25.4)

NOTE – An isolated dead metal part, such as a screw head or washer, interposed between uninsulated live parts of opposite polarity or between an uninsulated live part and grounded dead metal is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement.

[a] An air space of 0.013 inch (0.33 mm) or less between a live part and an insulating surface is to be disregarded and the part is to be considered in contact with the insulating material when measuring spacings.

[b] In measuring over-surface spacings, any slots, grooves, etc. 0.013 inch (0.33 mm) wide or less in the contour of insulating material are to be disregarded.

[c] A through-air spacing of not less than 1/2 inch (12.7 mm) is acceptable (1) at a circuit breaker or a switch other than a snap switch, and (2) between grounded dead metal and the neutral of a 3-phase, 4-wire panelboard.

16.1.5 In applying Table 16.1 it is to be assumed that:

a) The voltage from a live part, other than the neutral, to grounded dead metal equals the line-to-line voltage of the system.

b) The voltage from a neutral live part on an insulated neutral to grounded dead metal equals the line-to-neutral voltage of the system.

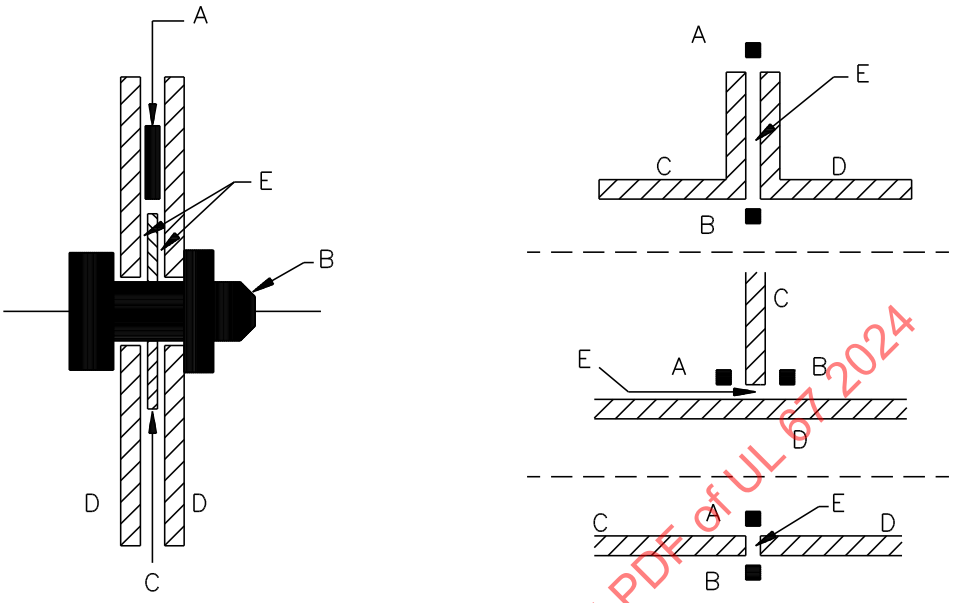
Exception: See 16.1.6.

c) Spacings at a fuseholder are to be measured with a fuse in place; the fuse being of the maximum standard dimensions including the maximum projections for assembly screws and rivets. Dimensions of fuses and fuseholders can be found in the Standards for Low-Voltage Fuses – Part 1: General Requirements, UL 248-1; Low-Voltage Fuses – Part 6: Class H Non-Renewable Fuses, UL 248-6; Low-Voltage Fuses – Part 7: Class H Renewable Fuses, UL 248-7; Low-Voltage Fuses – Part 9: Class K Fuses, UL 248-9; Low-Voltage Fuses – Part 11: Plug Fuses, UL 248-11; Low-Voltage Fuses – Part 12: Class R Fuses, UL 248-12; and the Standards for Fuseholders – Part 1: General Requirements, UL 4248-1; Fuseholders – Part 4: Class CC, UL 4248-4; Fuseholders – Part 5: Class G, UL 4248-5; Fuseholders – Part 6: Class H, UL 4248-6; Fuseholders – Part 8: Class J, UL 4248-8; Fuseholders – Part 9: Class K, UL 4248-9; Fuseholders – Part 11: Type C (Edison Base) and Type S Plug Fuse, UL 4248-11; Fuseholders – Part 12: Class R, UL 4248-12; Fuseholders – Part 15: Class T, UL 4248-15; respectively.

d) Spacings are to be measured through cracks unless a clamped joint has passed the test specified in 26.2.1. A clamped joint is a joint between two pieces of insulation that are under pressure as shown in Figure 16.1. Adhesives, cements, and the like, if used to effect a seal in place of a tightly mated joint, shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Figure 16.1

Clamped joint



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Parts A, B – Live parts of opposite polarity, or a live part and a grounded metal part with spacing through the crack between C and D less than required in Table 16.1 or Table 16.3.

Parts C, D – Insulating barriers clamped tightly together so that the dielectric strength between A and B is greater than the equivalent air spacing.

Part E – The clamped joint.

16.1.6 Terminals and other parts intended to be connected to the grounded conductor of a circuit are considered to be uninsulated live parts unless such parts are mounted directly on or in permanent electrical connection with grounded dead metal.

16.1.7 If the connection mentioned in 16.1.6 is solely by means of a screw, strap, or other bonding device that can be readily removed and is not depended upon to perform a mechanical function, the panelboard shall:

a) Comply with the requirement in 16.1.4 when the bonding device is removed, or

b) Be marked as described in 34.9.6.

16.1.8 The distance between a door or cover over a fuseholder and:

a) The center contact of an Edison-base fuseholder shall not be less than 1-9/16 inch (39.7 mm).

b) The center contact of a Type S fuseholder shall not be less than 1-5/16 inch (33.3 mm).

16.1.9 The spacings between screw shells of plug fuseholders that are protected by surrounding walls of insulating material, and between such screw shells and a metal cover plate, may be not less than 1/4 inch (6.4 mm) if the depth of the receptacle as measured from the top of the wall to the plane of the center contact is not less than 3/4 inch (19.1 mm). The measurement is to be made without a Type S adaptor in place.

16.1.10 Other than as noted in 16.1.11, the spacing through air and over surface shall not be less than 1/8 inch (3.2 mm) between uninsulated live parts of the same polarity:

a) On the load side of their respective switches or circuit breakers for parts in different circuits; and

b) On the line and load sides of a fuseholder, switch, or circuit breaker.

16.1.11 The requirements in 16.1.4 and 16.1.10:

a) Do not apply between:

1) Uninsulated live parts of opposite polarity within a component of the panelboard, such as industrial control equipment, a clock-operated switch, a circuit breaker, a meter socket, or the like,

2) Uninsulated live parts of the component and dead metal that is part of the component, or

3) Uninsulated live parts of the component and that part of the dead metal surface of the panelboard on which the component is mounted in the intended manner.

b) Do apply between:

1) Uninsulated live parts in different components, and

2) An uninsulated live part of a component and dead metal of the panelboard, other than the dead metal surface on which the component is mounted.

16.1.12 Spacings are to be measured with all terminals unwired, and wired with conductors determined in accordance with 12.1.6 – 12.1.10, except that a conductor smaller than 12 AWG (3.3 mm^2) is not to be employed.

16.1.13 In measuring the spacing between an uninsulated live part and a bushing installed at a knockout of an enclosed panelboard, it is to be assumed that a bushing having the dimensions specified in Table 16.2, but without a locknut inside the enclosure, is in place.

Table 16.2
Conduit bushing dimensions

Trade size of conduit, inches	Overall diameter,		Height,	
	inches	(mm)	inches	(mm)
1/2	1	(25.4)	3/8	(9.5)
3/4	1-15/64	(31.4)	27/64	(10.7)
1	1-19/32	(40.5)	33/64	(13.1)
1-1/4	1-15/16	(49.2)	9/16	(14.3)
1-1/2	2-13/64	(56.0)	19/32	(15.1)
2	2-45/64	(68.7)	5/8	(15.9)
2-1/2	3-7/32	(81.8)	3/4	(19.1)
3	3-7/8	(98.4)	13/16	(20.6)
3-1/2	4-7/16	(112.7)	15/16	(23.8)
4	4-31/32	(126.2)	1	(25.4)
4-1/2	5-35/64	(140.9)	1-1/16	(27.0)
5	6-7/32	(158.0)	1-3/16	(30.2)
6	7-7/32	(183.4)	1-1/4	(31.8)

16.1.14 All screws and nuts, other than those mentioned in 8.4 and 14.4.2, shall be staked, headed over, upset, or otherwise reliably prevented from loosening unless it can be shown that reduction of spacings cannot result from the loosening or falling out of such threaded parts.

16.1.15 Other than as indicated in 16.1.16, a soldering lug or pressure wire connector shall be prevented from turning so as to reduce spacings below the required values by a reliable restraint such as a shoulder or boss. A lock washer alone is not acceptable for this purpose.

16.1.16 Means to prevent turning as mentioned in 16.1.15 need not be provided if spacings are not less than the minimum acceptable values when:

a) A lug or connector and any lug or connector of opposite polarity have each been turned 30 degrees toward the other, and

b) A lug or connector has been turned 30 degrees toward any other opposite-polarity live part and toward grounded dead metal parts.

16.1.17 Any conductive part connected to a neutral that is factory bonded to the ground bus or enclosure as covered in the Exception to 11.2.2 that would interfere with the operation of the ground-fault protection system if in contact with the enclosure, shall be insulated and provided with at least 1/8 inch (3.2 mm) spacings through air or over surface to the enclosure.

a) For zero-sequence type ground-fault protection, and the residual-type ground-fault protection, parts that would interfere with operation if grounded include all neutral parts on the load side of the neutral-sensing means.

b) For the ground-return type, parts that would interfere with operation if grounded include all neutral parts except those on the ground side of the sensing means.

16.1.18 In a magnetically operated device, spacing in a control circuit that is protected by overcurrent devices set at not more than 30 amperes shall be as specified in Table 16.3.

Table 16.3
Control-circuit spacings

Potential involved	Minimum Spacings, inch (mm)					
	Between uninsulated live parts of opposite polarity and between an uninsulated live part and an exposed or uninsulated dead metal part other than the enclosure				Between uninsulated live parts and the walls of a metal enclosure, including fittings for conduit or armored cable	
	Over surface		Through air		Shortest distance	
125 or less volts	1/4	(6.4)	1/8	(3.2)[a]	1/2	(12.7)
126 – 250	3/8	(9.5)	1/4	(6.4)	1/2	(12.7)
251 – 600	1/2	(12.7)	3/8	(9.5)	1/2	(12.7)

[a] The spacing between wiring terminals of opposite polarity shall not be less than 1/4 inch (6.4 mm) in any case if the terminals are in the same plane. A metal piece attached to the enclosure shall be considered to be a part of the enclosure for the purpose of this note if deformation of the enclosure is likely to reduce the spacing between the metal piece and a live part.

16.2 Switches

16.2.1 In a snap switch employed as a main switch, the spacings between uninsulated live parts and grounded dead metal shall not be less than specified in Table 16.4.

Table 16.4
Spacings in snap switches employed as main switches

Switch rating, volts	Minimum spacings, inch (mm)			
	Through air		Over surface	
51 – 150	1/8	(3.2)	1/4	(6.4)
151 – 300	1/4	(6.4)	3/8	(9.5)
301 – 600	3/8	(9.5)	1/2	(12.7)

16.3 Barriers and liners

16.3.1 In 16.3.2 – 16.3.5, the liner or barrier referred to is insulating material that separates uninsulated live parts of opposite polarity, or separates an uninsulated live part and a grounded dead metal part – including the enclosure – where the through-air spacing between the parts would be less than the required value. The term “sole separation” as referred to in 16.3.2 means that if the barrier or liner were removed, the parts in question would either contact each other or not be separated by a spacing more than the thickness of the insulating material.

16.3.2 A barrier that comprises the sole separation or that is used in conjunction with an air space less than 0.013 inch (0.33 mm) shall comply with (a) – (e). The barrier shall:

a) Be of material acceptable for direct support of an uninsulated live part as covered in 8.1 and 8.3 or in compliance with Table 16.5.

Exception No. 1: A barrier located between the enclosure and an uninsulated live part electrically connected to a grounded circuit conductor (neutral) may be of electrical grade (vulcanized) fiber.

Exception No. 2: A barrier may be acceptable based on the end-product tests specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

b) Of such strength to withstand the stress associated with normal handling, installation, and use of the equipment.

c) Secured in place.

d) Located so that it will not be adversely affected by operation of the equipment in service.

e) Have a minimum thickness of 0.028 inch (0.71 mm).

Exception: A barrier of insulating material other than vulcanized fiber covered by Exception No. 1 to 16.3.2(a) may have a thickness less than 0.028 inch if it withstands a 48 – 62 hertz dielectric-withstand voltage of 5000 volts applied in accordance with 26.4.1.

Table 16.5
Maximum performance level category (PLC) for barrier used in place of spacing

Test specified[a]	Flammability rating of material[a]		
	V-0 or VTM-0	V-1 or VTM-1	V-2 or VTM-2
Comparative Tracking Index (CTI) under moist conditions	3[b,c]	3[b,c]	3[b,c]
High Current Arc Ignition (HAI)	3	2	2
Hot Wire Ignition (HWI)	4	3	2
NOTES 1 Barrier located within 0.013 inch (0.33 mm) of contact with live parts. 2 In addition, thermoplastic barriers shall also be subjected to the Mold Stress Relief Test, Section 24.			
[a] See note a to Table 8.1. [b] See note c to Table 8.1. [c] See note e to Table 8.1.			

16.3.3 A barrier used in conjunction with a minimum air space of 0.013 inch (0.33 mm) shall comply with (a) – (e). The barrier shall be:

a) Material that is acceptable for direct support of an uninsulated live part as covered in 8.1 and 8.3 or other than electrical grade (vulcanized) fiber, and shall comply with Table 16.6.

Exception No. 1: Vulcanized fiber with a minimum thickness of 0.028 inch (0.71 mm) and used in conjunction with a minimum 0.028 inch air space need not comply with 8.1.

Exception No. 2: A barrier may be acceptable based on the end-product tests specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

b) Of such strength to withstand the stress associated with normal handling, installation, and use of the equipment.

c) Secured in place.

d) Located so that it will not be adversely affected by operation of the equipment in service.

e) Of a minimum thickness of 0.028 inch.

Exception No. 1: Material other than vulcanized fiber may have a thickness less than 0.028 inch if it withstands a 48 – 62 hertz dielectric-withstand voltage of 5000 volts applied in accordance with the requirements in 26.4.1.

Exception No. 2: Material other than vulcanized fiber used in conjunction with an air space of 1/2 or more of the required through air spacing may have a thickness:

a) No less than 0.013 inch or

b) Less than 0.013 inch if it withstands a 48 – 62 hertz dielectric-withstand voltage of 2500 volts applied in accordance with the requirements in 26.4.1.

Table 16.6
Maximum performance level category (PLC) for barrier used in place of spacing in conjunction with minimum air space of 0.013 inch (0.33 mm)

Test specified[a]	Flammability rating of material[a]			
	V-0 or VTM-0	V-1 or VTM-1	V-2 or VTM-2	HB
Comparative Tracking Index (CTI) under moist conditions	4	4	4	4
High Current Arc Ignition (HAI)	3	2	2	1
Hot Wire Ignition (HWI)	4	3	2	2
NOTE – In addition, thermoplastic barriers shall also be subjected to the Mold Stress Relief Test, Section 24.				
[a] See note a to Table 8.1.				

16.3.4 A barrier or liner that is provided because spacings would be less than the minimum acceptable values or for any other reason shall be an integral part of the panelboard unless it is an integral part of a branch-circuit bus bar, a neutral bus bar, or other part that may be installed in the field.

16.3.5 A barrier need not be provided at each end of a two-way branch-circuit bus bar intended for field installation – a bus bar to each end of which a circuit breaker may be connected. A barrier at one end only is acceptable.

16.4 Tape

16.4.1 A wrap of thermoplastic tape, acceptable for use as sole insulation, may be employed if all of the following conditions are met:

a) At a point where the spacing prior to the application of the tape is not less than half the required through-air spacing, the wrap is not less than 0.013 inch (0.33 mm) thick and is applied in two or more layers;

b) At a point where the spacing prior to the application of the tape is less than half the required through-air spacing, the wrap is not less than 0.028 inch (0.71 mm) thick;

c) The tape is not subject to compression;

d) The tape is not wrapped over a sharp edge; and

e) The temperature rating of the tape is no less than the temperature rise observed during the Temperature Test, Section 21, plus 40°C (104°F). See note a to Table 21.1. If a temperature test is not required, the temperature rating is to be 105°C (221°F) minimum.

16.5 Tubing

16.5.1 If a spacing would be less than the required value, thermoplastic tubing may be employed if all of the following conditions are met:

a) The tubing is not subjected to compression, repeated flexure, or sharp bends;

b) All edges of the conductor covered with the tubing are well rounded and free from sharp edges;

c) For chemically dilated tubing, a solvent recommended by the tubing manufacturer is used;

d) The wall thickness of the tubing– after assembly – is not less than 0.022 inch (0.56 mm) for tubing 1/2 inch (12.7 mm) or less in diameter and not less than 0.028 inch (0.71 mm) for larger diameter tubing; and

Exception: For tubing larger than 1/2 inch diameter, the wall thickness may be less than 0.028 inch, but not less than 0.022 inch provided it is employed only in areas where it will not be subject to damage.

e) The temperature rating of the tubing is no less than the temperature rise observed during the Temperature Test, Section 21, plus 40°C (104°F). See note a to Table 21.1. If a temperature test is not required, the temperature rating is to be 105°C (221°F) minimum.

17 Wiring Space, Wiring Gutters, and Wire Bending Space

17.1 General

17.1.1 For the purpose of these requirements:

a) A termination area is determined to be a space into which wires will normally be brought only for connection to terminals in that space.

b) A wiring space is the cross sectional area through which conductors must pass in order to exit the enclosure or be terminated.

c) Other than as noted in 17.2.2.2, a wiring gutter is determined to be a space for accommodating wires for which there is no terminal or other uninsulated live metal parts. See 17.1.2.

d) A removable wiring terminal is identified as a terminal that is capable of being removed from its intended location without disturbing structural or electrical parts, other than a cover, and that is capable of being reinstalled with the conductor in place.

17.1.2 For the purposes of the requirments in this Section, a neutral is considered to be a grounded part.

17.1.3 Wiring space, wiring gutters, and wire bending space shall be judged using:

a) The size and conductor material of a wire used at a terminal in accordance with 12.1.6 – 12.1.10, except that for ampacities of 110 amperes or less, the size shall be based on 60°C insulated conductors if the marking specifies 60 and 75°C wire, and

b) The full complement of branch circuit devices intended to be installed in the panelboard, necessitating the largest wiring space installed in the panelboard.

If a terminal is acceptable for use with two or more combinations of conductors in multiple, each of which may be appropriate for that terminal in accordance with 12.1.6 – 12.1.10, the combination necessitating the largest wiring space shall be used, unless the panelboard is marked in accordance with 34.2.14. If a

terminal is used with conductors in multiple, it is to be assumed that each of the conductors will be run in separate conduit. See note 1 to Table 11.1.

17.1.4 A meter center shall be:

a) Divided by barriers into several sections for the purpose of isolating watt-hour meters so that field wiring is not installed from one section to another and

b) Provided with a separate cover for each meter socket compartment that may be individually sealed.

17.1.4A The wiring space, wiring gutters, and wire bending space required in each section of a meter center shall be based only on the field installed conductors to be located in that section. For example, in Figure 17.1, for wire bending space:

a) Distance A shall be 8-1/2 inches (216 mm) as determined by Table 17.1 assuming the largest conductor to be located in the section will be a 250 kcmil (127 mm^2) aluminum conductor, and

b) Distance B shall be 5-1/2 inches (140 mm) as determined by Table 17.1 assuming the largest conductor to be located in the section will be a 1/0 AWG (53.5 mm^2) aluminum conductor; or as another example, if Exception No. 1(a), to 17.3.1.1 was applied, Distance B would be required to be 3-1/2 inches (89 mm) for the same size and material of conductor.

Exception No. 1: The wiring space, wiring gutters, and wire bending space in the meter socket section may be in accordance with the Standard for Meter Sockets, UL 414.

Exception No. 2: If the wiring gutter complies with 17.1 and the conductor enters straight through a compartment wall and directly opposite of the conductor termination, then the compartment wall perpendicular and closest to the load side terminations shall not be used in determining wire bending distance. For this construction, the distance from the edge of the load side termination to the enclosure outer wall shall be used in determining wire bending distance. Refer to Figure 17.1A.

Figure 17.1

Example of wiring space for a meter center divided by barriers into two sections

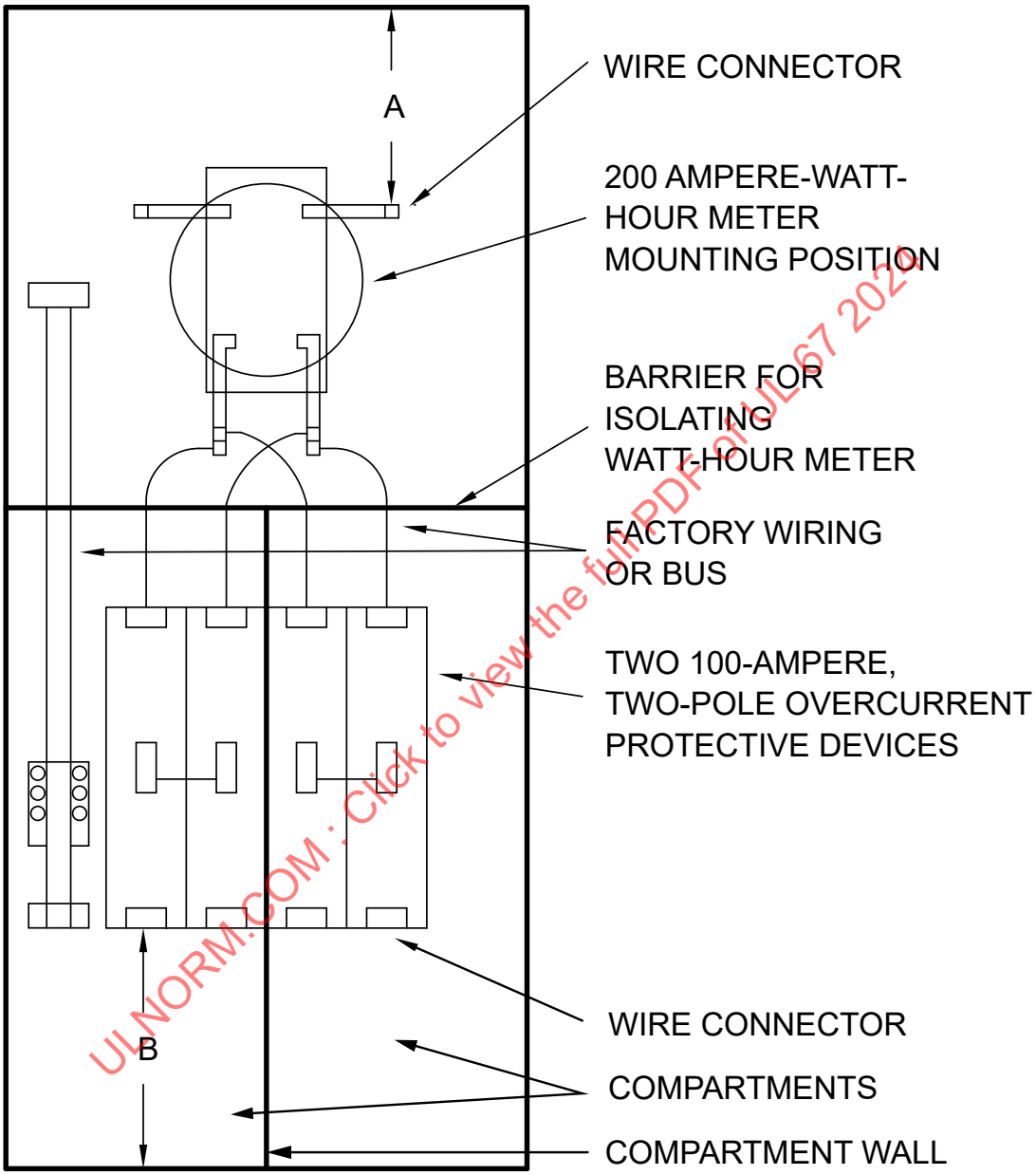

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Figure 17.1A

Example of wiring space for a meter center with compartment adjacent to wiring gutter

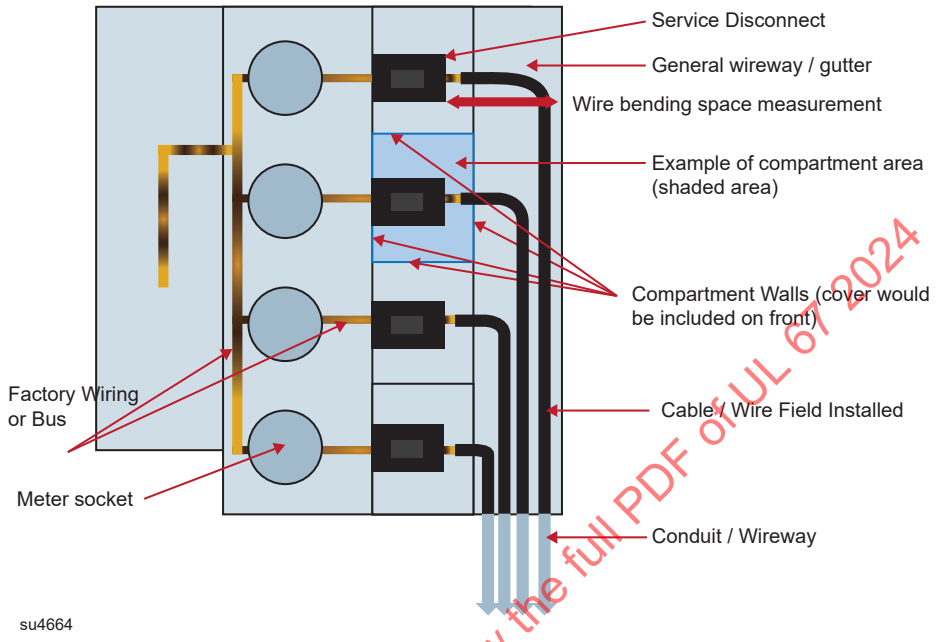


Table 17.1
Wire-bending space at terminals

Wire size, AWG or kcmil (mm²)				Minimum bending space, inches (mm)										
				Wires per terminal (pole) [a]										
All other conductors		Compact stranded AA-8000 Aluminum Alloy conductors		1			2			3			4 or more	
14 – 10	(2.1 – 5.3)	12 – 8	(2.1 – 8.4)	Not specified			–			–			–	
8	(8.4)	6	(13.3)	1-1/2	(38.1)		–			–			–	
6	(13.3)	4	(21.2)	2	(50.8)		–			–			–	
4	(21.2)	2	(33.6)	3	(76.2)		–			–			–	
3	(26.7)	1	(42.4)	3	(76.2)		–			–			–	
2	(33.6)	0	(53.5)	3-1/2	(88.9)		–			–			–	
1	(42.4)	2/0	(67.4)	4-1/2	(114)		–			–			–	
0	(53.5)	3/0	(85.0)	5-1/2	(140)		5-1/2	(140)		7	(178)		–	
2/0	(67.4)	4/0	(107)	6	(152)		6	(152)		7-1/2	(191)		–	
3/0	(85.0)	250	(127)	6-1/2	(165)	[6]	6-1/2	(165)	[6]	8	(203)		–	
4/0	(107)	300	(152)	7	(178)	[6]	7-1/2	(191)	[6]	8-1/2	(216)	[8]	–	

Table 17.1 Continued on Next Page

Table 17.1 Continued

Wire size, AWG or kcmil (mm^2)				Minimum bending space, inches (mm)											
				Wires per terminal (pole) [a]											
				1			2			3			4 or more		
All other conductors		Compact stranded AA-8000 Aluminum Alloy conductors													
250	(127)	350	(177)	8-1/2	(216)	[6-1/2]	8-1/2	(216)	[6-1/2]	9	(229)	[8]	10	(254)	
300	(152)	400	(203)	10	(254)	[7]	10	(254)	[8]	11	(279)	[10]	12	(305)	
350	(177)	500	(253)	12	(305)	[9]	12	(305)	[9]	13	(330)	[10]	14	(356)	[12]
400	(203)	600	(304)	13	(330)	[10]	13	(330)	[10]	14	(356)	[11]	15	(381)	[12]
500	(253)	700 – 750	(355 – 380)	14	(356)	[11]	14	(356)	[11]	15	(381)	[12]	16	(406)	[13]
600	(304)	800 – 900	(405 – 456)	15	(381)	[12]	16	(406)	[13]	18	(457)	[15]	19	(483)	[16]
700	(355)	1000	(507)	16	(406)	[13]	18	(457)	[15]	20	(508)	[17]	22	(559)	[19]
750	(380)	–	–	17	(432)	[14]	19	(483)	[16]	22	(559)	[19]	24	(610)	[21]
800	(405)	–	–	18	(457)		20	(508)		22	(559)		24	(610)	
900	(456)	–	–	19	(483)		22	(559)		24	(610)		24	(610)	
1000	(507)	–	–	20	(508)			–			–			–	
1250	(633)	–	–	22	(559)			–			–			–	
1500 – 2000	(760 – 1010)	–	–	24	(610)			–			–			–	

NOTES

1 The values in brackets are in inches and apply to removable and lay-in wire terminals intended for only one wire.

2 See 17.4.3.

[a] The main connection for a neutral is considered to be a pole – that is, neutral branch terminals are not counted in this determination.

17.1.5 An operating mechanism and its relation to the wiring space shall be such that it will not damage wires with which it may come in contact during its operation. Wiring space and other compartments intended to enclose wires shall be smooth and free from sharp edges, burrs, fins, and the like that may damage the insulation on a conductor.

17.2 Wiring space, wiring gutters, and terminal compartments

17.2.1 General

17.2.1.1 An enclosed panelboard shall have one or more back or side wiring gutters or spaces.

17.2.2 Wiring gutters and terminal compartments

17.2.2.1 A panelboard having provision for connection of more than four ungrounded conductors, other than main supply conductors, at any one side, top, or bottom shall be provided with wiring gutters and terminal compartments to reduce the risk of contact between any insulated conductor and an uninsulated live part.

17.2.2.2 A terminal for ungrounded conductors may be located in a wiring gutter if it is recessed between close fitting walls to such a depth that, when wired with a wire of the largest size that it is intended to accommodate, no part of the terminal is in contact with a straight edge placed across the edges of the

walls. More than one live terminal shall not be located in a recess in a wiring gutter. If more than one terminal is present, a termination area shall be provided to remove these terminals from the wiring gutter. See also 17.2.3.6.

17.2.2.3 Separate feed-through terminals – see 12.1.15 – shall be:

a) Located in a termination area;

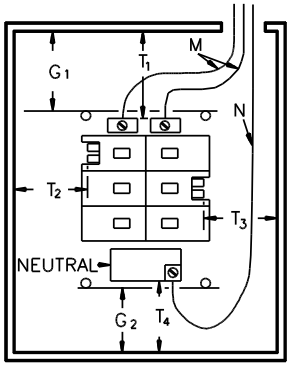
b) Individually recessed between close fitting walls – feed and tap connectors of the same phase may be located in the same recess – see 17.1.1, 17.2.1.1 – 17.2.2.2, and 17.2.3.3; or

c) Located in a separate enclosure that can be field assembled to the panelboard, see 34.12.14 and 34.12.15.

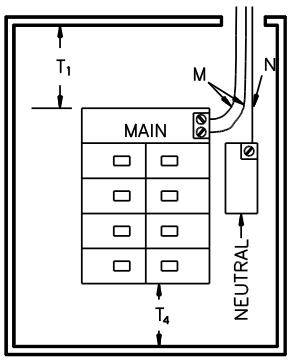
17.2.2.4 The width of the top and bottom wiring gutters (distances G_1 and G_2 in Illustrations 1, 3, and 4 of Figure 17.2) shall be sized in accordance with Table 17.2 for the largest conductor entering or leaving the enclosure.

Figure 17.2

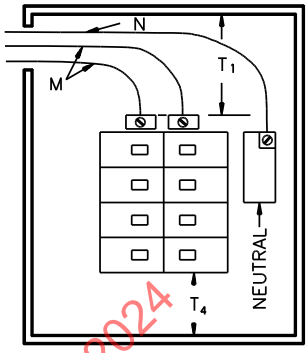
Illustrations for wire bending space determinations



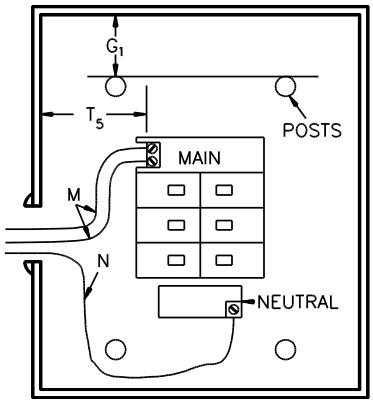
ILL. 1



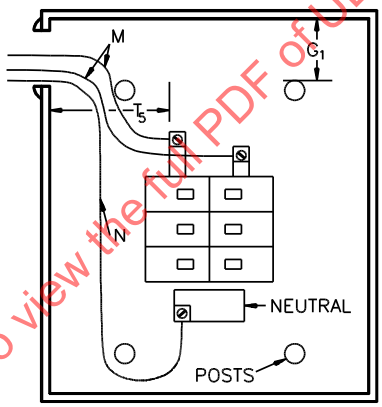
ILL. 2



ILL. 2a



ILL. 3



ILL. 4

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M – Ungrounded main conductor.

N – Neutral main conductor.

G_1, G_2 – Gutter distances. See 17.2.2.4.

T_1, T_2, T_3, T_4, T_5 – Wire bending distance.

Table 17.2
Minimum width of gutter and wire-bending space

Size of wire AWG or kcmil (mm^2)		Minimum bending space, terminal to wall, inches (mm)									
		Wires per terminal (pole)[a]									
		1		2		3		4		5	
14 – 10	(2.1 – 5.3)	Not specified		–		–		–		–	
8 – 6	(8.4 – 13.3)	1-1/2	(38.1)	–		–		–		–	
4 – 3	(21.1 – 26.7)	2	(50.8)	–		–		–		–	
2	(33.6)	2-1/2	(63.5)	–		–		–		–	
1	(42.4)	3	(76.2)	–		–		–		–	
1/0 – 2/0	(53.5 – 67.4)	3-1/2	(88.9)	5	(127)	7	(178)	–		–	
3/0 – 4/0	(85.0 – 107)	4	(102)	6	(152)	8	(203)	–		–	
250	(127)	4-1/2	(114)	6	(152)	8	(203)	10	(254)	–	
300 – 350	(152 – 177)	5	(127)	8	(203)	10	(254)	12	(305)	–	
400 – 500	(203 – 253)	6	(152)	8	(203)	10	(254)	12	(305)	14	(356)
600 – 700	(304 – 355)	8	(203)	10	(254)	12	(305)	14	(356)	16	(406)
700 – 900	(380 – 456)	8	(203)	12	(305)	14	(356)	16	(406)	18	(457)
1000 – 1250	(507 – 633)	10	(254)	–		–		–		–	
1500 – 2000	(760 – 1010)	12	(305)	–		–		–		–	

NOTES

1 The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned may be given further consideration.

2 For panelboards rated 110 amperes or less and marked to indicate use of both 60 and 75°C wire, the wire bending space is based on the use of 60°C (140°F) insulated wire. See 17.1.3.

3 See 17.4.3.

[a] The main connection for a neutral is considered to be a pole, that is, neutral branch terminals are not counted in this determination.

17.2.2.5 The width of the wiring gutter space mentioned in 17.2.2.4 shall be measured in a straight line from the wall of the enclosure perpendicular to any gutter defining barrier, branch unit, or other effective obstruction. In determining the available width of a wiring gutter, the space within or immediately above a termination area (between the compartment and the front of the enclosure) intended for an ungrounded conductor shall not be included.

17.2.3 Wiring space

17.2.3.1 If conduit or other raceways are intended to enter a floor-standing enclosed panelboard at the bottom, the minimum distance between the bottom part of the enclosure and an insulated or uninsulated bus bar and bus bar supports or other obstructions shall be:

a) Eight inches (203 mm) for an insulated bus bar,

b) Ten inches (254 mm) for an uninsulated bus bar, and

c) Eight inches for bus bar supports or other obstruction.

17.2.3.2 There shall be sufficient wiring space within the enclosure of a panelboard for the installation of wires and cables likely to be employed in connecting the main and branch circuits to the panelboard, including feed through conductors that may continue to another distribution center.

17.2.3.3 A panelboard intended to be installed with the line and load conductors passing into the enclosure at the same end shall have sufficient wiring space for the conductors to pass from their terminals to the point of entrance.

17.2.3.4 In a wiring space for through conductors, the conductors, splices, and tap terminals shall not fill the wiring space at any cross section to more than 75 percent of the cross-sectional area of the space. See 12.1.15.

17.2.3.5 The clear wiring space, independent of all projections, obstructions, or interference from a moving part of a switching mechanism, shall:

a) Not be smaller in width or depth than the values specified in Table 17.3; and

b) Be acceptable for the wiring of the device, and not smaller in total area than 250 percent of the total cross-sectional area of the maximum number of wires that may be used in the space.

Table 17.3
Wire space

Maximum size of wire or cable,		Minimum width and depth of wiring space,		Minimum area in square inches (cm^2) required for multiple wires based on factor of 2.5											
AWG or kcmil	(mm^2)	Inches	(mm)	Two wires		Three wires		Four wires		Five wires		Six wires		Seven wires	
12	(3.3)	3/8	(9.5)	0.14	(0.9)	0.21	(1.4)	0.28	(1.8)	0.35	(2.3)	0.42	(2.7)	0.49	(3.2)
10	(5.3)	3/8	(9.5)	0.23	(1.5)	0.34	(2.2)	0.46	(3.0)	0.57	(3.7)	0.68	(4.4)	0.80	(5.2)
8	(8.4)	1/2	(12.7)	0.43	(2.8)	0.64	(4.1)	0.85	(5.5)	1.07	(6.9)	1.28	(8.3)	1.50	(9.7)
6	(13.3)	5/8	(15.9)	0.62	(4.0)	0.93	(6.0)	1.24	(8.0)	1.55	(10.0)	1.86	(12.0)	2.17	(14.0)
4	(21.2)	3/4	(19.1)	0.80	(5.2)	1.20	(7.7)	1.60	(10.3)	2.00	(12.9)	2.40	(15.5)	2.80	(18.1)
3	(26.7)	3/4	(19.1)	0.91	(5.9)	1.36	(8.8)	1.82	(11.7)	2.27	(14.6)	2.72	(17.5)	3.18	(20.5)
2	(33.6)	7/8	(22.2)	1.03	(6.6)	1.55	(10.0)	2.06	(13.3)	2.58	(16.6)	3.10	(20.0)	3.61	(23.3)
1	(42.4)	1	(25.4)	1.36	(8.8)	2.04	(13.2)	2.72	(17.5)	3.40	(21.9)	4.08	(26.3)	4.76	(30.7)
1/0	(53.5)	1	(25.4)	1.55	(10.0)	2.33	(15.0)	3.10	(20.0)	3.88	(25.0)	4.66	(30.1)	5.43	(35.0)
2/0	(67.4)	1	(25.4)	1.79	(11.5)	2.68	(17.3)	3.58	(23.1)	4.47	(28.8)	5.36	(34.6)	6.26	(40.4)
3/0	(85.0)	1-1/8	(28.6)	2.08	(13.4)	3.11	(20.1)	4.16	(26.8)	5.19	(33.5)	6.22	(40.1)	7.27	(46.9)
4/0	(107)	1-1/4	(31.8)	2.42	(15.6)	3.63	(23.4)	4.84	(31.2)	6.05	(39.0)	7.26	(46.8)	8.47	(54.6)
250	(127)	1-3/8	(34.9)	2.96	(19.1)	4.44	(28.6)	5.92	(38.2)	7.40	(47.7)	8.88	(57.3)	10.36	(66.8)
300	(152)	1-1/2	(38.1)	3.42	(22.1)	5.13	(33.1)	6.84	(44.1)	8.55	(55.2)	10.26	(66.2)	11.96	(77.2)
350	(177)	1-1/2	(38.1)	3.81	(24.6)	5.72	(36.9)	7.62	(49.2)	9.53	(61.5)	11.44	(73.8)	13.34	(86.1)
400	(203)	1-5/8	(41.3)	4.18	(27.0)	6.27	(40.5)	8.36	(53.9)	10.45	(67.4)	12.54	(80.9)	14.63	(94.4)
500	(253)	1-3/4	(44.5)	4.92	(31.7)	7.38	(47.6)	9.84	(63.5)	12.30	(79.4)	14.76	(95.2)	17.22	(111.1)
600	(304)	1-7/8	(47.6)	5.97	(38.5)	8.96	(57.8)	11.94	(77.0)	14.93	(96.3)	17.92	(115.6)	20.90	(134.8)
700	(355)	2	(50.8)	6.68	(43.1)	10.02	(64.6)	13.36	(86.2)	16.70	(107.7)	20.04	(129.3)	23.38	(150.8)

Table 17.3 Continued on Next Page

Table 17.3 Continued

Maximum size of wire or cable, AWG or kcmil	(mm²)	Minimum width and depth of wiring space, Inches	(mm)	Minimum area in square inches (cm²) required for multiple wires based on factor of 2.5											
				Two wires		Three wires		Four wires		Five wires		Six wires		Seven wires	
750	(380)	2	(50.8)	7.04	(45.4)	10.56	(68.1)	14.08	(90.8)	17.60	(113.5)	21.12	(136.3)	24.64	(159.0)
800	(405)	2-1/8	(54.0)	7.39	(47.7)	11.09	(71.6)	14.78	(95.4)	18.48	(119.2)	22.18	(143.1)	25.87	(166.9)
900	(456)	2-1/4	(57.2)	8.09	(52.2)	12.13	(78.3)	16.18	(104.4)	20.22	(130.5)	24.26	(156.5)	28.31	(182.6)
1000	(507)	2-1/4	(57.2)	8.77	(56.6)	13.15	(84.8)	17.54	(113.2)	21.92	(141.4)	26.30	(169.7)	30.69	(198.0)
1250	(633)	2-1/2	(63.5)	11.03	(71.2)	16.55	(106.8)	22.06	(142.3)	27.58	(177.9)	33.10	(213.5)	38.61	(249.1)
1500	(760)	2-3/4	(69.8)	12.74	(82.2)	19.11	(123.3)	25.48	(164.4)	31.85	(205.5)	38.22	(246.6)	44.59	(287.7)
1750	(887)	2-7/8	(73.0)	14.45	(93.2)	21.67	(139.8)	28.90	(186.5)	36.12	(233.0)	43.34	(279.6)	50.57	(326.3)
2000	(1010)	3-1/8	(79.4)	16.04	(103.5)	24.06	(155.2)	32.08	(207.0)	40.10	(258.7)	48.12	(310.5)	56.14	(362.2)

17.2.3.6 In determining whether a wiring space complies with the requirements in 17.2.3.5, consideration is to be given to the actual size of wires that will be used in the space; but it is to be assumed that wires smaller than 12 AWG (3.3 mm²) will not be used. In computing the area of a wiring space, consideration is to be given to all the available space that may be used for the more common multiple wire connections as specified in Table 17.1. The space occupied by a termination area and the space above such an area – see 17.1.1(a) – is not included when wiring space is determined, but space above or around an individual terminal or neutral located in a wiring gutter – see 17.2.2.2 – is considered to be available space.

17.2.3.7 No wiring system shall enter or exit the enclosure in a wiring space.

17.3 Wire deflection and bending space

17.3.1 Top and bottom bending space

17.3.1.1 Enclosed panelboards shall be provided with bending space at the top and bottom. Each space (distances T_1 and T_4 in Illustrations 1, 2, and 2a of Figure 17.2) shall be as specified in Table 17.1 for the largest conductor (conductors M and N) entering or exiting the enclosure.

Exception No. 1: For a panelboard having both top and bottom bending spaces, either of these spaces, but not both, shall be as specified in Table 17.2 for the largest conductor entering or leaving the enclosure when:

a) The panelboard is rated 225 amperes or less and has provisions for 42 over-current protective devices or less,

b) There are no conductors terminated in that space, or

c) At least one of the side bending spaces complies with Table 17.1 for the largest conductor to be terminated in any panelboard side bending space.

Exception No. 2: For a panelboard that is provided with both top and bottom bending spaces, both spaces shall be as specified in Table 17.2 for the largest conductor entering or leaving the enclosure when the panelboard is intended and constructed for wiring using only one single 90 degree bend for the main and main neutral conductors (the M and N conductors of Illustration 2a, Figure 17.2) and the panelboard is

marked in accordance with 34.2.1. However, the main neutral conductor (Conductor N of Illustration 2, Figure 17.2) is capable of being wired straight in or having more than one bend when the distance for this conductor is in accordance with Table 17.1.

Exception No. 3: Bending space is not required when the main supply connections are made using bus bars or using factory installed wire through openings into adjacent equipment which in combination with the panelboard has been investigated and found capable of being used in the application. The bending space at the opposite end of the line connection shall be in accordance with Table 17.2.

17.3.2 Side bending space

17.3.2.1 Other than as mentioned in 17.3.2.2, side wire bending space (distances T_2 and T_3 in Figure 17.2) shall be in accordance with Table 17.2 for the largest conductor to be terminated in that space.

17.3.2.2 With reference to the requirements in 17.3.2.1, if a hole, knockout, or other provision for connection of a wiring system for the main ungrounded conductors is provided in a sidewall opposite the main terminals, it will be assumed that the main conductors, ungrounded and grounded, will enter or exit the enclosure through that wall and the wire bending space for those conductors (distance T_5 in Illustration 3 of Figure 17.2) shall be as specified in Table 17.1.

Exception: The wire bending space (distance T_5 in Figure 17.2) may be in accordance with Table 17.2 if the provision for the wiring system in the enclosure wall opposite the terminal is located at the end of the gutter where it joins the adjacent gutter, and the adjacent gutter provides wiring space (distance G_1 in Figure 17.2) in accordance with Table 17.1 for that conductor. See Illustration 4 of Figure 17.2.

17.3.3 Individual connector bending space

17.3.3.1 The wire bending space from a connector to any barrier or other obstruction that is part of a panelboard shall be as specified in Table 17.2. The adjacent space shall be so arranged that normal routing of conductors (such as down a gutter) will not be restricted. See 17.4.7 and 17.4.8.

17.4 Determination of deflection and bending space distances

17.4.1 For the purpose of determining deflection and bending space distances, the size and material of conductors shall be determined as described in 17.1.3. For top and bottom spaces, conductor sizing shall be based on the maximum ampere rating of the mains. Conductor sizing for side bending spaces shall be based on the largest conductor to be terminated in that space. For individual connector spacings, conductor sizing shall be based on the maximum ampere rating of the connector application.

17.4.2 The wire terminal shall be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it can assume without defeating any means provided to prevent its turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or the like. A barrier, shoulder, or the like is to be disregarded when the measurement is being made if it does not reduce the radius to which the wire must be bent. However, it is to be assumed that the connector is not oriented so that the wire will be directed into a corner of the box to such extent that the transverse wall would necessitate additional bending.

17.4.3 When measuring wire bending space for compliance with Table 17.1 or Table 17.2, the distance is to be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. That is, no credit is to be given for angling of terminals as illustrated by distance D_1 in Figure 17.3; the correct method is to measure perpendicular to the box wall from the edge of the terminal, as illustrated by distance D_2 in Figure 17.3. If a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance is to be measured from the wire opening closest to the wall of the enclosure. If the connectors for a circuit are fixed in position – for

example, by the walls of a recess– so that they are turned toward each other, the distance is to be measured at the wire opening nearest the wall in a direction perpendicular to the wall.

Exception: When measuring bending space for compliance with Table 17.2, the distance (distance D_3 in Figure 17.4) may be measured in a straight line from the center of the wire opening in the direction the wire leaves the terminal.

Figure 17.3

Measurement of wire bending space distances

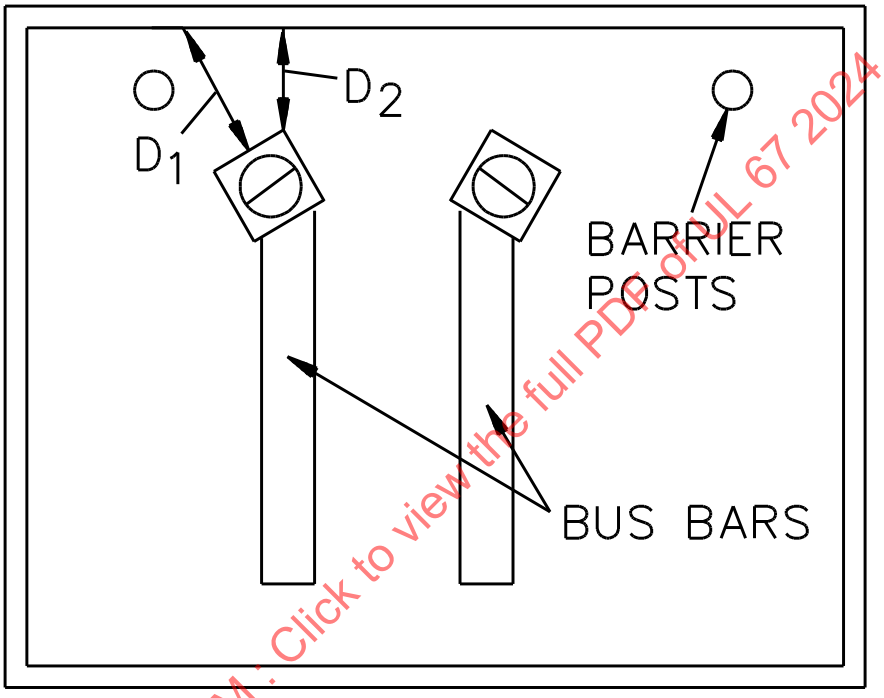
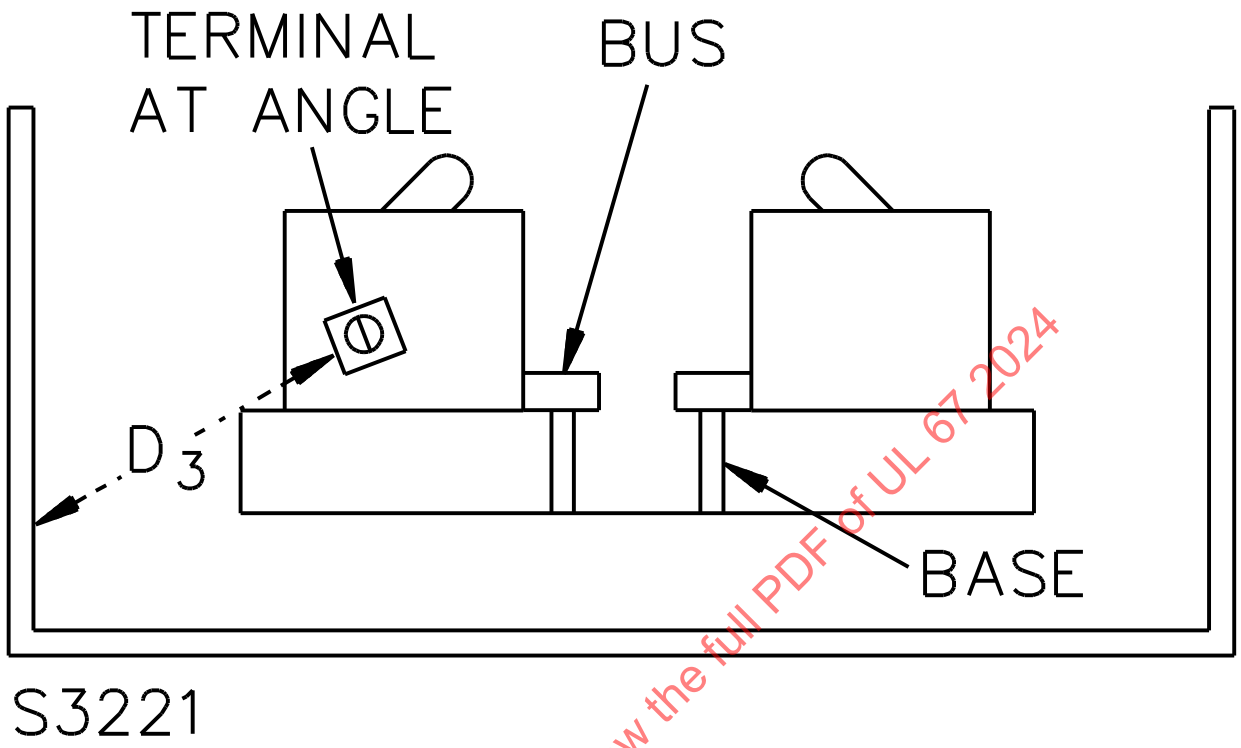


Figure 17.4

Optional measurement of wire bending space distance for compliance with Table 17.2

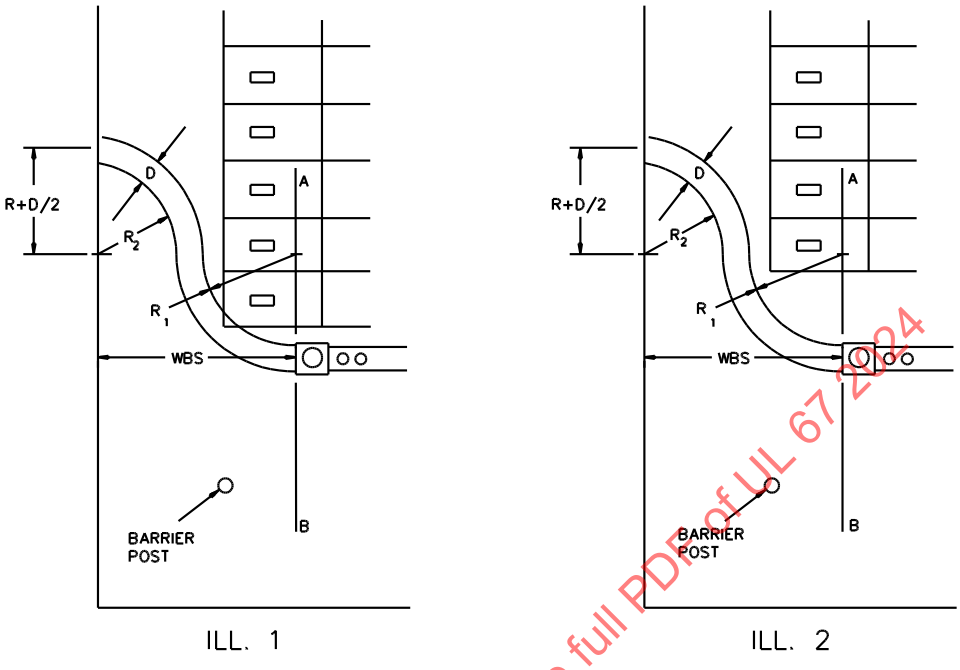


17.4.4 If a wire is restricted by barriers, branch circuit units, or other means from being bent in a 90 degree or S bend from the terminal to any usable location in the wall of the enclosure, the distance is to be measured from the end of the barrier or other obstruction.

17.4.5 With reference to 17.4.4, a barrier is considered to restrict wire bending if the barrier extends beyond an arc with radius R described in 17.4.6. For example, the barrier (branch circuit unit) in Illustration 1 of Figure 17.5 is considered to restrict wire bending; the barrier in Illustration 2 of Figure 17.5 is not considered to restrict wire bending.

Figure 17.5

Restriction of S bends[a,b]



[a] The diameter of the wire, D, in the illustrations is as specified in the National Electrical Code, ANSI/NFPA 70, Chapter 9, Table 5 for the wire size being considered.

[b] WBS is the distance available for wire bending, but is not to be less than the value specified in Table 17.2 for the wire size being considered.

17.4.6 The arc mentioned in 17.4.5 is to be constructed as specified in (a) and (b):

a) For an S bend, see Figure 17.5, line AB is to be:

1) Perpendicular to the line measuring wire bending space (line WBS), and

2) Through the face of the wire connector for which the determination is being made.

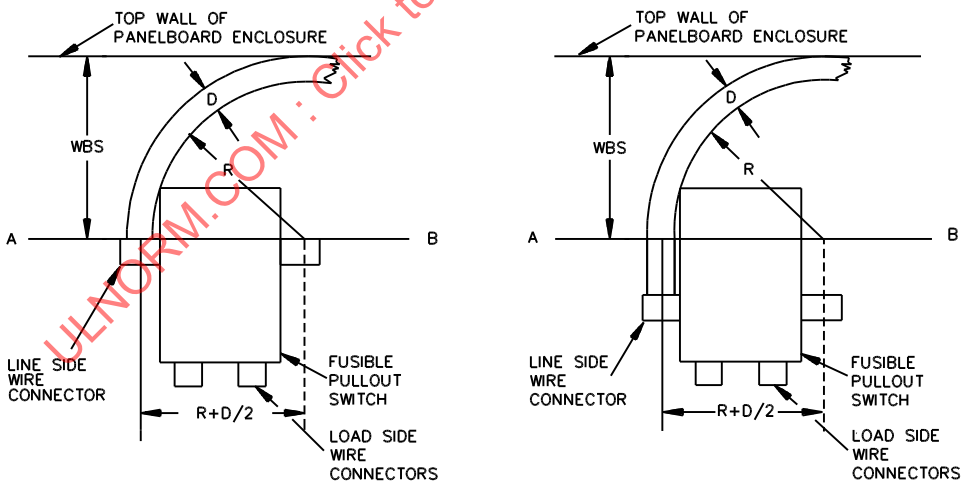
Arc R_1 has a center located on line AB at a distance equal to R+(D/2) from the center of the wire opening with a radius R equal to (WBS-D)/2 and is the inside radius of a wire exiting the wire connector. A second arc with the same center and a radius equal to R+D represents the outside radius of the wire exiting the wire connector. Arc R_2 has center at the intersection of a line perpendicular to line AB and through the center of the radius of arc R_1 and the enclosure wall. The inside and outside radius is the same as for arc R_1.

b) For a 90 degree bend, see Illustration 1 of Figure 17.6, line AB is to be perpendicular to the line measuring wire bending space (line WBS) and through the face of the wire connector for which the determination is being made. The arc has a center located on line AB at a distance equal to R+(D/2) from the center of the wire opening with a radius R equal to WBS-D and is the inside radius of a wire exiting the wire connector. A second arc with a radius equal to WBS represents the outside radius of the wire.

Exception: If the wiring space provided is greater than the value specified in Table 17.2, line AB may be located at the required distance and need not be through the face of the wire connector. See Illustration 2 of Figure 17.6 as an example.

Figure 17.6

Restriction of 90 degree bends[a,b]



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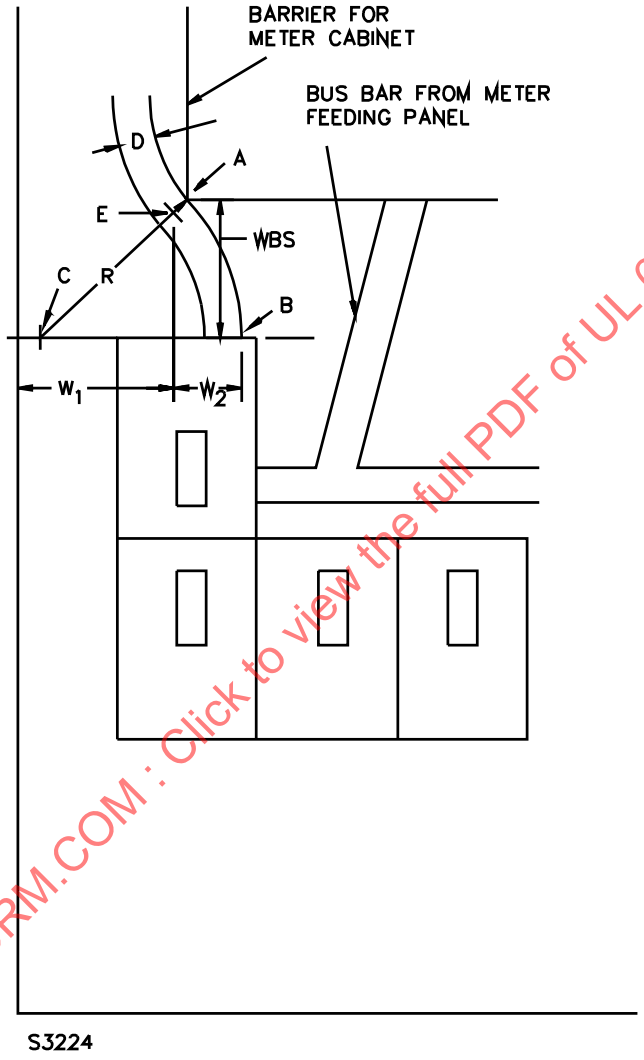
[a] The diameter of the wire, D, in the illustrations is as specified in the National Electrical Code, ANSI/NFPA 70, Chapter 9, Table 5 for the wire size being considered.

[b] WBS is the distance available for wire bending, but is not to be less than the value specified in Table 17.2 for the wire size being considered.

17.4.7 With reference to 17.3.3.1, the adjacent space is considered to restrict normal routing of conductors if the adjusted width W_1 of an adjacent space is less than the adjusted width W_2 required to route the conductor. See Figure 17.7 and 17.4.8.

Figure 17.7

Restriction of wire to be directed down a gutter



17.4.8 With reference to Figure 17.7, to determine the adjusted widths, W_1 and W_2, mentioned in 17.4.7, a line CB perpendicular to the line measuring wire bending space (line WBS) and through the face of the connector is found. An arc AB is located with center on line CB and a radius that:

a) Is the maximum radius that will just clear the barrier, and

b) Is not less than:

$$\frac{WBS + D}{2}$$

in which:

WBS is the distance specified in Table 17.2 for the applicable wire; and

D is the diameter of the wire for the size being considered in accordance with Chapter 9, Table 5 of the National Electrical Code, ANSI/NFPA 70.

A line AC through arc AB is found and a point E is located on line AC at a distance D/2 from point A. The distance W_1 is the distance between a line through point E and perpendicular to line CB and the enclosure wall or barrier. W_2 is the distance between the perpendicular line through line CB and point B. If an arc that complies with (a) and (b) cannot be constructed, then the spacing is unacceptable.

18 Grounding and Bonding

18.1 General

18.1.1 Other than as indicated in 18.1.2, there shall be provision for permanently and effectively grounding a metal plate that covers uninsulated live parts.

18.1.2 The provisions for grounding the plate mentioned in 18.1.1 need not be included if the plate is provided with a means for effectively insulating it from live parts or is located so that it is not likely to become energized.

18.1.3 A panelboard marked as being suitable for use as service equipment shall have provision for connection of the grounding electrode conductor to the grounded service conductor. The size of the grounding electrode conductor shall be assumed to be in accordance with Table 18.1. A soldering lug or other connection means that depends upon solder is not acceptable.

Table 18.1
Size of grounding electrode conductor and main bonding jumper

Ampere rating not exceeding	Size of main bonding jumper (minimum)[a,b,h]				Cross section of main bonding jumper in square inches (mm²) minimum[b,c]				Size of grounding electrode[b] conductor (minimum)			
	Copper, AWG or kcmil (mm²)		Aluminum, AWG or kcmil (mm²)		Copper		Aluminum		Copper, AWG (mm²)		Aluminum,AWG or kcmil (mm²)	
90	8	(8.4)	6	(13.3)	0.013	(8.4)[c]	0.021	(13.6)[c]	8	(8.4)	6	(13.3)
100	6	(13.3)	4	(21.2)	0.021	(13.6)[c]	0.033	(21.3)[c]	6	(13.3)	4	(21.2)
125	6	(13.3)	4	(21.2)	0.021	(13.6)[c]	0.033	(21.3)[c]	6	(13.3)	4	(21.2)
150	6	(13.3)	4	(21.2)	0.021	(13.6)[d]	0.033	(21.3)[d]	6	(13.3)	4	(21.2)

Table 18.1 Continued on Next Page

Table 18.1 Continued

Ampere rating not exceeding	Size of main bonding jumper (minimum)[a,b,h]				Cross section of main bonding jumper in square inches (mm^2) minimum[b,c]				Size of grounding electrode[b] conductor (minimum)			
	Copper, AWG or kcmil (mm^2)		Aluminum, AWG or kcmil (mm^2)		Copper		Aluminum		Copper, AWG (mm^2)		Aluminum,AWG or kcmil (mm^2)	
200	4	(21.2)	2	(33.6)	0.033	(21.3)[d]	0.052	(33.6)[d]	4	(21.2)	2	(33.6)
225	2	(33.6)	1/0	(53.5)	0.052	(33.6)[e,f]	0.083	(53.5)[e,f]	2[e,f]	(33.6)	1/0	(53.5)
400	1/0[g]	(53.5)	3/0[g]	(85.0)	0.083	(53.5)[f,g]	0.132	(85.0)	1/0[g]	(53.5)	3/0[g]	(85.0)
500	1/0	(53.5)	3/0	(85.0)	0.083	(53.5)	0.132	(85.0)	1/0	(53.5)	3/0	(85.0)
600	2/0	(67.4)	4/0	(107.2)	0.105	(67.7)	0.167	(107.7)	2/0	(67.4)	4/0	(107.2)
800	2/0	(67.4)	4/0	(107.2)	0.105	(67.7)	0.167	(107.7)	2/0	(67.4)	4/0	(107.2)
1000	3/0	(85.0)	250	(127)	0.132	(85.2)	0.196	(127.0)	3/0	(85.0)	250	(127)
1200	250	(127)	250	(127)	0.196	(127.0)	0.196	(127.0)	3/0	(85.0)	250	(127)
1600	300	(152)	400	(203)	0.236	(152.0)	0.294	(189.7)	3/0	(85.0)	250	(127)
2000	400	(203)	500	(253)	0.314	(203.0)	0.393	(253.0)	3/0	(85.0)	250	(127)
2500	500	(253)	700	(355)	0.393	(253.0)	0.550	(355.0)	3/0	(85.0)	250	(127)
3000	600	(304)	750	(380)	0.412	(265.8)	0.589	(380.0)	3/0	(85.0)	250	(127)
4000	750	(380)	1000	(507)	0.589	(380.0)	0.785	(507.0)	3/0	(85.0)	250	(127)

[a] The cross section may be reduced to 12.5 percent of the total cross section of the largest main service conductor(s) of the same material (copper or aluminum) for any phase on a panelboard rated 1200 amperes and above. This applies when the cross section of the service conductors is limited by the wire terminal connectors provided.

[b] For a panelboard rated 1200 amperes or more and that has wiring terminals intended to connect service conductor wires sized larger than 600 kcmil copper or 750 kcmil aluminum, the cross section of the main bonding jumper shall be at least 12.5 percent of the total cross section of the largest main service conductor(s) of the same material (copper or aluminum) for any phase.

[c] A No. 8 or larger brass or No. 10 or larger steel screw may be used.

[d] A No. 10 or larger brass or steel screw may be used.

[e] A No. 10 or larger brass screw may be used.

[f] A 1/4-inch (6.4 mm) diameter or larger brass or steel screw may be used.

[g] When the ampere rating is 400 and the wire terminal connectors for the main service conductors are acceptable for two 3/0 AWG copper or two 250 kcmil aluminum conductor but will not accept a 600 kcmil conductor, these values may be reduced to 2 AWG (0.052 square-inch) copper or 1/0 AWG (0.083 square-inch) aluminum.

[h] These are also sizes for the grounded service conductor mentioned in 18.1.3.

18.1.4 The provision for connection of the grounding-electrode conductor specified in 18.1.3 shall be on the neutral.

Exception: The provision may be on the equipment-grounding terminal assembly, bus, or the like if the main bonding jumper is a bus bar or wire and is connected, or is intended to be field connected, directly from the neutral to the equipment-grounding-terminal assembly. See 34.2.2.

18.1.5 For a panelboard marked as being suitable for use as service equipment, when an insulated neutral is provided, a main bonding jumper consisting of a separate screw, strap, or other means shall be provided to bond:

a) The box or the interior pan, if a box is provided, or

b) The interior pan if no box is provided,

to the insulated grounded circuit conductor – the insulated neutral – of an alternating-current system. Except for steel or brass screws as noted in the notes to Table 18.1, the bonding means shall be of copper

or aluminum and shall have a cross-sectional area as specified in Table 18.1. The means used to provide the removable bonding means described in 16.1.7 shall also comply with the foregoing requirement. When an insulated neutral is provided, the construction shall be such that when the bonding means is not used, at least the minimum acceptable spacings will exist. Unless the intended use and method of installation of the bonding means are obvious, instructions for its installation shall be provided. See 11.2.12 for thread engagement requirements.

18.1.6 For a panelboard marked as being suitable for use as service equipment, when the neutral is mounted directly on or is otherwise in permanent electrical connection with the enclosure (or mounting pan if no enclosure is provided), the connecting joint between the uninsulated neutral and the enclosure (or mounting pan) shall have a cross-sectional area as specified in Table 18.1. If threaded fasteners are used, see 11.2.12 for thread engagement requirements. Panelboards constructed as described in this paragraph shall be marked as specified in 34.9.1(a).

18.1.7 With respect to 18.1.5, if the main bonding jumper is a screw, the screw shall have a green colored head that is hexagonal, slotted, or both. The screw shall be visible without disassembly or removal of devices inside the panelboard.

18.1.8 If the main bonding jumper is a screw as permitted in 18.1.7 or includes a screw, either of which are field-installable and permitted to be located in the back plane of the enclosure's intended mounting position, the screw should not project past the back plane of the enclosure's intended mounting position by more than 0.063 inches (1.6 mm).

18.1.9 A panelboard that is marked for service equipment use shall be provided with a terminal for a grounded service conductor even though there may be no provision for a load conductor to be connected to the grounded service conductor. If there is no provision for such a load conductor, the grounded service conductor terminal shall:

a) Accommodate a conductor of the same size as the main bonding jumper specified in Table 18.1,

b) Be bonded to the enclosure, and

c) Be directly-connected to the grounding-electrode-conductor terminal.

Exception: The terminals may be omitted if the panelboard is marked in accordance with 34.12.7.

18.1.10 When installed as intended, the bonding connection described in 18.1.5, 18.1.6, and 18.1.9 shall:

a) Provide a reliable bond to the panelboard frame or enclosure; and

b) Be such that the resistance of the connection between an installed grounded service conductor and the frame or enclosure is not more than 0.005 ohm. See Bonding Resistance Test, Section 27.

18.1.11 In a panelboard incorporating ground-fault protection of the ground-return type as described in 15.7, the main bonding jumper as required by 18.1.5 shall be factory connected to the insulated grounded circuit conductor (neutral) and to the box or interior pan and the panelboard shall be marked to indicate that it is suitable only for use as service equipment.

18.2 Equipment-grounding terminals

18.2.1 A panelboard, or the enclosure in which it is intended to be installed, shall be provided with a means for terminating equipment-grounding conductors for both the main equipment grounding conductor and for the branch-circuit equipment-grounding conductors in accordance with Table 18.2.

Exception No. 1: A panelboard or enclosure marked in accordance with 34.13.4 or 34.13.5.

Exception No. 2: For a panelboard marked in accordance with 34.9.1(a), a terminal for connection of the grounding electrode conductor provided in accordance with 18.1.3 may be considered to be the main equipment-grounding-conductor means if it is acceptable for the wire size specified in Table 18.2.

Exception No. 3: For a panelboard marked in accordance with 34.9.1(b), and employing the construction described in 18.1.9, a terminal for connection of the grounding-electrode conductor may be considered to be the main equipment-grounding-conductor means if it is acceptable for the wire size specified in Table 18.2.

Exception No. 4: For a panelboard marked in accordance with 34.9.1(b) and employing pressure terminal connectors for the connection of the main bonding jumper, the terminal mounted on the panelboard frame or enclosure for the connection of the main bonding jumper may be considered to be the main equipment-grounding-conductor means if it is acceptable for the wire size specified in Table 18.2.

Table 18.2
Equipment-grounding conductor

Rating, amperes	Size, AWG or kcmil (mm^2)			
	Copper		Aluminum or copper-clad aluminum	
15	14	(2.1)	12	(3.3)
20	12	(3.3)	10	(5.3)
30	10	(5.3)	8	(8.4)
40	10	(5.3)	8	(8.4)
60	10	(5.3)	8	(8.4)
100	8	(8.4)	6	(13.3)
200	6	(13.3)	4	(21.2)
300	4	(21.2)	2	(33.6)
400	3	(26.7)	1	(42.4)
500	2	(33.6)	1/0	(53.5)
600	1	(42.4)	2/0	(67.4)
800	0	(53.5)	3/0	(85.0)
1000	2/0	(67.4)	4/0	(107)
1200	3/0	(85.0)	250	(127)
1600	4/0	(107)	350	(177)

18.2.2 An equipment-grounding terminal or terminal assembly and associated parts shall be of a metal or metals that are not likely to be adversely affected by electrolysis in service.

18.2.3 Metal employed for an equipment-grounding terminal shall be nonferrous, stainless steel, or other metal that is inherently resistant to corrosion, or it shall be protected by a coating of zinc or cadmium that complies with 18.2.4 or by an equivalent metallic-plated coating.

18.2.4 With reference to 18.2.3, a protective coating of zinc or cadmium on other than a mounting screw or wire-binding screw shall be such that it will withstand the metallic coating thickness test for the interval specified in Table 18.3.

Table 18.3
Metallic coating thickness test

Temperature		Time, seconds	
°F	°C	Zinc	Cadmium
65	18.3	106	78
70	21.1	102	76
75	23.9	98	72
80	26.7	94	70
85	29.4	90	68
90	32.2	86	64
95	35.0	84	62

18.2.5 A pressure wire connector employed at an equipment grounding terminal shall comply with the requirements for such devices.

Exception: The connector may be of iron or steel, and need not comply with the requirements for the temperature test.

18.2.6 A single opening in a wiring terminal intended for equipment-grounding connections shall not be used:

a) For connection of more than one 8 AWG (8.4 mm^2) or larger conductors, or

b) For connection of more than three 10 AWG (5.3 mm^2) or smaller conductors.

18.2.7 When installed as intended, an equipment-grounding terminal or terminal assembly shall:

a) Provide a reliable bond to the panelboard frame or enclosure;

b) Be such that the resistance of the connection between an installed equipment-grounding conductor and the frame or enclosure is not more than 0.005 ohm. See Bonding Resistance Test, Section 27;

c) Comply with the thread engagement requirements described in 11.2.12; and

d) Constructed such that any field-installable screws located in the back plane of the enclosure's intended mounting position and used to secure parts of the terminal or assembly do not project past the back plane of the enclosure's intended mounting position by more than 0.063 inches (1.6 mm).

18.2.8 The equipment-grounding terminal or assembly shall be:

a) Green or the heads of the terminal screws thereon shall be green; or

b) Identified by markings:

1) Described in 34.13.2 and 34.13.3 and

2) Located adjacent to the terminal or assembly or on a wiring diagram.

19 Sharp Edges

19.1 An enclosure, an opening, a frame, a guard, a knob, a handle, or the like shall not be sufficiently sharp to cause a risk of injury to persons in normal maintenance or use.

19.2 Whenever referee measurements are necessary to determine that a part as mentioned in 19.1 is not sufficiently sharp to constitute a risk of injury to persons, the method described in the requirements for determination of sharpness of edges on equipment in the Standard for Tests for Sharpness of Edges on Equipment, UL 1439, is to be employed. See 17.1.5 for sharp edge requirements as they apply to potential damage to conductors.

20 Separation of Circuits

20.1 Other than as covered in 20.3, conductors or cables of factory- or field-installed Class 2 and Class 3 circuits shall be separated from conductors or cables of factory- or field-installed electric light, power, Class 1, non-power-limited fire alarm circuits, and medium power network-powered broadband communications circuits by:

a) Barriers complying with the requirements of 9.1.7 – 9.1.10; or

b) A minimum permanent 1/4 inch (6.4 mm) separation.

Note: Conductors or cables of low-voltage circuits not classified as Class 2 and Class 3 circuits, and conductors or cables of Class 2 and Class 3 circuits reclassified as Class 1 circuits are to be installed as a power circuit.

20.2 With reference to 20.1(b), separation of conductors shall be accomplished by clamping, routing, or an equivalent means. Field-installed conductors are capable of being separated by arranging the location of openings in an enclosure for the various conductors.

20.3 In a space where field-installed conductors will not be present, a barrier or 1/4 inch (6.4 mm) separation is not needed for factory-installed conductors or cables of Class 2 or Class 3 circuits (conductors that are integral to circuits that are contained within the panelboard enclosure) if the factory-installed conductors or cables are insulated for the maximum voltage of all circuits that are, or could become, in contact.

20.4 With reference to 20.1(a), when the intended uses of the equipment are such that in some applications a barrier is required while in other applications no barrier is required, a removable barrier or one having openings for the passage of conductors is not prohibited from being employed. In those applications where a removable barrier may be utilized, the removable barrier may be supplied in the form of a field installable kit. Instructions for the use of such a field installable barrier shall be a permanent part of the panelboard. Barrier kits shall be provided with complete instructions in conjunction with a wiring diagram provided.

PERFORMANCE

21 Temperature Test

21.1 General

21.1.1 A temperature test on a panelboard is to be conducted in accordance with 21.1.2 – 21.4.3.2. The tests described do not cover such features as panelboards without branch bus bars or panelboards with divided or ampacity-tapered main bus bars. Such panelboards are tested in a similar manner, modified as may be necessary to determine that the current-carrying parts have adequate ampacity.

21.1.2 The panelboard, in an appropriate enclosure, is to be mounted on a vertical wooden surface. Unless it is plainly evident that it is intended to be mounted in some other position, the panelboard is to be mounted with the line terminals at the top. The line leads are to enter the enclosure at a point adjacent to the terminals to which they are connected unless the design dictates otherwise. The unused part of the opening for the leads is to be closed with cotton. Each connecting lead is to have a minimum length of 4 feet (1.22 m) and is to be of copper of a size determined in accordance with 12.1.10. However, aluminum wire of a size determined as specified in 12.1.10 may be used for the test, if the panelboard is marked for use with aluminum wire only in accordance with 34.2.5. Branch-circuit units are to be mounted in all spaces intended for such devices, whether or not all of the units carry current during the test, but the sample panelboard selected for test is to be such that the number of unloaded units is a minimum.

21.1.3 When tested in an ambient temperature within the range of 10 – 40°C (50 – 104°F) the temperature rise on current-carrying parts shall not exceed the values specified in Table 21.1.

Table 21.1
Maximum acceptable temperature rises

	Materials and components	Degrees C	Degrees F
1.	Any bus within 6 inches (152 mm) of a fuseholder along the current path when tested with dummy fuses	30	54
2.	Unplated bus bar or unplated joint other than as covered in item 1	50	90
3.	Plated bus bar or plated joint except as covered in item 1[d]	65[a]	117[a]
4.	Plated bus bar at the point of connection to a molded case circuit breaker[d]	65	117
5.	Neutral parts tested in accordance with Neutral "Black Box" Test. See 21.4.2	30	54
6.	Neutral parts tested as Part of Complete Panelboard. See 21.4.3	50	90
7.	Any part that may be contacted by field wiring	50[a]	90[a]
8.	Pressure terminal connectors for field installed conductors except as noted in items 9 and 10	50[a]	90[a]
9.	Pressure terminal connectors for field wiring to switches or circuit breakers as covered in items 2 – 5 of Table 21.2 if marked in accordance with 34.3.2 and connectors for internal wiring with copper conductors	60[a]	108[a]
10.	Pressure terminal connectors used in circuits rated 110 amperes or less and marked for use with 75°C (167°F) wire	65[e]	117[e]
11.	Pressure terminals or wire connectors for internal wiring involving aluminum conductors unless the connector has been investigated for higher temperatures	50[a]	90[a]
12.	Wire insulation or insulating tubing	35[a,b]	63[a,b]
13.	Electrical tape	55[a,b]	99[a,b]
14.	Varnished cloth insulation	60[a,b]	108[a,b]
15.	Fiber employed as electrical insulation	65[a,b]	117[a,b]
16.	Sealing compound	50[a,b,c]	90[a,b,c]
17.	Phenolic composition employed as electrical insulation or as a part the deterioration of which would result in a risk of fire or electric shock	125[a,b]	225[a,b]

Table 21.1 Continued on Next Page

Table 21.1 Continued

Materials and components	Degrees C	Degrees F
[a] In a panelboard section tested with dummy fuses, the recorded temperature rise shall be increased 20°C (36°F) to represent the heating of fuses except that where only a few fuses such as control circuit fuses are involved, the increase shall only apply to parts within 12 inches (304 mm) of the fuses.		
[b] This limitation does not apply to an insulated conductor or other material as covered in 8.6, that has been investigated and found acceptable for a higher temperature.		
[c] The softening point shall be at least 40°C (72°F) higher than the temperature rise at the point where the compound is employed but not less than 90°C (194°F) in any case. See 8.7.		
[d] Both surfaces of a joint shall be plated but not necessarily the entire length of the bus bar.		
[e] Applicable for the following combinations of conductor and connector: 1) Copper conductor terminated in a copper or copper alloy bodied connector. 2) Copper or aluminum conductor terminated in an aluminum bodied connector, provided the connector has a rating of 90°C (194°F). 3) Aluminum conductor terminated in a copper or copper alloy bodied connector, provided the connector has a rating of 90°C (194°F).		

21.1.4 Temperatures are to be measured by thermocouples consisting of wires no larger than 24 AWG (0.21 mm^2) and no smaller than 30 AWG (0.05 mm^2). when thermocouples are used in determining temperatures in electrical equipment, it is standard practice to employ thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer-type instrument, and such equipment is to be used whenever referee temperature measurements by thermocouples are necessary. The thermocouple wire is to conform with the requirements listed in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M. The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice.

21.1.5 For tests that are to be continued until constant temperatures are attained, thermal equilibrium is to be considered to exist only if three successive readings indicate no change when taken at the conclusion of each of three consecutive equal intervals of time, the duration of each interval being whichever of the following is longer:

a) 15 minutes, or

b) 10 percent of the total test time elapsed previous to the start of the first interval up to a maximum of 30 minutes.

21.1.6 A thermocouple junction and adjacent thermocouple lead wire are to be securely held in good thermal contact with the surface of the material whose temperature is being measured. In most cases, good thermal contact will result from securely taping or cementing the thermocouple in place but, if a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

21.1.7 A panelboard incorporating fuseholders and being tested only to determine the acceptability of main bus bars is to be loaded to rated value by distributing the load proportionally among the branch-circuit units according to their ratings. Tests to determine the acceptability of main bus bars, branch bus bars, or both; or bolted or spring-pressure joints; or fuseholders shall be conducted with dual element time-delay fuses in place if such fuses are available for the class of fuseholder installed. The current to be used for tests is specified in Table 21.2.

Exception: Dummy fuses or the equivalent may be used in place of fuses in fuseholders intended for plug fuses, Class H, K, and R fuses, or for Class J fuses rated 200 ampere maximum.

Table 21.2
Current through fuseholders and other overcurrent devices

Type device		Percent of device rating
1.	Dummy fuse	100
2.	Molded-case circuit breakers marked suitable for 100 percent loading	100
3.	Class L fuses in miscellaneous switches, 1200 ampere or less	80
4.	200 – 1200 ampere Class T fuses	80
5.	400 – 600 amperes Class J fuses	80
6.	All other fuses or circuit breakers	80

21.1.8 For a test on a circuit-breaker panelboard each branch-circuit breaker mentioned specifically in 21.2.1 is to be loaded to the values specified in Table 21.2. The term circuit breaker of maximum or minimum current rating is intended to designate a circuit breaker of the maximum or minimum current rating intended for use with that panelboard or with the particular set of bus bars.

21.1.9 Selection of overcurrent devices shall consider the maximum number of fuseholder or circuit-breaker poles intended to be installed in the panelboard.

21.1.10 Testing with a 60 Hz AC source represents testing with a lower frequency or a DC source.

21.2 Main lug

21.2.1 If a circuit-breaker panelboard mentioned in 21.1.8 does not employ a main circuit breaker or a main switch, it is to be tested as follows:

a) A panelboard in which all branch-circuit bus bars are of the same size:

1) A panelboard in which only one branch-circuit circuit breaker is to be connected to each branch-circuit bus bar or set of bus bars.

i) A circuit breaker of the highest rating that does not exceed 50 percent of the mains rating is to be connected to the uppermost branch bus bars of each phase. A sufficient number of circuit breakers of minimum marked current rating are to be connected to the remainder of the branch-circuit bus bars to load the panelboard to rated value; except that if it is not possible because of space limitations to obtain the full main bus-bar loading in this manner, one or more of these may be replaced by a circuit breaker with a current rating next larger than the minimum.

ii) If the maximum marked current rating of a circuit breaker that can be used in the panelboard is more than 50 percent of the rating of the main bus bars, a test using the same sample is also to be conducted with a circuit breaker of the maximum marked rating intended for use in the panelboard connected to the uppermost branch-circuit bus bars, and with circuit breakers of minimum marked current rating connected to the remaining bus bars to load the panelboard to its rated current.

2) A panelboard in which two circuit breakers are to be connected to each branch-circuit bus bar or set of bus bars.

i) Two circuit breakers, having a total marked current rating equal to the maximum sum of circuit-breaker ratings intended for use with that bus bar – but not more than 50 percent of the mains rating – are to be connected to the uppermost branch-circuit bus bar of each phase. A sufficient number of circuit breakers of minimum marked

rating to load the panelboard to rated value are to be connected to the remainder of the branch-circuit bus bars, except that, if it is not possible because of space limitations to obtain the full main-bus-bar loading in this manner, one or more of these may be replaced by a circuit breaker with a current rating next larger than the minimum.

ii) If the sum of the maximum marked current ratings of the pair of circuit breakers that are intended for use with that branch-circuit bus bar is more than 50 percent of the rating of the main bus bars, a test using the same sample is also to be performed as follows. One circuit breaker of the maximum rating intended for use in the panelboard is to be connected to the uppermost branch-circuit bus bars, together with another circuit breaker of whatever rating is necessary to load these bus bars to their rating. Additional circuit breakers of a minimum rating are to be connected to the remaining branch-circuit bus bars to load the panelboard to its rated current.

b) A panelboard employing two or more different sizes of branch-circuit bus bars. The procedure is the same as that described in 21.2.1(a)(1) or 21.2.1(a)(2), whichever is applicable, except the panelboard is to be mounted so that the section incorporating the branch-circuit bus bars of largest rating will be uppermost unless the design dictates otherwise. The procedure described in 21.2.1(a) is to be followed, except that each group of branch-circuit bus bars of the same size is to be considered separately in determining how the selection of branch-circuit breakers is to be made.

21.3 Main circuit breaker

21.3.1 If the circuit-breaker panelboard mentioned in 21.1.8 employs a main circuit breaker, it is to be tested as described in 21.2.1 in accordance with the construction utilized, except that the main bus bars and main circuit breaker are to be loaded to 80 percent of their rated capacities. However, this test may be omitted if:

a) The means of interconnecting the main circuit breaker and the main bus bars complies with 11.3.2(a) and 11.3.2(b) or has a cross section not less than that of the main bus bar, and

b) The panelboard, without the main circuit breaker, has been tested in accordance with 21.2.1.

21.3.2 If the circuit-breaker panelboard mentioned in 21.1.8 employs a main fusible switch, the selection of branch-circuit breakers, shall be in accordance with 21.2.1, as determined by the construction of the panelboard being investigated. The selection of fuses or dummy fuses shall be in accordance with 21.1.7. The loading shall be as specified in Table 21.2.

21.4 Neutral

21.4.1 General neutral temperature test requirements

21.4.1.1 For the temperature test, the main neutral terminal is to carry not less than its rated current. A panelboard with increased neutral ampacity is to have the neutral loaded to the increased ampacity of the neutral bus. See 11.5.2.

21.4.1.2 Each section of the neutral is to carry a current equal to its required ampacity in accordance with 11.5.3 or 11.5.4, whichever applies. For this current, one or more of the larger conductors that are likely to be accommodated in that section and, if necessary, one or more of the smaller conductors are to be used, all carrying current in accordance with 11.5.5. It is not necessary to load a section identical to and represented by the loading of another section. The terminals selected for carrying current are those located so as to produce the longest current path through the neutral. More than one test may be necessary if it is not possible to load simultaneously all sections of the neutral that require tests to their respective required ampacity without exceeding the rated ampacity of the neutral, unless temperature

rises are not more than allowed when tested with the sections loaded simultaneously and with the main terminal overloaded. See 21.4.2.2 and 21.4.3.2.

21.4.1.3 Neutral assemblies may be tested by either Method A or B. See 21.4.2 for Method A and 21.4.3 for Method B. For DC rated systems, the “neutral” is the DC negative bus.

21.4.2 Neutral “black box” test (Method A)

21.4.2.1 For the "black box" temperature test, a neutral bus bar is to be mounted in a black-painted steel box of such size as to provide a 5 – 6 inch (127 – 152 mm) clearance between the current-carrying parts of the bus bar and the box wall at the sides and top when the neutral is mounted to the back of the box in the intended manner. The box is to be mounted on a vertical wooden surface. The space between a conductor and the edge of a hole through which it passes to enter the box is to be closed with surgical cotton.

21.4.2.2 Temperature rises on any portion of the neutral assembly shall not be more than 30°C (54°F) when tested in accordance with this method.

21.4.3 Neutral tested as part of complete panelboard (Method B)

21.4.3.1 Neutral assemblies tested as part of complete panelboard are to be mounted in the smallest panelboard assembly for which they are intended. The panelboard assembly shall be loaded as required by main lug test procedures described in 21.2 and main circuit breaker test procedures described in 21.3. More than one test may be necessary to address considerations in main lug and main circuit breaker test procedures. Testing that involves breakers with integral neutral connections, such AFCI/GFCI circuit breakers with direct plug-in neutrals, shall be arranged in accordance with the procedures described in 21.2 or 21.3. Based on this configuration, the current path through the neutral is not required to be the longest current path as specified in 21.4.1.2.

Exception: Selection of panelboard test configuration may be based on comparison of results of testing on panelboards without neutral loads. In selecting the worst case scenario for neutral assembly testing, results from testing of the configuration that provided the maximum internal ambient temperature without neutral loads would be considered representative of other configurations.

21.4.3.2 Temperature rises on any portion of the neutral assembly shall not be more than 50°C (90°F) when tested in accordance with this method.

21.5 Clamped joints

21.5.1 If a panelboard employs a clamped joint construction as permitted by Exception No. 1 to 11.1.7 and Exception No. 1 to 11.1.8, the test described in 21.5.2 is to be conducted. The temperature rise at the joint during the 500th cycle shall not be more than 15°C (27°F) higher than the temperature rise at the end of the 25th cycle.

21.5.2 The test sample is to consist of an assembly of bus bars connected together to form a series circuit. The bus bars are to be clamped together with the joint construction used in actual production. The number and size of the bus bar are to represent the maximum ampere rating and the maximum current density in which the joint construction is employed. This may necessitate more than one test. The length of each bus bar is to be 2 feet (609 mm). The bus bar is to be connected to a power supply by any convenient means that will not affect the joint temperature. The power supply is to be adjusted to deliver a value of current that will result in a temperature of 75°C (135°F) above room temperature at the joint. The assembly is then to be subjected to a 500-cycle test. At the end of the 24th cycle, the current is to be readjusted to bring the temperature of the joint to 75°C above room temperature; and this current value is to be maintained for the remainder of the cycling test. At the end of the 25th and 500th cycles, the temperatures are to be recorded. The temperatures are to be measured on both sides of the joint as close

as possible to the bolt or rivet. The cycling rate is to be 3 hours on and 1 hour off. The on period during which temperatures are recorded may be extended to more than 3 hours if necessary for the joint to attain thermal equilibrium.

Exception: The length of the bus bar may be less than 2 feet with the concurrence of those concerned.

21.6 Other bus bar coatings

21.6.1 If a coating as covered by Exception No. 3 to 11.1.5 is employed, a panelboard that employs a clamped joint or a spring-loaded, plug-in joint construction shall be subjected to the tests as described in 21.5.1 and 21.5.2. Before conducting the cycling test, the joints shall be conditioned by assembling and disassembling the joints 25 times.

21.7 Joints with insulators

21.7.1 An assembly that incorporates a thermoset polymeric material insulator depended upon to maintain the clamping force in a joint (see 11.2.3) is to be:

a) Subjected to the tests specified in 21.1.2 – 21.4.3.2 and the temperature rise and current are to be recorded;

b) Conditioned for 168 hours (7 days) at 125°C (257°F); and

c) Again subjected to the tests specified in 21.1.2 – 21.4.3.2 using the recorded current.

The temperature rise attained during the repeat temperature test shall not be greater than 7°C higher than the temperature rise recorded during the original temperature test.

Exception: With the concurrence of those concerned, the bolted joint assembly may be subjected to a current sufficient to induce a 65°C temperature rise in accordance with Table 21.1, and the current recorded. Following the conditioning specified in (b), the temperature test is to be repeated using the recorded current. The temperature rise shall not be greater than 72°C.

22 Rain Test

22.1 An enclosed panelboard, without ventilating openings and designated Type 3R, or 3RX shall be subjected to the Rain Test described in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, with modification to the acceptance criteria as specified in 22.2. An enclosed panelboard with ventilating openings and designated as Type 3R or 3RX shall be subjected to the test described in 22.3, with acceptance criteria as specified in 22.2.

22.2 A Type 3R or 3RX enclosure shall be considered to have met the requirements if at the conclusion of the test:

a) There is no accumulation of water within the enclosure and

b) No water has entered the enclosure at a level higher than the lowest uninsulated live part.

Exception: Water may enter above uninsulated live parts if the construction is such that no water is visible on the uninsulated live parts, insulating material, or mechanism parts, and no water has entered any space within the enclosure in which field installed wiring may be present above uninsulated live parts, insulating material, or mechanism parts, under any proper installation conditions.

Note: Wiring that is located above live parts may serve as a path for water to track to a location where uninsulated live parts, insulating material, or mechanism parts, are present.

22.3 A ventilated enclosed panelboard is to be subjected to water spray simulating a lawn sprinkler applied to exposed surfaces. The nozzle is to be the same as that used for the rain test but the pressure is to be 15 pounds per square inch (103 kPa). The nozzle is to be located 3 feet (914 mm) from the enclosure and is to be aimed upward at an angle of 30 degrees from the horizontal at a point on the enclosure so that the spray covers the entire enclosure. More than one such test may be necessary if the spray does not cover the entire enclosure. In each test, the spray is to be applied for 1 hour.

23 Strength of Insulating Base and Support Test

23.1 The insulating base of a panelboard shall not be damaged when wire connectors securing short lengths of conductors of rated ampacity are torqued to 110 percent of the value marked on the panelboard.

23.2 Damage is considered to have occurred if the base insulating material cracks or rotates; bosses, recesses, or other means to prevent turning do not perform their intended function; straps or bus bars bend or twist; or members move at electrical joints. Minor chipping or flaking of brittle insulating material is acceptable if the performance is not otherwise impaired. Momentary flexing of metallic members without permanent deformation is acceptable.

24 Mold Stress Relief Test

24.1 Conditions of the equipment as described in 24.2 shall not cause softening of the material as determined by handling immediately after the conditioning, nor shall there be any shrinkage, warpage, or other distortion as judged after cooling to room temperature, that results in any of the following:

a) Reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible grounded metal, uninsulated live parts and the enclosure below the minimum acceptable values;

b) Making uninsulated live parts or internal wiring accessible to contact, or defeating the integrity of the enclosure so that unacceptable mechanical protection is not afforded to internal parts of the equipment; or

c) Causing interference with the intended operation or servicing of the equipment.

24.2 One sample of the complete unit shall be placed in a full-draft circulating-air oven maintained at a uniform temperature at least 10°C (50°F) higher than the maximum temperature of the material measured during the temperature test, but not less than 70°C (158°F) in any case. The sample shall remain in the oven for 7 hours. After its removal from the oven and return to room temperature, the sample shall be investigated for compliance with 24.1.

25 Short-Circuit Current Test

25.1 General

25.1.1 These requirements cover a panelboard intended for use on circuits having available short-circuit currents not more than 200,000 amperes. Panelboards shipped without an enclosure shall be rated 10,000 amperes rms symmetrical maximum, unless they are marked for use with a specific enclosure as noted in 34.12.9.

25.1.2 A fuseholder used in series with a circuit breaker in a panelboard having a marked short-circuit-current rating higher than the interrupting capacity rating of the branch-circuit breakers shall have provision for accommodating a Class CC, G, J, L, R or T fuse.

25.1.3 A panelboard with a short-circuit-current rating shall be subjected to the applicable tests specified in 25.1.6 and 25.1.7 and Table 25.1 and Table 25.2.

Exception No. 1: A panelboard employing molded-case circuit breakers as branch-circuit overcurrent-protective devices, with or without a main overcurrent-protective device, is acceptable for the short-circuit current rating equal to the minimum of the molded-case circuit breaker interrupting ratings of 5000, 7500, or 10,000 amperes without short-circuit testing.

Exception No. 2: A panelboard employing fuseholders only, with or without switches, is acceptable for a 10,000 ampere short-circuit-current rating without short-circuit testing.

Exception No. 3: As indicated otherwise in Table 25.1.

Exception No. 4: Unless further restricted as noted in Exception No. 1, a meter center is acceptable for 10,000 amperes or less short-circuit-current rating without any short-circuit testing.

Exception No. 5: A panelboard rated 10,000 amperes or less having a main overcurrent-protective device in series with molded-case circuit breakers having short-circuit ratings that are less than the panelboard short-circuit rating serving as branch-circuit overcurrent-protective devices need not be tested if the series combination has been investigated and found acceptable for the purpose in accordance with the requirements for molded-case circuit breakers.

Exception No. 6: A device in the secondary of a control transformer or in a control circuit that does not extend beyond the panelboard need not be subjected to a short-circuit test.

Exception No. 7: A panelboard employing industrial control switches, snap switches, or clock-operated switches is acceptable for a 5000-ampere short-circuit rating without short-circuit testing.

Table 25.1
Applicable short-circuit tests

Construction or circuit arrangement							Short-circuit-current rating, kA	Test required[a]	
Main lug	Separate main		Integral main		Branch devices			With stand	Maximum voltage
	Circuit breaker	Fusible	Circuit breaker	Fusible	Circuit breaker	Fusible			
1 X					X		5	None	
2 X					X		7.5 and greater[b]	X	X
3 X						X	10 and less	None	
4 X						X	More than 10	X	
5			X		X		5	None	
6			X		X		7.5 and greater[b]	X	X
7			X			X	10 and less	None	
8			X			X	More than 10	X	
9				X	X		5	None	
10				X	X		7.5 and greater[b,d]	X	X
11				X		X	10 and less	None	
12				X		X	More than 10	X	
13 X	X				X		7.5 and greater[c]	X	X
14 X	X					X	More than 10[c]	X	
15	X		X		X		7.5 and greater[c]	X	X

Table 25.1 Continued on Next Page

Table 25.1 Continued

Construction or circuit arrangement							Short-circuit-current rating, kA	Test required[a]	
Main lug	Separate main		Integral main		Branch devices			With stand	Maximum voltage
	Circuit breaker	Fusible	Circuit breaker	Fusible	Circuit breaker	Fusible			
16 X		X			X		7.5 and greater[c,d]	X	X
17 X		X				X	More than 10	X	
18		X	X		X		7.5 and greater[c,d]	X	X

[a] "X" denotes that a test is required. See 25.9.2 for the Withstand test and 25.9.3 for Maximum Voltage test.

[b] No tests required when short-circuit-current rating of panelboard is 7.5 KA or 10 KA and the rating does not exceed the interrupting rating of the circuit breakers as indicated in Exception No. 1 to 25.1.3.

[c] Test required only when the short-circuit-current rating of the panelboard depends on its being used on the load of a separately field-installed main.

[d] See 25.1.2.

Table 25.2
Additional short-circuit tests for panelboards with subfeed or feed-through lugs

Panelboard constructed with	Tests required[a]	
	Withstand	3-cycle withstand
No overcurrent-protective device	–	X
Separate main	X[b]	–
Integral main	X	–
Integral main	–	X[c]

[a] "X" denotes that a test is required. See 25.9.2 for the Withstand Test and 25.9.3 for Maximum Voltage Test.

[b] See 34.1.22 for required marking.

[c] The subfeed or feed-through circuit is not protected by an integral main, see Figure 5.1 and Figure 5.4.

25.1.4 For required tests, a representative number of sizes and ratings of a panelboard of each design shall be tested to determine the acceptability of all assemblies to be manufactured.

25.1.5 In a line of panelboards manufactured either with or without a main overcurrent-protective device, testing of a panelboard without the main device will represent both types if:

a) The short-circuit-current ratings of both types of panelboards are the same,

b) The bus-bar connections between the main overcurrent-protective device and the main bus bars are judged to be acceptably braced or the construction is represented by the nonmain bus-bar construction, and

c) A circuit breaker serving as the main overcurrent-protective device is installed in the same manner as the branch-circuit breakers in the panelboard or is installed in the same manner in which it was installed when it was tested as a circuit breaker under the requirements for molded-case circuit breakers. Installed in the same manner refers to method of attachment, proximity to live parts or dead metal parts, and the like, and not the position of mounting. A molded-case circuit breaker that is marked for a specific position of mounting is to be mounted only in that position.

25.1.6 The panelboard shall be tested at the marked maximum short circuit current rating for a single branch breaker or fuse and with the maximum ampere rating branch breaker or fuse. If both of these ratings occur with the same breaker or fuse only one test is required. See 25.2 and Table 25.1.

25.1.7 A panelboard shall be tested at the maximum short circuit current rating on the panel. If this rating is only achieved by the use of a separate main overcurrent protective device the panelboard shall be tested with that main overcurrent protective device installed ahead of the panelboard. The branch breaker shall be the maximum ampere rating for use at the marked short circuit current rating on the panelboard. See Table 25.1. If there is more than one main overcurrent protective device for the short circuit current rating the panelboard shall be tested with the maximum ampere main overcurrent protective device to be marked on the panelboard. The main and the branch breaker shall comply with the requirements in UL 489 for series combinations.

25.2 Sample selection

25.2.1 Withstand

25.2.1.1 The sample panelboard selected for the withstand test in accordance with 25.1.4 shall have the weakest bus-bar structure when 50 percent filled in accordance with 25.2.1.4.

25.2.1.2 Among the factors to be considered in determining the weakest structure as mentioned in 25.2.1.1 are the length of bus, length of span, supports, cross-section, components mounted, and similar features. The combination of these factors may require more than one test to be conducted.

25.2.1.3 The branch-circuit device having the maximum ampere rating shall be used in this test.

25.2.1.4 Branch-circuit devices shall be installed together in a group to occupy as nearly as possible 50 percent of the available space, starting from the feed end. Of this group, the branch-circuit device for test shall be the one located farthest from the feed end. Devices mounted between the feed end and the device under test shall be selected to provide the least support for the main bus bars.

25.2.2 Maximum voltage

25.2.2.1 A panelboard having a main bus bar of the maximum ampere rating for the construction shall be tested.

25.2.2.2 A circuit breaker having the maximum ampere rating for each frame size shall be tested in locations within the panelboard and in the combinations with other circuit breakers or with blank spaces that are most likely to cause unacceptable results. Such other circuit breakers shall be in the on position. Filler plates shall cover blank spaces. This may require more than one test.

25.2.2.3 With reference to 25.2.2.2, consideration is to be given to the following:

a) Venting of circuit breakers toward or near live parts and grounded metal parts – shortest uninsulated electrical spacings (such as Figure 25.2, Illustration I);

b) Blocking or partial blocking of arc vents in circuit breakers (such as Figure 25.2, Illustration I);

c) Location that causes maximum let-through current in the circuit breaker under test; and

d) Mounting of circuit breakers so that the arc vent in one circuit breaker is directly opposite the arc vent in another circuit breaker (such as Figure 25.2, Illustration 2).

25.2.2.4 Branch-circuit devices shall be installed together in a group to occupy as nearly as possible 50 percent of the available space, starting from the feed end.

25.3 Sample preparation

25.3.1 Enclosure

25.3.1.1 The enclosure is to be mounted and supplied as in a normal installation. All unused openings are to be closed.

25.3.1.2 The enclosure is to be connected through a 30-ampere nondelay-type cartridge fuse to the line lead of the pole least likely to arc to the enclosure. The fuse is to have a voltage rating not less than the test voltage. The connection is to be made to the load side of the limiting impedance by a 10 AWG (5.3 mm^2) copper wire 4 – 6 feet (1.22 – 1.83 m) long.

25.3.2 Doors, fronts, and the like

25.3.2.1 The panelboard, complete with dead-front shield and filler plates, is to be installed in its intended enclosure. If the enclosure is to be provided with a door, the door is to be installed and closed during the withstand test.

25.3.3 Circuit breakers

25.3.3.1 A circuit breaker having adjustable trip features shall have all adjustments set at maximum current or time settings.

25.4 Line connections

25.4.1 General

25.4.1.1 The panelboard terminals are to be supplied by means of copper cables having an ampacity, based on 75°C insulation, nearest to but not less than the rating of the panelboard. The cables are to enter the gutter through approximately 12 inches of conduit at the line-end of the cabinet, at a point that will provide the maximum length of unsupported cables within the panelboard enclosure. The line terminals are to be wired and tightened to the torque specified by the manufacturer in accordance with 12.1.5. See 34.5.1 and 34.5.3. The cables shall not be braced inside the cabinet unless the design includes provision for such bracing. A cable may be braced as it leaves the conduit on the supply side.

25.4.2 Without main overcurrent-protective device or with main circuit breaker

25.4.2.1 The panelboard or main circuit breaker terminals are to be supplied through a cable having a length of 4 feet (1.22 m) per terminal.

Exception: Cable length as provided for in 25.5.4.

25.4.3 With integral main fusible switch

25.4.3.1 Supply cables are to be connected to the terminals of the panelboard. A test fuse in accordance with 25.6.2 is to be installed in the main fusible switch. If the size of the test fuse is such that it cannot fit in the fuseholder, an external fuseholder is to be used. The external fuseholder is to be inserted:

a) Between the load side of the fusible switch and the main bus bars,

b) On the load side of the branch-circuit device, or

c) On the line side of the fusible switch.

When external fuses are used, a copper bus or tube – dummy fuse – is to be installed in each fuseholder of the main fusible switch in accordance with 25.6.1. The combined length of all leads and the supply cable shall not exceed 4 feet (1.22 m).

Exception: Longer cables may be used as provided in 25.4.4.1.

25.4.4 With separate main overcurrent-protective device

25.4.4.1 The method of making line connections to a separate main circuit breaker is to be as illustrated in Figure 25.3. In the case of a separate fusible main, fuses are to be installed in an external fuseholder in accordance with 25.6.2 and Figure 25.3. The main device terminals shall be connected to a cable having a length of 4 feet (1.22 m) per terminal and the combined length of each cable – line and load – shall not exceed 8 feet (2.44 m) in accordance with Figure 25.1.

Exception: Cable length as provided for in 25.5.4.

Figure 25.1

Line connection for tests

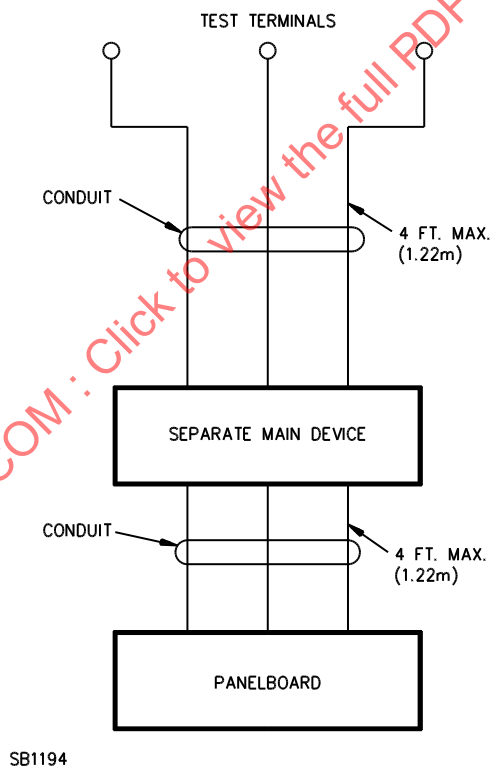
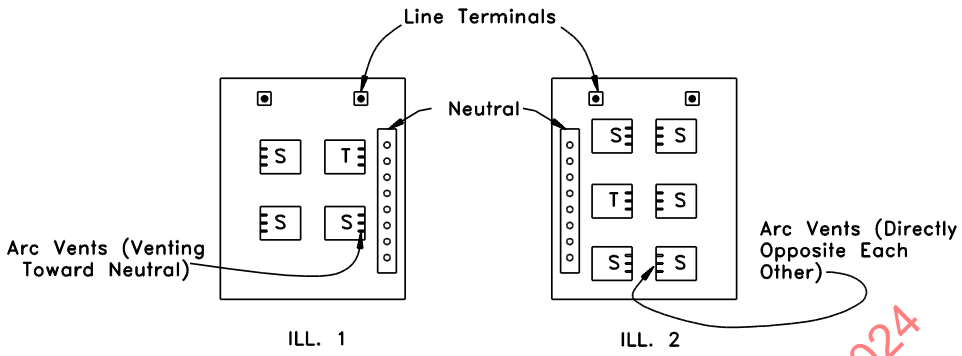


Figure 25.2

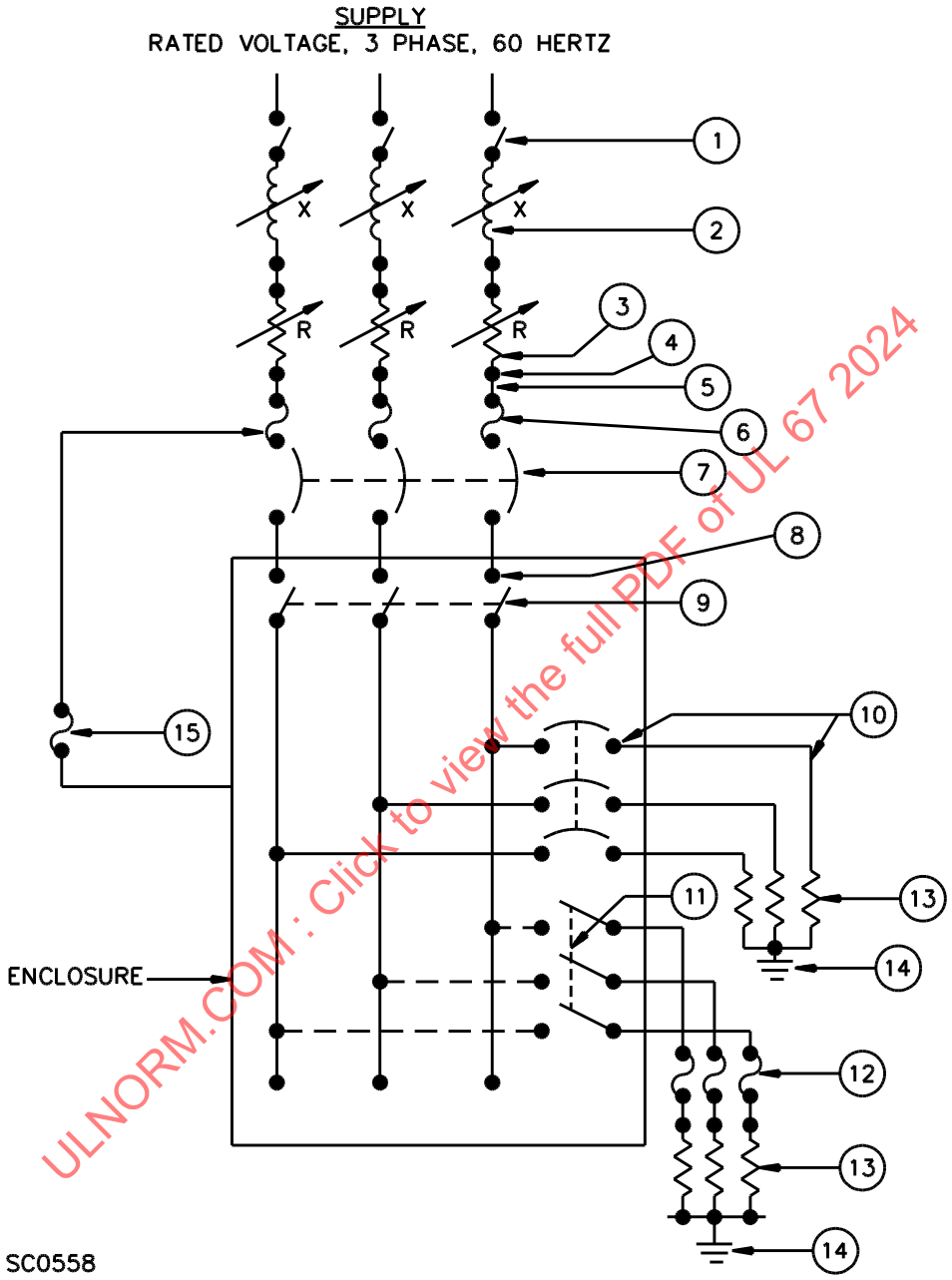
Examples of vent locations for tests



In Illustration 2, the test circuit breaker is not in the position that will allow maximum let-through current. However, it is positioned as close as possible to the incoming line terminals while still permitting it to be surrounded by other circuit breakers for maximum arc-vent blocking.

Figure 25.3

Test-circuit wiring diagram



1. Closing switch
2. Variable tap air-core reactors
3. Variable resistors
4. Test-station terminals
5. Line leads
6. External fuseholder, see 25.4.4.1
7. Separate main circuit breaker
8. Panelboard line terminals
9. Main circuit breaker or fusible switch. For locations of main fuses see 25.4.3.1
10. Branch-circuit breaker and load connection
11. Branch-circuit fusible switch with dummy fuses
12. Fuses, see 25.5.2
13. Instrument shunts, if needed
14. Ground connection, if needed
15. See 25.3.1.2

25.5 Load connections

25.5.1 If the branch-circuit device used in this test is a circuit breaker, the load terminals are to be short-circuited by a cable having a length of 4 feet (1.22 m) per terminal and an ampacity not less than the rating of the circuit breaker. The cables shall be lashed outside the cabinet to prevent whipping during the test. Cables to the load terminal or the instrument shunts shall be short-circuited by a copper bar having a cross-sectional area not less than that of the cables.

Exception: Cable length as provided for in 25.5.4.

25.5.2 If the branch-circuit device used in the test is a fusible switch, cables having a length of 4 feet (1.22 m) per terminal and an ampacity not less than that of the switch shall be run from each switch terminal to the test fuses located outside the panelboard in accordance with 25.6.2 and Figure 25.3. The load terminals of the test fuses or the instrument shunts shall be short-circuited by a copper bar having a cross-sectional area not less than that of the cables. All load cables shall be lashed together or braced outside the enclosure to prevent whipping during the test. A copper bus or tube – dummy fuse – shall be installed in each fuseholder of each fusible switch in accordance with 25.6.1.

Exception: The cable length may be as provided for in 25.5.4.

25.5.3 The short circuit test for panelboards with subfeed or feed-through lugs is to be conducted with the subfeed or feed-through lugs short circuited by cables 4 feet (1.22 m) in length, per terminal. The size of the cables shall be based on:

a) The maximum rated wire size for the subfeed or feed-through lugs,

b) The maximum rating of the specified or incorporated overcurrent protection device, or

c) The ampere rating of the panelboard.

The cables or the instrument shunts shall be short-circuited by a copper bar having a cross-section not less than that of the cables.The cables may be braced outside the enclosure to prevent whipping during the test. However, the cables are not to be braced inside the panelboard unless the panelboard includes markings for bracing the cables (see 34.1.25).

Exception: The cable length may be as specified in 25.5.4.

25.5.4 If the physical arrangement of the test facilities requires leads longer than specified in 25.4.2 – 25.5.2, or lengths of bus bars necessary to extend the terminals, the additional lengths of leads or bus bars shall be included in the circuit calibration.

25.6 Fuses

25.6.1 A copper bus bar or tube shall have a cross-section not less than that of the blade or ferrule of the fuse that the fuseholder is intended to accommodate. Each of these bars or tubes may be individually reinforced to enable it to withstand the short-circuit forces. The bar or tube shall be secured in place in the same manner as are the fuses in normal service.

25.6.2 Each test fuse shall have such characteristics that, when tested on a single-phase circuit in accordance with the requirements for the class of fuse used in the panelboard, it will permit a let-through current I_P and clearing I^2t not less than the corresponding values specified in Table 25.3, for the ampere rating of the largest fuse intended for use in or with the panelboard. To obtain the required values it may be necessary to employ a fuse of a different class or having a higher current rating than that of the fuse the panelboard accommodates. The values of I^2t and I_P are to be determined at the voltage rating of the fuse

except that with the concurrence of those concerned the determination may be made at the voltage rating of the panelboard.

Table 25.3
Peak-let-through currents and clearing I^2t for fuses

Fuse rating	Between threshold and 50 KA		100 KA		200 KA	
A	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$
Class CC fuses						
0 – 15	3	2	3	2	4	3
16 – 20	3	2	4	3	5	3
21 – 30	6	7	7.5	7	12	7
Class G fuses						
0 – 1	–	–	1	0.8	–	–
2 – 3	–	–	1.5	1.2	–	–
4 – 6	–	–	2	1.8	–	–
7 – 10	–	–	3	2.8	–	–
11 – 15	–	–	4	3.8	–	–
16 – 20	–	–	5	5	–	–
21 – 25	–	–	6	6	–	–
26 – 30	–	–	7	7	–	–
31 – 35	–	–	8	14	–	–
36 – 40	–	–	8.5	17	–	–
41 – 45	–	–	9	18.5	–	–
46 – 50	–	–	9.5	21	–	–
51 – 60	–	–	10.5	25	–	–
300-V Class T fuses						
0 – 30	5	3.5	7	3.5	9	3.5
31 – 60	7	15	9	15	12	15
61 – 100	9	40	12	40	15	40
101 – 200	13	150	16	150	20	150
201 – 400	22	550	28	550	35	550
401 – 600	29	1000	37	1000	46	1000
601 – 800	37	1500	50	1500	65	1500
801 – 1200	50	3500	65	3500	80	4000
Class J and 600-V T fuses						
0 – 30	6	7	7.5	7	12	7
31 – 60	8	30	10	30	16	30
61 – 100	12	60	14	80	20	80
101 – 200	16	200	20	300	30	300
201 – 400	25	1000	30	1100	45	1100
401 – 600[a]	35	2500	45	2500	70	2500
601 – 800	50	4000	55	4000	75	4000

Table 25.3 Continued on Next Page

Table 25.3 Continued

Fuse rating	Between threshold and 50 KA		100 KA		200 KA	
A	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$
Class L fuses						
601 – 800	80	10 000	80	10 000	80	10 000
801 – 1200	80	12 000	80	12 000	120	15 000
1201 – 1600	100	22 000	100	22 000	150	30 000
1601 – 2000	110	35 000	120	35 000	165	40 000
2001 – 2500	–	–	165	75 000	180	75 000
2501 – 3000	–	–	175	100 000	200	100 000
3001 – 4000	–	–	220	150 000	250	150 000
4001 – 5000	–	–	–	350 000	300	350 000
5001 – 6000	–	–	–	350 000	350	500 000
Class RK5 fuses[b]						
0 – 30	11	50	11	50	14	50
31 – 60	20	200	21	200	26	200
61 – 100	22	500	25	500	32	500
101 – 200	32	1600	40	1600	50	2000
201 – 400	50	5200	60	5000	75	6000
401 – 600	65	10 000	80	10 000	100	12 000

[a] 800 A values apply to 600 V Class T fuses only.

[b] The value for a Class RK5 fuse shall be used when a Class RK1 fuse is specified for overcurrent protection.

25.7 Meter mounting positions

25.7.1 A watt-hour meter shall be in place during any required short-circuit tests of a meter center.

Exception: Copper bars may be used in the jaws of the meter socket when such equipment is used in conjunction with current transformers. The cross sectional dimensions of such bars are to be 3/32 inch by 3/4 inch (2.4 mm by 19.1 mm).

25.8 Short-circuit procedure

25.8.1 Number of phases

25.8.1.1 A 3-phase panelboard shall be tested on a 3-phase circuit using three overcurrent devices in the branch-circuit position as illustrated in Figure 25.3. These tests will qualify:

a) A 3-phase, 4-wire panelboard, and

b) A single-phase, 3-wire panelboard employing nonadjacent main bus bars of the 3-phase construction.

Exception: If only single-pole or double-pole branch-circuit devices are accommodated in a 3-phase, 4-wire panelboard, the panelboard shall be tested on a single-phase circuit using adjacent main bus bars and two branch-circuit poles, following the same test procedure as for the 3-phase circuit, except that the test circuit is to be controlled so that closing as described in 25.8.3.1 occurs within 10 electrical degrees of the zero point of the supply-voltage wave.

25.8.1.2 A single-phase ac panelboard employing adjacent main bars of the 3-phase construction are to be tested on a single-phase circuit controlled as indicated in the Exception to 25.8.1.1.

25.8.1.3 A panelboard rated 277/480 volts and intended to accommodate only single-pole circuit breakers is to be tested on a 277/480 volt wye or 277/554 volt delta, 3-phase, 4-wire supply with a short-circuit from the line to neutral.

25.8.1.4 A panelboard having a higher short-circuit current rating for line-to-neutral faults than for line-to-line faults, is to be tested with line-to-neutral faults as well as line-to-line faults.

25.8.2 Voltage

25.8.2.1 The open-circuit voltage at the supply connections is to be 100 – 105 percent of rated voltage for the test being conducted, except that with the concurrence of those concerned a voltage higher than 105 percent may be employed. The supply frequency is to be in the range of 48 – 60 hertz.

25.8.3 Closing

25.8.3.1 Random closing is to be employed in all 3-phase tests. Controlled closing is to be employed in single-phase tests in accordance with the Exception to 25.8.1.1.

25.8.4 Current

25.8.4.1 The available current is to be determined at the test station terminals. See item 4 of Figure 25.3.

Exception: Cable lengths as provided for in 25.5.4.

25.8.4.2 The magnitude of the test current, the power factor of an alternating current circuit, and the time constant of a direct-current circuit are to be determined by the applicable method described in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures, UL 489. The power factor for an alternating current circuit shall be in accordance with Table 25.4. The time constant for direct-current circuit shall be in accordance with Table 25.4A.

Table 25.4
Power factor

Short-circuit current, symmetrical amperes	Maximum power factor
0 – 10,000	0.5
10,001 – 20,000	0.3
20,001 and higher	0.2

Table 25.4A
Time Constant

Short-circuit current, amperes	Minimum time constant (seconds)
0 – 10,000	0.003
10,001 and higher	0.008

25.8.4.3 The available short-circuit current shall not be less than the short-circuit current specified for the test. The circuits employed for the tests, see 25.8.1.3 and 25.8.1.4, shall be calibrated line to neutral.

25.8.5 Maximum peak let-through current

25.8.5.1 The overcurrent protection and other features of a panelboard having a short-circuit-current rating in excess of 14,000 amperes shall limit the let-through current of a direct-connected meter as specified in 25.8.5.2.

25.8.5.2 The maximum peak let-through current shall be measured during the short-circuit testing of meter centers. The short-circuit-current rating of the panelboard shall be such that the measured value does not exceed 30,000 amperes. See note to Table 33.1.

Exception No. 1: This measurement need not be made if:

a) The I_p value of the overcurrent protective device is known to be 30,000 amperes or less, or

b) The meter socket is on the secondary side of current transformers.

Exception No. 2: This measurement need not be made if the short-circuit-current rating of the panelboard or the assumed rms symmetrical short-circuit-current rating of the circuit containing the meter as specified in 2.6 and 2.7 is 14,000 amperes or less.

25.9 Short-circuit tests

25.9.1 General

25.9.1.1 A panelboard shall be subjected to the applicable tests described in 25.1.3. After being tested the panelboard shall comply with the requirements in 25.10.1.

25.9.2 Withstand

25.9.2.1 The test is to be conducted at the rated voltage corresponding to the maximum short-circuit-current rating of the panelboard in accordance with 25.8.2.1.

25.9.2.2 With the branch-circuit device, either a fused switch or circuit breaker, and all the main overcurrent-protective devices or short-circuit current limiters, integral or separate, in the fully-closed positions, the test circuit is to be closed on the panelboard. If the enclosure is provided with a door, it is to be closed during this test.

25.9.2.3 The duration of the test for feed-through and subfeed panelboards that do not specify an integral or remote overcurrent-protective device, or incorporate an integral overcurrent-protective device is to be not less than 3 cycles.

25.9.3 Maximum voltage

25.9.3.1 The test is to be conducted at the rated short-circuit current corresponding to the maximum rated voltage of the panelboard.

25.9.3.2 With all circuit breakers, except the branch-circuit breaker connected into the test circuit, and the main overcurrent-protective device, integral or separate, in the fully-closed position, the test branch-circuit breaker is to be closed on the circuit.

25.9.3.3 The test is to be repeated for a panelboard provided with an integral main circuit breaker and marked with a short-circuit-current rating that exceeds the short-circuit rating of the integral main circuit breaker. With all the branch-circuit breakers and the separate main overcurrent-protective device in the fully-closed position, the integral main circuit breaker shall be closed on the circuit.

25.9.3.4 The test is to be repeated for a panelboard provided with a short-circuit current limiter and marked with a short-circuit current rating that exceeds the short-circuit rating of the integral main circuit breaker, if provided, or the branch-circuit breakers. With all the branch-circuit breakers, except the branch-circuit breaker connected into the test circuit, and the integral main circuit breaker, if provided, in the fully-closed position, the test branch-circuit breaker is to be closed on the circuit.

25.9.3.5 If an integral main circuit breaker is provided, the test is to be repeated and the integral main circuit breaker is to be closed on the circuit with the branch-circuit breaker, fully closed, connected into the test circuit.

25.9.3.6 For the tests described in 25.9.3.1 – 25.9.3.5, if the enclosure is provided with a door, it may be open during the test.

25.10 Evaluation of test results

25.10.1 After being tested under any of the short-circuit conditions described as specified in 25.9.2.1 – 25.9.3.6, the mechanical condition of a panelboard shall be substantially the same as its condition prior to the test, and:

a) Bus bars or straps shall not have been permanently distorted or displaced to an extent that affects the normal functioning of the panelboard or reduces an electrical spacing to less than 85 percent of the value specified in Table 16.1.

b) An insulator or support shall not have been broken or cracked to such extent that the integrity of the mounting of a live part is impaired.

c) The fuse mentioned in 25.3.1.2 shall not have opened.

d) The enclosure or parts of the enclosure, such as a filler plate, a door, and the like, shall not have been damaged or displaced to the extent that live parts are accessible.

e) A closed door of the enclosure shall not have blown open more than 60 degrees from the closed position.

f) There shall be no evidence of arcing between live parts of opposite polarity.

g) No conductor shall have been pulled out of a terminal connector and neither the insulated conductor nor the connector shall have been damaged.

h) Component devices, such as a circuit breaker, a fuseholder, and the like, shall not have been damaged other than as permitted by the requirements for such components.

i) The panelboard shall withstand the dielectric voltage-withstand test described in 26.3.1.

j) In the case of a meter center containing a direct connected meter socket, the maximum peak let-through current measured during the short circuit test shall not exceed 30,000 A, when measured as required in 25.8.5.2.

26 Dielectric Voltage-Withstand Test

26.1 General

26.1.1 A panelboard is to be subjected for 1 minute to the application of a 48 – 62 hertz essentially sinusoidal potential of 1000 volts plus twice the rated voltage under the following conditions. A transformer, coil, or other device connected between lines of opposite polarity is to be disconnected from

one side of the line during the test in (b). The results are acceptable if there is no dielectric breakdown between:

a) A live part and a dead metal part with all switching devices closed.

b) Live parts of opposite polarity, with all switching devices closed.

Exception: If a meter socket base incorporates spacings less than those shown in Table 16.1, the test potential applied to it is to be 6000 volts.

26.1.2 If the overcurrent devices, such as fuses or interchangeable trip units, are not in place during the tests described in 26.1.1 (a) and (b), it is necessary to repeat these tests on the load side of the switching devices or to install shorting links in place of the missing fuses or trip units during the tests.

26.1.3 The test potential is to be supplied from a 500 volt ampere or larger capacity testing transformer, the output voltage of which can be varied. The applied potential is to be increased from zero at an essentially uniform rate and as rapidly as is consistent with its value being correctly indicated by the voltmeter until the required test value is reached; it is to be held at that level for 1 minute. The voltage is then to be reduced to zero at the same uniform rate.

Exception: A 500 volt ampere or larger capacity transformer need not be used if the transformer is provided with a voltmeter to measure directly the applied output potential.

26.2 Joints with insulators

26.2.1 With respect to 16.1.5(d), a clamped joint between two insulators is to be tested using two samples.

a) The first sample is to have the clamped joint opened up to produce a space 1/8 inch (3.2 mm) wide. This may be accomplished by loosening the clamping means or by drilling a 1/8 inch diameter hole at the joint between the insulators at a point of minimum spacing between the metal parts on the opposite sides of the joint. The drilled hole shall not decrease spacings between the opposite polarity parts as measured through the crack between the insulators. The 48 – 62 hertz dielectric breakdown voltage through this hole is then determined by applying a gradually increasing voltage (500 volts per second) until breakdown occurs.

b) The second sample with the clamped joint intact is to be subjected to a gradually increasing 48 – 62 hertz voltage until 110 percent of the breakdown voltage of (a) has been reached and held for 1 second. If the breakdown voltage of (a) was less than 4600 volts rms, the voltage applied to the second sample is to be further increased to 5000 volts rms and held for 1 second. The clamped joint is acceptable if there is no dielectric breakdown of the second sample.

26.3 After short circuit

26.3.1 In accordance with 25.10.1 and with every switching device closed, a panelboard that has been subjected to a short-circuit test is to be subjected for 1 minute to the application of a 48 – 62 hertz essentially sinusoidal potential of twice the maximum rated voltage, but not less than 900 volts as follows. The results are acceptable if there is no dielectric breakdown:

a) Between wiring terminals of opposite polarity, and

b) Between an uninsulated live part and the enclosure.

Exception: If breakdown occurs within a switching device, the device may be removed and the test repeated.

26.4 Insulating barriers

26.4.1 With respect to 16.3.2 and 16.3.3, the barrier material is to be placed between two flat metal electrodes. The electrodes are to be cylindrical brass or stainless steel rods 1/4 inch (6.4 mm) in diameter with edges rounded to a 1/32 inch (0.8 mm) radius. The test potential is to be increased to the test value and is to be maintained for 1 second. The result is acceptable if there is no dielectric breakdown.

27 Bonding Resistance Test

27.1 To determine if a connection complies with the requirement in 18.2.7(b), a current of 30 amperes is to be passed through the bonding connection. The resulting voltage drop is to be measured between a point – file mark– on the conductor 1/16 inch (1.6 mm) from the connection and a similar point on the frame or enclosure not less than 1/16 inch from the bonding connection.

28 Test Requirements for Panelboards Used as Transfer Equipment

28.1 A panelboard that is intended for use in accordance with Article 702 of the National Electrical Code, ANSI/NFPA 70, along with its circuit breakers or switches and interlock, shall be tested in accordance with the Standard for Transfer Switch Equipment, UL 1008. See 6.6.9 and 6.6.10 for construction requirements, 34.1.27 and 34.12.18 for marking requirements.

Exception No. 1: Circuit breakers or switches, provided with a mechanical means to prevent the load switching from the normal source of supply to the alternate source of supply in one continuous motion, are not required to be tested in accordance with UL 1008.

Exception No. 2: Circuit breakers or switches provided with a mechanical interlock that prevents the normal and alternate supply circuit breakers or switches from being in motion simultaneously are not required to be tested in accordance with UL 1008.

28.2 A panelboard that is intended for use as interconnection equipment in accordance with Article 702 of the National Electrical Code, ANSI/NFPA 70, along with its circuit breakers, switches, devices, or relays shall be tested in accordance with the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741. See 34.12.18 and 34.12.19 for marking requirements.

MANUFACTURING AND PRODUCTION TESTS

29 Ground-Fault Protection Test

29.1 A factory test shall be conducted on each panelboard incorporating ground-fault-protection equipment to determine that the ground-fault-sensing and -protective equipment functions.

29.2 With a simulated (see 29.3) ground-fault current flowing, the primary of the control transformer, if any, is to be energized at 57 percent of its voltage rating. The relay may be set for any convenient pick-up value. Following this test, with simulated ground-fault current no longer flowing, an attempt is to be made to close the main switch or circuit breaker without pushing any reset button. If the switch or breaker will stay closed, the simulated ground-fault current is to be reapplied and the ground-fault-protection system shall function.

Exception No. 1: The applied voltage may be approximately rated voltage if the particular combination of transformer, ground-fault-sensing and -relaying equipment, and disconnecting means has been previously tested at 57 percent of rated voltage.

Exception No. 2: The factory test is not required for a residual-type ground-fault protector if:

a) Operation is powered by the fault current itself so that no other control-circuit potential is required, and

b) The ground-fault protection other than the neutral-current sensor is contained within and has been investigated with the circuit breaker or switch.

29.3 One method of simulating a ground-fault current is by wrapping a number of turns of wire through the sensor. A current approximately 125 percent of the pick-up setting of the relay divided by the number of turns is passed through the wire to simulate the ground-fault current.

RATING

30 General

30.1 A panelboard shall be rated in amperes and in volts. An alternating-current rating shall include the number of phases, if other than single-phase, and the frequency, if other than 50 or 60 hertz. A separate current rating shall be indicated for a circuit breaker or fused switch not electrically connected to the panelboard bus bars.

30.2 The number of phases, the frequency, or a-c may be used to denote alternating-current voltages. The symbol 0 may be used in place of the word phase.

30.3 The overall ampere rating of a meter center that:

a) Is marked to indicate that it is suitable for use as service equipment; and

b) *Deleted*

c) Is not provided with a single main disconnect,

shall not be less than the percentage of the sum of the continuous ampere ratings of the assembled meter positions specified in Table 30.1.

Table 30.1
Minimum ampere rating of assembly

Number of meter positions assembled together	Percent of sum of ampere ratings
2	50
3 – 5	45
6	44

31 Current

31.1 The current rating of a panelboard shall not be more than the smaller of the following:

a) The ampacity of the bus bars; or

b) The current rating of the main switch and fuseholders, or the current rating – trip rating – of the main circuit breaker, except as noted in 34.1.26.

31.2 For NEC Article 705 applications noted in 6.6.11:

a) Supply side connections – The combined sum of the current rating of all supply side disconnect(s) shall not exceed the rating of the panelboard. See 34.16.6.

b) Load side connections – The combined sum of the current rating of all overcurrent devices supplying the panelboard shall not exceed the rating of the panelboard.

Exception: The combined sum may exceed the rating of the bus bars, or the rating of the main overcurrent device by up to 120% if overcurrent device(s) are positioned as noted in 6.6.11(b)(2), Exception. See 34.16.5.

31.3 The current rating referred to in 31.1 is capable of being supplemented by one or more reduced ratings, each applicable under specified conditions – such as use of aluminum main conductors or a main circuit breaker having a current rating less than the rating normally required of the breaker – when the panelboard is marked in accordance with 34.1.16.

31.4 If a panelboard employs a snap switch rated 30 amperes or less in any branch circuit, the rating of the panelboard shall not be more than 200 amperes unless there is overcurrent protection at 200 amperes or less, within the panelboard, on the line side of that switch.

31.5 Other than as noted in 31.6 and 31.7, a panelboard marked suitable for use as service equipment shall have a rating of not less than 60 amperes.

31.6 A panelboard marked suitable for use as service equipment and having provision for the connection of only two 2-wire branch circuits shall have a rating of not less than 30 amperes.

31.7 Meter centers marked suitable for use as service equipment and having provisions for the connection of only a single branch circuit shall have a rating of not less than 15 amperes.

31.8 For meter centers, the continuous duty rating but not the maximum rating of the meter position may be less than the rating of the circuit in which it is used.

Exception: A meter position intended to be used on the secondary side of current transformers may be rated less than the circuit in which it is used.

32 Voltage

32.1 The voltage rating of a panelboard shall not be more than 1000 volts, and shall not be more than the voltage rating of any part of the panelboard, such as a switch or circuit breaker, that is conductively connected to the main supply circuit.

32.2 In a panelboard with a combination voltage rating in accordance with 32.4, a switch or circuit breaker having a voltage rating of not less than the line (phase) to neutral potential, if properly connected in a 125/250-volt or 120/208-volt panelboard, is acceptable, but a 125/250-volt switch or circuit breaker in a 250-volt panelboard is not acceptable.

32.3 A panelboard designed for use on a supply circuit involving two different potentials, such as: 120/240 volts, 3-wire, or 208Y/120 volts, 3-phase, 4-wire, shall have an appropriate combination voltage rating as indicated in 32.4.

32.4 32.3 requires the combination rating on a panelboard that is intended for use only on circuits such as:

a) 120/240-volt, single-phase, 3-wire, a-c, with grounded neutral,

b) 125/250-volt, 3-wire, d-c, with grounded neutral,

c) 208Y/120-volt, 3-wire, a-c (from 3-phase, 4-wire network),

d) 480Y/277-volt, 3-wire, a-c (from 3-phase, 4-wire network),

e) 208Y/120-volt, 3-phase, 4-wire,

f) 240/120-volt, 3-phase, 4-wire, delta,

g) 480Y/277-volt, 3-phase, 4-wire, and

h) 120/240-volt, 2-phase, 5-wire.

32.5 A single-phase, 3-wire panelboard shall not be marked with a 120/240-volt, 3-phase, 4-wire rating derived from a delta system.

33 Short Circuit Current – Details

33.1 The short-circuit rating of a panelboard shall be one or more of the values specified in Table 33.1.

Table 33.1
Short-circuit-current ratings, rms symmetrical or DC amperes

5,000	25,000	65,000
7,500	30,000	85,000
10,000	35,000	100,000
14,000	42,000	125,000
18,000	50,000	150,000
22,000		200,000
NOTE – See 25.8.5.2 for meter centers. Short-circuit fault currents may adversely affect the accuracy and operation of a watt-hour meter.		

MARKING

34 Details

34.1 General

34.1.1 A panelboard shall be marked in a location such that the marking will be plainly visible after the panelboard has been installed with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified – hereafter referred to as manufacturer's name – and

b) The electrical rating.

A panelboard intended for use in a particular position shall be so marked.

34.1.2 A panelboard shall be marked with a catalog number, a general type designation, or the equivalent.

34.1.3 With reference to the requirements in 34.1.1, the markings giving the manufacturer's name, the current and voltage ratings, and the number of phases shall be visible without disturbing interior parts and factory- or field-installed wiring. A marking is not considered to be visible without disturbing field-installed wiring if it is:

a) On a back wall of the box,

b) On the side of a barrier facing a wiring space, and is more than 1 inch (25.4 mm) from the plane of the front of the box,

c) Less than 1/2 inch (12.7 mm) or more than 1 inch from the front edge on a side or end wall of a box having a flange on the front edge, or

d) More than 1 inch from the front edge on a side or end wall of a box without flanges on the front edge.

34.1.4 A panelboard provided with a manual, pamphlet, or instruction sheet in a pocket as specified in the Exception to 35.1, shall additionally be marked:

a) With a statement that the manual, pamphlet, or instruction sheet should be consulted before installation of the panelboard; and

b) To indicate the location of the pocket, and where a replacement manual, pamphlet, or instruction sheet may be obtained should the original become lost.

34.1.5 If a manufacturer produces or assembles panelboards at more than one factory, each panelboard shall have a distinctive marking – which may be in code – by which it may be identified as the product of a particular factory.

34.1.6 A panelboard intended to be accessible only to qualified persons shall include the following permanently attached statement: "This panelboard shall be located where accessible only to qualified persons." See 9.1.3 or 14.4.8.

34.1.7 If the electrical-safety features, performance, or spacings of a panelboard are dependent upon the proper connection of line and load conductors, the marking shall plainly indicate the proper connections.

34.1.8 The word line or load and the number of branch circuits are usually employed to indicate the proper connections. Such markings may be placed at the terminals; or on a wiring diagram that clearly indicates the proper connections and is attached to the panelboard proper or in a location where it will be visible after installation is acceptable. See 35.3.

Exception: A wiring diagram may be located in a pamphlet. See the Exception to 35.1 and Table 35.1.

34.1.9 With reference to 11.6.1 and 11.6.4, if the ampacity of a bus bar or wire is less than the maximum current rating of any fuse accommodated by a fuseholder that it supplies or is less than the current rating of any trip unit of an interchangeable-trip circuit breaker that it supplies, there shall be a clear and permanent marking that is plainly visible when the fuse or trip unit is being replaced and that prohibits the use of a fuse or trip unit having a rating more than the ampacity of the bus bar or wire.

34.1.10 A panelboard supplied with branch-circuit bus bars to which a branch-circuit unit – circuit breaker, switch, or fuseholder, – may be added in the field shall be plainly marked on a wiring diagram, on the branch-circuit bus bars, or in some other location to indicate the ampacity of that bus bar, unless the ampacity of the bus bar is not less than:

a) The maximum current rating of any unit that is intended to be connected to it, or

b) The current rating of the panelboard.

34.1.11 If a panelboard is provided with two or more sets of main bus bars, the current and voltage ratings for each set of bus bars shall be marked. The marking may be on one or more nameplates; and if the marking appears on only one nameplate, it shall be clear as to which bus bars the various ratings apply.

34.1.12 If the ampacities of all the main bus bars, including the neutral bus bar, are not identical, the marked current rating of the panelboard shall indicate the ampacity of each bus bar.

34.1.13 A panelboard that is acceptable for use on alternating current only or on direct current only shall be marked accordingly.

34.1.14 If one of the current values given in note c to Table 11.1 is employed as a rating of a single-phase, 3-wire panelboard, the panelboard shall be marked to indicate that this rating is applicable only if the panelboard is installed as single-phase, 3-wire residential service equipment.

34.1.15 The current rating of the meter positions shall be marked on meter centers. If the meter position is rated for continuous duty, the marking shall be "___Amps Continuous." If the meter position is rated for a maximum rating, the marking shall be "___ Amps (___ Amps Continuous)" in which case the maximum amperes shall not be more than 125 percent of the continuous duty amperes.

34.1.16 The conditions under which each supplementary current rating as mentioned in 31.3 applies shall be marked on the panelboard.

34.1.17 A panelboard intended for use with a back-fed unit hold down kit as described in the Exception to 6.6.8 shall be marked "back-fed _____ requires hold-down kit Cat. No. _____" or the equivalent. An identification of the applicable back-fed unit shall be included in the first blank – for example, circuit breaker, fused switch, or terminal kit; and the catalog number of the required hold-down kit shall be included in the second blank.

34.1.18 A panelboard shall be marked with the following or the equivalent information:

a) The phrase "Short-Circuit-Current Rating," the short-circuit-current rating in DC or rms symmetrical amperes (see Table 33.1), and, if the panelboard is a meter center containing meter mounting equipment other than those for use with current transformers, with the phrase "Watthour meter not included in short-circuit-current rating.";

b) The maximum DC or rms voltage rating for each short-circuit-current rating;

c) A phrase indicating that an additional or replacement device (other than a fuse) shall be of the same manufacturer, type designation, and equal or greater interrupting rating. This may be accomplished by specific reference to the device if the interrupting rating of the device is not less than any marked short-circuit-current rating of the panelboard. For a fuse, the class of fuses shall be specified. For a direct current short-circuit-current rating, the direct current voltage and short-circuit-current rating of a field installed fuse or circuit breaker shall be specified. See Table 2.1;

d) The ampere rating of the devices if not all of the same type designation are acceptable for the short-circuit-current rating of the panelboard; and

e) When applicable, the identity of the combinations of integral or remote main and branch-circuit overcurrent-protective devices that are required when applying the marked short-circuit current rating. See 34.1.21.

f) A statement that the short-circuit-current rating is limited to the lowest interrupting rating of any installed circuit breaker or fused switch, or combination series connected circuit breaker. See 34.1.20.

34.1.19 A panelboard shall not be marked with a short-circuit-current rating that:

a) Exceeds the short-circuit current, interrupting, or withstand rating of any device intended to be installed therein for that rating, or

b) Exceeds the short-circuit current, interrupting, or withstand rating of the remote main overcurrent-protective device with which it is intended to be used for that rating.

Exception No. 1: A branch-circuit breaker connected to the load side of an integral main overcurrent-protective device may have short-circuit current or interrupting ratings less than the marked short-circuit-current rating of the panelboard if the combination is tested in accordance with Table 25.1 or complies with the requirement in Exception No. 5 to 25.1.3.

Exception No. 2: A branch-circuit breaker or the main circuit breaker, if provided, or both, may have short-circuit current or interrupting ratings less than the marked short-circuit-current rating of the panelboard if the panelboard is intended for use at this short-circuit-current rating only when connected to the load side of a separately-installed main or feeder-main overcurrent-protective device, having a short-circuit current or interrupting rating not less than that of the panelboard. The combination shall be tested in accordance with Table 25.1 unless it complies with the requirement in Exception No. 5 to 25.1.3.

Exception No. 3: A panelboard rated 5000 amperes.

Exception No. 4: The short-circuit-current rating of a panelboard may exceed the component interrupting or withstand rating marked on the device or in accordance with Table 2.1 if the components interrupting or withstand rating is adequate for the assumed available short-circuit current as covered in 2.6 and 2.7 and the panelboard is marked as specified in 34.1.18(e).

34.1.20 With regard to 34.1.18, the following is an example of a marking for a panelboard for which field-installed units are available that have a lower interrupting or withstand rating than the panelboard short-circuit-current rating, and some of the units, are acceptable for use above their marked interrupting or withstand rating when used on the load side of a specific overcurrent device (blank spaces shall be filled with appropriate information). The marking in (b) shall be adjacent to the marking in (a) but does not need to comply with the permanence of marking requirements in 35.1. The indication of a voltage rating for a line-side fused switch is necessary only for Class T fuses.

a) "The short-circuit-current rating of this panelboard is equal to the lowest interrupting rating of any installed circuit breaker or fused switch, but not more than ____ rms symmetrical (for AC circuits) amperes at ____ volts, 3-phase (for AC circuits), or ____ rms symmetrical (for AC circuits) amperes at ____ volts, single phase (for AC circuits);" and

b) "The interrupting rating of a circuit breaker is 5,000 rms symmetrical (for AC circuits) amperes and for a fused switch is 10,000 rms symmetrical (for AC circuits) amperes, or as marked on the device, except for the following series combination ratings:

Load Side Circuit Breakers				Line Side Circuit Breakers			Interrupting Rating		
Mfr.	Type	Poles	Ampere Rating	Mfr.	Type	Ampere Rating	Symmet. amperes rms (for AC circuits)	Volts ac	Phases
Load Side Circuit Breakers				Line Side Fused Switch			Interrupting Rating		
Mfr.	Type	Poles	Ampere Rating	Fuse Class	Volts (ac or dc)	Amperes	Symmet. amperes rms (for AC circuits)	Volts ac	Phases

A load side circuit breaker may be a branch, submain, or an integral main used on the load side of a remote main. A line side circuit breaker or fused switch may be a submain, integral main, or a remote main. The series combination interrupting rating shall not exceed that of the line side circuit breaker or fused switch."

Exception: This information may be located in a pamphlet. See the Exception to 35.1 and Table 35.1.

34.1.21 With reference to 34.1.18(e) only those combinations of circuit breakers or fuses and circuit breakers, or both, that have been demonstrated by test to comply with the applicable requirements in UL 489 shall be marked on the panelboard. The circuit breaker manufacturer's name, type designation or the equivalent, and the ampere rating if applicable shall be specified in the marking. For a fusible switch, the manufacturer's name, catalog number, and the class of fuse shall be specified. The panelboard is permitted to utilize any of the afore mentioned series combinations where all of the following conditions are met:

a) The branch circuit breaker in the series rating is a circuit breaker that has been evaluated for use in the panelboard.

b) The series rating to be marked on the panelboard is equal to or less than the tested and marked short circuit current rating on the panelboard.

c) If the short circuit current rating of the panelboard is dependent on a series rating the ampere rating of the main utilized in the series rating shall be equal to or less than the ampere rating of the main overcurrent protective device employed in the short circuit current testing of the panelboard.

34.1.22 If the short-circuit rating of a panelboard is dependent upon the use of specific overcurrent devices ahead of the panelboard, the panelboard in addition to 34.1.18(c) shall be marked "When protected by _____ ampere maximum Class R[+] fuse or (Manufacturer's name and type designation) circuit breaker rated not more than _____ amperes this panelboard is suitable for use on a circuit capable of delivering not more than _____ rms symmetrical (for AC) amperes, _____ volts maximum" or the equivalent. The value of amperes shall correspond to the values given in Table 33.1.

[+] – Class CC, G, J, L, T, or R – RK1 or RK5 may be specified in place of or in addition to Class R.

34.1.23 If the short-circuit rating of a panelboard is dependent upon integral short-circuit current limiters, the panelboard in addition to the marking required in 34.1.18(c) shall also be marked to indicate that a short-circuit current limiter is installed in the panelboard. The catalog number, ampere rating, and the manufacturer's name of the short-circuit current limiter shall be marked on the panelboard.

34.1.24 The short-circuit rating of a panelboard shall be located where it will be visible if a front or trim is removed. This marking shall be an integral part of:

a) A marking containing the manufacturer's name, or

b) Other required marking. If there is more than one short-circuit rating, all such ratings shall appear together.

34.1.25 With reference to 25.5.3, a marking concerning the bracing of subfeed or feed-through cables routed through a panelboard shall be located adjacent to the subfeed or feed-through lugs. A drawing depicting the bracing requirements may be provided adjacent to the subfeed or feed-through lugs.

34.1.26 If a panelboard incorporates a main circuit breaker having a current rating less than the marked rating of the panelboard, the marked current rating shall be followed with the words "Maximum – see main circuit breaker rating".

34.1.27 A panelboard that is capable of being used as transfer equipment in accordance with Article 702 of the National Electrical Code, ANSI/NFPA 70, and has circuit breakers, switches and interlocks assembled at the factory shall be marked "Suitable for use in accordance with Article 702 of the National Electrical Code, ANSI/NFPA 70".

34.1.28 Markings that include references to the National Electrical Code may include any of the following designations: “NEC”, “ANSI/NFPA 70”, “NFPA 70”, “National Electrical Code”. In addition, the marking may include a reference to a specific edition of the National Electrical Code.

34.2 Wiring space and terminals

34.2.1 A panelboard constructed in accordance with Exception No. 2 to 17.3.1.1 shall be marked by means of a diagram that shows and specifies the method of wiring that shall be used to accomplish the 90-degree bend.

34.2.2 If the main bonding jumper specified in the Exception to 18.1.4 is intended for field connection, instructions for its installation shall be provided.

34.2.3 If any terminal of the panelboard – see 34.2.8 – is marked to indicate that aluminum wire may be used at that terminal, such as by being marked with the symbol "Al", and if such marking is visible under the conditions described in 34.2.9, the panelboard shall be marked in accordance with 34.2.4, 34.2.6, or 34.2.7, whichever applies.

34.2.4 If, because of wiring space or other factors, a terminal of the panelboard is not acceptable for use with aluminum wire, the panelboard shall be marked "Use copper wire only."

34.2.5 If a panelboard is acceptable for aluminum wire only, the panelboard shall be marked "Use aluminum wire only."

34.2.6 If the wiring space and other factors are such that all terminals of the panelboard are acceptable for use with aluminum and copper wire, the panelboard shall be marked "Use copper or aluminum wire."

34.2.7 If the wiring space and other factors are such that some terminals of the panelboard are acceptable for use with aluminum and copper wire and the remainder of the terminals are acceptable for use with copper wire only, the panelboard shall be marked "Use copper wire only except at terminals..." The marking shall positively identify the terminals that are acceptable for use with aluminum wire.

34.2.8 The word terminal as used in 34.2.3 – 34.2.7 signifies any terminal of the panelboard or a terminal of any component unit, such as a circuit breaker, switch, or the like, that is installed or intended to be installed in the panelboard.

34.2.9 The term visible as used in 34.2.3 signifies a marking that will be visible when a front, trim, or dead-front shield has been removed, or that is visible when a hinged cover of a component has been opened. A marking on a separately supplied connector or a connector or part thereof that is likely to be removed or displaced during the wiring operation is considered to be visible.

34.2.10 Markings provided in accordance with 34.2.4, 34.2.6, 34.2.7, or 34.2.12 shall be readily and clearly visible when the cover, front, or trim of the cabinet is removed.

34.2.11 The characters in the markings described in 34.2.4 – 34.2.7 and 34.2.12 shall not be less than 3/32 inch (2.4 mm) high.

34.2.12 A marking employing a wording differing from that given in 34.2.4 – 34.2.7 may be accepted if it clearly and completely conveys the significant information. Any abbreviation designating copper and aluminum shall be "AL CU," "CU AL," or equivalent.

34.2.13 If a terminal is acceptable for the connection of more than one conductor and is intended for such use, the marking shall indicate the proper connection.

34.2.14 A terminal of a panelboard capable of securing two or more combinations of conductors in multiple, any of which has an ampacity acceptable for the application, shall be identified and marked unless the panelboard is acceptable for use with the combination of wires requiring the largest wiring space in accordance with 17.1.3. The terminal shall be identified by a prominent marking, such as on a wiring diagram, on the panelboard that will state the number and size of wires for which the terminal is acceptable.

34.3 Field-installed conductors

34.3.1 A panelboard shall be marked in a location readily visible prior to wiring to indicate the required temperature rating of each field-installed conductor.

34.3.2 If the temperature rise exceeds 50°C (90°F) on a terminal as covered in item 9 of Table 21.1, a marking shall be provided near the terminal indicating that 90°C (194°F) wire shall be used and it shall be sized based on the ampacity of wire rated 75°C (167°F). If the panelboard is marked for use with aluminum or copper-clad aluminum conductors, there shall be a marking to indicate that the wire connectors shall be identified AL9, AL9CU, or CU9AL. The marking shall be:

a) Provided by the panelboard manufacturer if not already provided on the switch or circuit breaker, and

b) Visible after installation.

34.3.3 If a pressure wire connector provided in a panelboard for field installation of conductors requires the use of a specific tool other than a common screwdriver or wrench for securing the conductor, the necessary instructions for using the tool shall be provided with the panelboard in a readily visible location, such as on the connector, on a wiring diagram, or on a tag secured to the wire connector.

34.4 Arrangement of terminals

34.4.1 The relative arrangement of terminals for the connection of circuit conductors shall be such that the terminals for any one circuit can be readily identified, or, except for neutral terminals, such terminals shall be identified by markings. The marking shall appear on or near terminal plates, but shall not be placed only on parts, such as terminal screws and the like, that might be removed and not subsequently replaced or improperly replaced.

34.4.2 The requirement in 34.4.1 does not preclude a marking on trim, a dead-front shield, and the like.

34.4.3 Corresponding numbering of all terminals of branch-circuits may be used to comply with the requirement in 34.4.1. A wiring diagram may also be used if it complies with 35.3.

34.4.4 An orange color may be used to indicate the leg having the highest voltage to ground for a midpoint grounded 3-phase, 4-wire, delta-connected secondary system as covered in 11.2.5. A white or gray color is only to be used to indicate the neutral, which is the grounded conductor. A continuous green color with or without one or more yellow stripes is only to be used for grounding or bonding conductors.

34.4.5 A panelboard intended for use on a 240/120-volt, 3-phase, 4-wire, delta system shall be marked to clearly identify the different bus bars with reference to the voltages between them or, if the panelboard is intended for use only on this system, the main bus bar having the higher voltage to ground may be identified by a marking that is orange or by tagging. The panelboard shall also be marked by means such as a diagram to indicate the necessary voltage rating of the device for each branch-circuit overcurrent-protective-device position. See 14.2.2.

34.4.6 A panelboard provided with less than 75 percent of the total number of individual branch-circuit neutral terminals as permitted by the Exception to 12.2.11 shall be marked to indicate the maximum number of circuits and the need to use multipole units to limit the number of terminals to a specific number.

34.5 Tightening torque

34.5.1 A panelboard shall be marked to indicate the specific tightening torque in pound-inches or pound-feet for each wire connector in the panelboard that is intended for field wiring. If different connectors are used for line, load, neutral, or ground, the specific torques to be applied to each connector shall be clearly indicated. The torque marking may be provided in a written format or pictorially.

Exception No. 1: The value of tightening torque for a field wiring terminal provided on a component such as a circuit breaker, switch, or the like, need not be marked on the panelboard.

Exception No. 2: The value of tightening torque for a wire binding screw or stud and nut type terminal need not be provided.

Exception No. 3: A panelboard using a tool-applied compression wire connector shall be marked with:

a) The tool and die information along with the number of crimps as specified with the wire connector, or

b) Reference to the wire connector manufacturer's tool, die, and crimp information as provided with the panelboard or in installation instructions provided with the panelboard.

34.5.2 If the socket jaws of a meter socket are mounted on terminals or extensions to which terminals are mounted, and these terminals are intended for field-installed wires, the meter center shall be marked to indicate the maximum torque to be applied to these terminals to prevent rotation of the jaws and terminals, as specified in the rotation prevention test for socket jaws and wire connectors in the Standard for Meter Sockets, UL 414.

34.5.3 With reference to 34.5.1, the torque to be marked for each connector shall be determined as specified in 12.1.5. An example of a typical torque marking is shown in Table 34.1. The example is based on a 400 ampere panelboard equipped with the following wire connectors:

a) Main terminals – A connector for paralleling with 5/16-inch (7.9 mm) socket head screws; the wire range of the connector is 4 AWG – 300 kcmil (21.2 – 152 mm^2), copper or aluminum.