UL 508A

STANDARD FOR SAFETY

Industrial Control Panels

UL Standard for Safety for Industrial Control Panels, UL 508A

Third Edition, Dated April 24, 2018

Summary of Topics

This revision of ANSI/UL 508A dated July 28, 2022 reissues the July 21, 2022 revisions to correct paragraph 1.1 by deleting the second paragraph which was erroneously included.

The topics of the July 21, 2022 revisions are noted below for reference:

- ***Limit for Ambient Temperature; 1.1, 52.1***

- ***Deletion of Requirements for Elevator Control Panels; 1.2, 1.25, Section 80***

- ***Include Reference in Scope to UL 67 Regarding Panelboard Construction; 1.12, 1.26, Appendix A***

- ***Clarification of Branch and Feeder Circuit Spacings; 10.2***

- ***Removal of SIS as an Example of Conductor Type Not Readily Available; 17.3, 17.4***

- ***Clarification of the Requirements for an Air Outlet from a Forced Ventilation System Located in the Area Occupied by an Operator; 21.2.2, Figure 21.1***

- ***Alignment with NFPA 79 for GFCI for Receptacles; 66.4.4***

- ***Alignment with NFPA 79 and NEC Regarding the Term Used to Indicate the Full-load Current; 2.26, 28.3.3, 29.6.1, 29.6.2, 31.3.1, Table 31.1, 31.4.1, 31.4.2, 33.2.1, 33.5.1, Table 33.2, 42.2.3.2, 45.2.1, 49.1, 49.2, 50.1, Table 50.1, Table 50.2, Table 52.1, 66.5.5, 67.1.1, 90.4.3, 98.1.2***

- ***Clarification of 31.3.3 for Self-protected Combination Motor Controllers; 31.3.3***

- ***Misprint in Paragraph 32.3.1***

- ***Revision of Requirements for Feeder Taps for Motor Loads; 32.5.1***

- ***Addition of Reactors Covered by UL 508; 36.3.1, 36.3.2***

- ***Manual Motor Starters as Overcurrent Protection for Control Transformers; 40.1.6, 40.2.3, 40.3.7***

- ***UPS with Supercapacitors; 47.3.2***

- ***Clarification of Overload Relay Heater Table Marking Requirement; 58.1***

- ***Alternate Enclosure Types; Table 19.2, 62.4, 62.5, 64.3***

- ***Enclosure Access; 66.1.2, 66.1.3, 66.1.3.1, 66.1.3.2, 67.4.2, 67.4.3***

- ***Deletion of Marking Requirement; 67.1.2***

- ***RFI/EMI Filters Rated Greater Than 400A; Table SB4.1***

- ***Power Monitoring Devices; SB4.2.1***

- ***Table SB4.2 Correction of Class RK1 I^2t Let-through Values at 50kA***

- ***SCCR Marking of Required Overcurrent Protective Device; SB4.2.3, SB5.1.1, SB5.1.3***

- ***Overload Protection Exemption for TP, IP, and EP Motor Circuits; 34.3.1, 50.4, 60.1***

- ***Alternative Testing of Component Bonding Connection; B.3.2***

- ***Interrupting Rating Versus Short-circuit Current Rating; 2.28B, SB3.2.1, Table SB4.1, SB4.2.1, SB4.4.1, SB4.4.2***

- ***Internal Conductor Ampacity Requirements for Power Circuits; 29.6.1***

- ***Schematic Wiring Diagrams; 61.1***

- ***Protection for Variable-Speed Drives; 31.3.2***

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

The revised requirements are substantially in accordance with Proposal(s) on this subject dated July 16, 2021, February 11, 2022 and June 17, 2022.

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1

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Standard for Industrial Control Panels

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This ANSI/UL Standard for Safety consists of the Third Edition including revisions through July 28, 2022.

The most recent designation of ANSI/UL 508A as an American National Standard (ANSI) occurred on July 21, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page. Any other portions of this ANSI/UL standard that were not processed in accordance with ANSI/UL requirements are noted at the beginning of the impacted sections.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

POWER CIRCUITS

CONTROL CIRCUITS

RATING

MARKINGS

PART 2 – SPECIFIC USE INDUSTRIAL CONTROL PANEL TYPES

ENCLOSURES

INDUSTRIAL MACHINERY

CRANE CONTROL

SERVICE EQUIPMENT USE

ELEVATOR CONTROL

FLAME CONTROL

MARINE USE

AIR CONDITIONING AND REFRIGERATION EQUIPMENT

FOUNTAIN CONTROL PANELS

INDUSTRIAL CONTROL PANELS FOR IRRIGATION EQUIPMENT

CONTROL PANELS FOR AQUATIC PLAYGROUNDS

CONTROL PANELS FOR SWIMMING POOLS AND IN-GROUND SPAS

CONTROL PANELS FOR WATER PARK RIDES AND SIMILAR INSTALLATIONS

SUPPLEMENT SA – *Deleted*

SUPPLEMENT SB – SHORT CIRCUIT CURRENT RATINGS FOR INDUSTRIAL CONTROL PANELS

APPENDIX A

APPENDIX B – (informative) – USE OF COMPONENTS NOT UL LISTED OR RECOGNIZED IN INDUSTRIAL CONTROL PANELS

Appendix C – *Reserved for Future Use*

Appendix D – Maximum 100 000 Ampere Short-Circuit Current Rating Without Short-Circuit Test(normative)

PART 1 – GENERAL USE INDUSTRIAL CONTROL PANELS

INTRODUCTION

1 Scope

1.1 These requirements cover industrial control panels intended for general industrial use, operating from a voltage of 1000 volts or less. This equipment is intended for installation in ordinary locations, in accordance with the National Electrical Code, ANSI/NFPA 70 and where the ambient temperature shall be between 5°C (41°F) and 40°C (104°F), unless marked with an ambient temperature rating.

1.2 These requirements also cover industrial control panel enclosures and industrial control panels primarily intended for flame safety supervision of combustible fuel type equipment, crane or hoist control, service equipment use, marine use, air conditioning and refrigeration equipment, equipment for load management applications, fountain control, irrigation equipment control, and for control of industrial machinery including metalworking machine tools, power press controls, and plastic injection molding machinery. Also covered are industrial control panels intended for control of permanently installed electrical equipment for aquatic playgrounds, permanently installed electrical equipment associated with commercial water park rides, wave pools and similar installations, and permanently installed electrical equipment associated with commercial and large residential swimming pools and in-ground spas.

1.3 This equipment consists of assemblies of two or more power circuit components, such as motor controllers, overload relays, fused disconnect switches, and circuit breakers, or control circuit components, such as pushbuttons, pilot lights, selector switches, timers, and control relays, or a combination of power and control circuit components, with associated wiring, and terminals. These components are mounted on, or contained within, an enclosure, or are mounted on a sub-panel.

1.4 An industrial control panel does not include an evaluation of the controlled equipment such as motors, heaters, lighting, and other loads connected to power circuits. Unless specifically noted on the wiring diagram of the industrial control panel, an industrial control panel does not include equipment mounted remotely from the panel and connected via a wiring systems or equipment field installed on or within the industrial control panel.

1.5 An evaluation of the adequacy of the controls and protective devices contained in an industrial control panel for supervision and proper functioning of the controlled loads or equipment is not covered by the requirements in this standard. Such evaluations are covered by the standards applicable to the complete piece of utilization equipment.

1.6 The evaluation of a pre-fabricated building, structure, or platforms supplied with industrial control panels are not covered by the requirements in this standard.

1.7 Fire pump controllers are covered by the Standard for Fire Pump Controllers, UL 218.

1.8 Equipment intended for use in hazardous locations, as defined in the National Electrical Code, ANSI/NFPA 70, are covered by the Standard for Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations, UL 1203.

1.9 Industrial control panels incorporating intrinsic safety barriers and intended for connection to circuits residing in hazardous locations are covered by the Standard for Industrial Control Panels Relating to Hazardous (Classified) Locations, UL 698A.

1.10 Motor control centers, including motor control center sections and units, or equipment intended for field installation into a motor control center are covered by the Standard for Motor Control Centers, UL 845.

1.11 Assemblies of electrical control units or equipment containing electrical control units for fire-protective signaling systems are covered by the Standard for Control Units and Accessories for Fire Alarm Systems, UL 864.

1.12 A freestanding assembly of overcurrent protective devices and busses for control of electric light and power circuits or equipment intended for field installation in dead-front switchboards shall be evaluated to the Standard for Switchboards, UL 891.

1.13 Equipment intended to supply automatic illumination, power, or both, to critical areas and equipment essential to safety of human life is covered by the Standard for Emergency Lighting and Power Equipment, UL 924.

1.14 Control equipment for use with swimming pools and spas is covered by the Standard for Electric Spas, Equipment Assemblies, and Associated Equipment, UL 1563.

1.15 Portable control panels containing switches, overcurrent protection, and cord connected via attachment plugs and receptacles for use at carnivals, circuses, fairs, exhibition halls, motion picture and television studios, theaters, construction sites and similar locations are covered by the Standard for Portable Power-Distribution Equipment, UL 1640.

1.16 Equipment for the control of fuel cells, photovoltaic systems, or utility interactive systems are covered by the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741.

1.17 Enclosures or pedestals containing terminals for connection of power circuit conductors are covered by the Standard for Termination Boxes, UL 1773.

1.18 Emergency alarm equipment or control panels containing emergency alarm equipment are covered by the Standard for General-Purpose Signaling Devices and Systems, UL 2017.

1.19 Equipment for gas or vapor detection or control panels containing gas or vapor detection equipment is covered by the Standard for Gas and Vapor Detectors and Sensors, UL 2075.

1.20 Control panels containing predominately communication equipment, such as telephone equipment and intended for installation in accordance with Chapter 8 of the NEC, is evaluated to the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1.

1.21 Control equipment intended for use in physical access control systems, which provide an attended or unattended means of monitoring or controlling traffic through portals of a protected area for security purposes; or in key management systems, which regulate or control access to the use of a device by electrical, electronic or mechanical means, are covered by the Standard for Access Control System Units, UL 294.

1.22 Electrically operated or mechanically operated control equipment or enclosures intended for theft deterrent or warning purposes, such as detectors, security containers or alarms for merchandise or property, are covered by the Standard for Antitheft Alarms and Devices, UL 1037.

1.23 Equipment primarily intended to energize or de-energize electrical loads to achieve the desired use of electrical power is covered by the Standard for Energy Management Equipment, UL 916. Such equipment is intended to control electrical loads by responding to sensors or transducers monitoring power consumption, by sequencing, by cycling the loads through the use of preprogrammed data logic circuits, or any combination thereof.

1.24 Control panels, control units, and other various electrical circuits employed within a control circuit device intended for support functions, maintain operation and limiting safety control features for use in a Stationary Engine Driven Assembly or similar power production equipment (generator) control applications are covered by the Standard for Controllers for Use in Power Production, UL/ULC 6200.

1.25 Industrial control panels intended for control of elevators, dumbwaiters, escalators, moving walks, inclined lifts, and associated equipment are evaluated to the requirements contained in ANSI/ASME A17.1, American National Standard Safety Code for Elevators and Escalators, and ANSI/ASME A17.5, Elevator and Escalator Electrical Equipment.

1.26 An assembly of overcurrent protective devices and busses for control of electric light and power circuits, provided as part of an industrial control panel, shall be evaluated to the Standard for Panelboards, UL 67.

2 Glossary

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

2.2 APPLIANCE – A piece of utilization equipment that incorporates both controls and loads.

2.3 BRANCH CIRCUIT – The conductors and components following the last overcurrent protective device protecting a load.

2.4 BRANCH CIRCUIT PROTECTION – Overcurrent protection with an ampere rating selected to protect the branch circuit. For a motor branch circuit, the overcurrent protection is required for overcurrents due to short circuits and faults to ground only, see 2.5 and 2.23 and 2.29. For motor overload protection, see 2.39.

2.5 BRANCH CIRCUIT PROTECTIVE DEVICE – A fuse or circuit breaker that has been evaluated to a safety standard for providing overcurrent protection. See 2.23 and 2.30.

2.6 CLASS 1 CIRCUIT – A control circuit on the load side of overcurrent protective device where the voltage does not exceed 600 volts, and where the power available is not limited, or control circuit on the load side of power limiting supply, such as a transformer.

2.7 CLASS 1 WIRING – Conductors of a Class 1 Circuit.

2.8 CLASS 2 CIRCUIT – A control circuit supplied from a source having limited voltage (30 Vrms or less) and current capacity, such as from the secondary of a Class 2 transformer, and rated for use with Class 2 remote-control or signaling circuits.

2.9 CLASS 2 WIRING – Conductors of a Class 2 circuit.

2.10 COMBINATION MOTOR CONTROLLER – One or more devices assembled to provide disconnecting means, branch circuit protection, motor control, and motor overload protection for a single motor circuit.

2.11 CONTROL CIRCUIT – A circuit that carries the electric signals directing the performance of a controller, and which does not carry the main power circuit. A control circuit is, in most cases, limited to 15 amperes.

2.12 CONTROL TRANSFORMER – A transformer whose secondary supplies power to control circuit devices only (excluding loads).

2.13 CONTROLLER – A device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.

2.14 COVER – An unhinged portion of an enclosure that covers an opening.

2.15 DISCONNECT SWITCH – A device that disconnects all ungrounded conductors of a circuit from their electrical supply.

2.16 DOOR – A hinged portion of an enclosure that covers an opening.

2.17 DUTY, INTERMITTENT – Operation for alternate intervals of:

a) Load and no load; or

b) Load and rest; or

c) Load, no load, and rest.

2.18 ENCLOSED INDUSTRIAL CONTROL PANEL – An industrial control panel provided with an enclosure at the factory.

2.19 FEEDER CIRCUIT – The conductors and circuitry on the supply side of the branch circuit overcurrent protective device.

2.20 FIELD INSTALLED EQUIPMENT – Devices to be installed after an industrial control panel is built/labeled.

2.21 FIELD WIRING – Conductors to be installed by others to connect the industrial control panel to source(s) of supply, remote control devices, and loads.

2.22 FIELD WIRING TERMINAL – A terminal provided in an industrial control panel to terminate field wiring.

2.23 FUSE, BRANCH CIRCUIT TYPE – A fuse of Class CC, CF, G, H, J, K, L, R, and T. These fuses are able to provide branch circuit protection.

2.24 FUSE, SEMICONDUCTOR TYPE – A fuse designed for the protection of semiconductor devices. These fuses are able to provide branch circuit protection of motor circuits containing power conversion equipment as in 31.1.3.

2.25 FUSE, SUPPLEMENTARY TYPE – Miscellaneous type and miniature type fuses. These fuses are able to provide supplementary protection only.

2.26 GENERAL-USE RATING – A rating, expressed in volts and amperes, assigned to a device that is intended to control:

a) A load with a continuous or inrush current rating not exceeding the ampere rating of the device;

b) When ac rated, a load that has a power factor of 0.75 to 0.80 (inductive); and

c) When dc rated, a load that is resistive (noninductive).

2.27 HEATER TABLE – Table supplied by the manufacturer of an overload relay having replaceable current elements that provides additional instructions as to the proper installation.

2.28 INDUSTRIAL CONTROL PANEL FOR GENERAL USE – A control panel intended to be installed in accordance with the general use requirements in Chapter 4 of the National Electrical Code, ANSI/NFPA 70.

2.28A INTERLOCK (for safeguarding of industrial machinery) – An arrangement that interconnects guard (s) or device (s) with the control system or all or part of the electrical energy distributed to the machine.

2.28B INTERRUPTING RATING – The highest current at rated voltage that a device is identified to interrupt under standard test conditions.

2.29 INSTANTANEOUS TRIP CIRCUIT BREAKER – A circuit breaker in which no delay is introduced into the tripping action of the circuit breaker. These circuit breakers are able to provide motor branch circuit protection when evaluated as a part of a combination motor controller as in 31.1.1.

2.30 INVERSE-TIME CIRCUIT BREAKER – A circuit breaker in which a delay is introduced into the tripping action of the circuit breaker. The delay decreases as the magnitude of the current increases. These circuit breakers are able to provide branch circuit protection.

2.31 ISOLATED SECONDARY CIRCUIT – A circuit derived from an isolating source (such as a transformer, optical isolator, limiting impedance, or electro-mechanical relay) and having no direct connection back to the primary circuit (other than through the grounding means). A secondary circuit that has a direct connection back to the primary circuit is evaluated as part of the primary circuit.

2.32 LOAD – A device external to the industrial control panel that is connected to the power circuit.

2.33 LOW-VOLTAGE LIMITED ENERGY CIRCUIT – A control circuit involving a peak open-circuit potential of not more than 30 volts ac rms, 42.4 volts peak, or 60 volts dc supplied by a primary battery or by an isolated secondary circuit, and where the current capacity is limited by an overcurrent device, such as a fuse, or by the inherent capacity of the secondary transformer or power supply, or a combination of a secondary winding and an impedance. A circuit derived from a line-voltage circuit by connecting a resistance in series with the supply circuit to limit the voltage and current is not identified as a low-voltage limited energy circuit.

2.34 MANUAL SELF-PROTECTED COMBINATION MOTOR CONTROLLER – A self-protected combination motor controller that is operable only by manual means.

2.35 MOTOR STARTER – An assembly of an overload relay and a contactor.

2.36 ONE-PORT SPD – An SPD having provisions (terminals, leads, plug) for connection to the ac power circuit but no provisions (terminals, leads, receptacles) for supplying current to ac power loads.

2.37 OPEN INDUSTRIAL CONTROL PANEL – An industrial control panel that includes internal wiring, field wiring terminals, and components mounted on a subpanel without a complete enclosure. The enclosure is intended to be supplied/completed at the installation.

2.38 OVERCURRENT PROTECTION – A device designed to open a circuit when the current through it exceeds a predetermined value. The ampere rating of the device is selected for a circuit to terminate a condition where the current exceeds the rating of conductors and equipment due to overloads, short circuits and faults to ground.

2.39 OVERLOAD PROTECTION – Protection required for motor circuits that will operate to prohibit excessive heating due to running overloads and failure to start.

2.40 PILOT DUTY RATING – A rating assigned to a relay or switch that controls the coil of another relay or switch.

2.41 POWER CIRCUIT – Conductors and components of branch and feeder circuits.

2.42 POWER TRANSFORMER – A transformer whose secondary winding supplies power to loads or a combination of loads and control circuit devices operating at the secondary voltage.

2.43 SELF-PROTECTED COMBINATION MOTOR CONTROLLER – A combination motor controller that contains coordinated overload and short circuit protection, and also provides disconnecting means and remotely-operable motor controller. Coordinated protection is able to be inherent or obtained by correct selection of components or accessory parts in accordance with the manufacturer's instructions.

2.44 SHORT CIRCUIT CURRENT RATING – The prospective symmetrical fault current at a nominal voltage to which an apparatus or system is able to be connected without sustaining damage exceeding the defined acceptance criteria.

2.45 SUPPLEMENTARY PROTECTION – A device intended to provide additional protection subsequent to branch circuit protection. They have not been evaluated for providing branch circuit protection.

2.46 SUPPLEMENTARY PROTECTOR – A manually resettable device designed to open the circuit automatically on a predetermined value of time versus current or voltage within an appliance or other electrical equipment. It is also able to be provided with manual means for opening or closing the circuit. These devices are able to provide supplementary protection only.

2.47 SURGE PROTECTIVE DEVICE (SPD) – A device composed of at least one non-linear component and intended for limiting surge voltages on equipment by diverting or limiting surge current and is capable of repeating these functions as specified. SPDs were previously known as Transient Voltage Surge Suppressors or secondary surge arresters.

2.48 SURGE PROTECTIVE DEVICE (SPD) ELECTRICAL RATINGS:

a) NOMINAL DISCHARGE CURRENT (In) – Peak value of the current, selected by the manufacturer, through the SPD having a current waveshape of 8/20 where the SPD remains functional after 15 surges.

b) MAXIMUM CONTINUOUS OPERATING VOLTAGE (MCOV) rating – The maximum continuous operating voltage that may be applied between the terminals of a surge protective device (SPD).

c) NORMAL OPERATING VOLTAGE RATING – The voltage rating assigned to an SPD by the manufacturer. For an SPD, other than a Component-SPD, it is generally equal to the nominal value of the voltage of the circuit (for example, 120, 208, 240, 347, 480, or 600 Vrms).

2.49 SURGE PROTECTIVE DEVICE (SPD) TYPE DESIGNATIONS – SPD Type designations are as follows:

TYPE 1 – Permanently connected SPDs intended for installation between the secondary of the service transformer and the line side of the service equipment overcurrent device, as well as the load side, including watt-hour meter socket enclosures and intended to be installed without an external overcurrent protective device.

TYPE 2 – Permanently connected SPDs intended for installation on the load side of the service equipment overcurrent device – including SPDs located at the branch panel.

TYPE 3 – Point of utilization SPDs, installed at a minimum conductor length of 10 meters (30 feet) from the electrical service panel to the point of utilization, for example cord connected, direct plug-in, receptacle type and SPDs installed at the utilization equipment being protected. The distance of 10 meters (30 feet) is exclusive of conductors provided with or used to attach SPDs.

TYPE 4 COMPONENT ASSEMBLIES – Component assembly consisting of one or more Type 5 components together with a disconnect (integral or external) or a means of complying with the limited current tests.

TYPE 1, 2, 3 COMPONENT ASSEMBLIES – Consists of a Type 4 component assembly with internal or external short circuit protection. These types are tested and rated based on the intended application as either Type 1, 2 or 3 SPD's.

TYPE 5 – Discrete component surge suppressors, such as MOVs that may be mounted on a PWB, connected by its leads or provided within an enclosure with mounting means and wiring terminations.

2.50 TUNGSTEN RATING – A rating assigned to devices intended to control incandescent lamp loads.

2.51 TWO-PORT SPD – An SPD having provisions (terminals, leads, plug) for connection to the ac power circuit and provisions [terminals, leads, receptacles(s)] for supplying current to one or more ac power loads. SPDs provided with a minimum of two adjacent terminals for each circuit conductor may be considered and tested as a two-port SPD.

2.52 WIRE BENDING SPACE – The amount of space required between a field wiring terminal and an enclosure wall directly opposite the terminal, to provide enough space for field wiring conductors.

3 Undated References

3.1 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.

4 Components

4.1 Except as indicated in 4.2, 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 used in the products covered by this standard.

4.2 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.

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

4.4 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.

4.5 A component that complies with the requirements of Appendix B, or Appendix D is able to be used in a product covered by this standard.

5 Units of Measurement

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

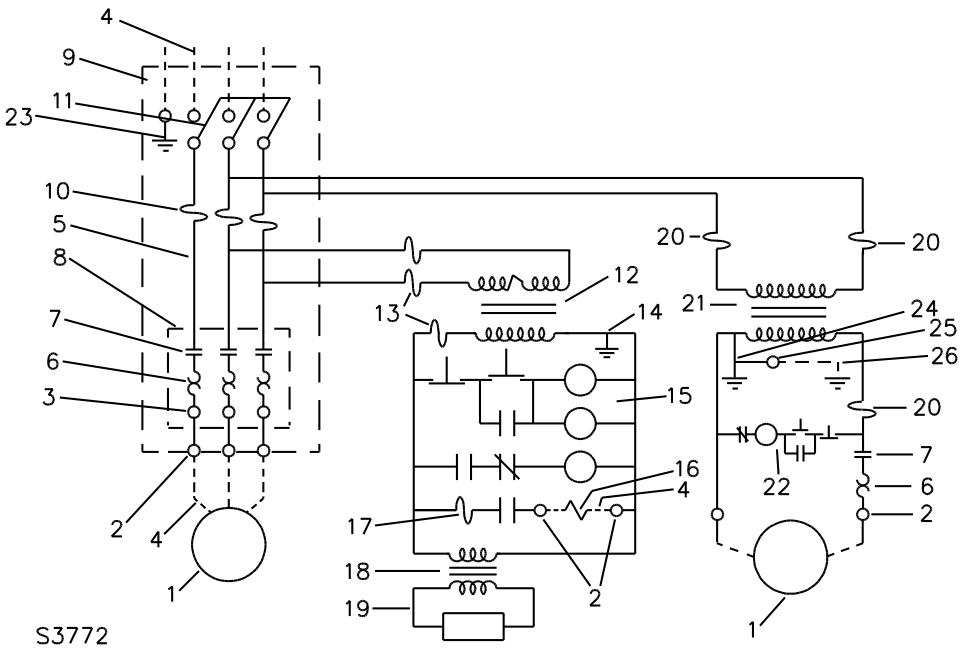
5.2 For calculations involving amperes, calculations resulting in a fraction of less than 0.5 shall be rounded down to the next whole number. Calculations resulting in a fraction of 0.5 or more shall be rounded up to the next whole number.

6 Terminology

6.1 For the purpose of this standard, the terms illustrated in Figure 6.1, Figure 6.2, and Figure 6.3 shall apply.

Figure 6.1

Description of terminology



1 Load (provided in field)

2 Field wiring terminals

3 Alternate field terminals

4 Field wiring

5 Power circuit internal wiring

6 Overload relay & heater elements

7 Contactor/Controller

8 Starter

9 Combination motor controller

10 Branch circuit protection

11 Fused disconnect switch or circuit breaker

12 Control transformer

13 Control transformer fuse/supplementary protection

14 Control transformer ground (for 1000 VA max control transformer)

15 Control circuit devices and wiring/Class 1 circuit/isolated secondary circuit

16 Solenoid or other control device – provided in field

17 Supplementary protection

18 Class 2 transformer

19 Class 2 circuit

20 Power transformer fuse/branch circuit protection

21 Power transformer – for motor load and control circuit

22 Control circuit/Class 1 circuit/common control circuit

23 Equipment ground and equipment ground terminal

24 Bonding conductor/bonding jumper

25 Grounding electrode conductor terminal

26 Grounding electrode conductor (provided in field)

Figure 6.2

Description of control circuits and power circuits

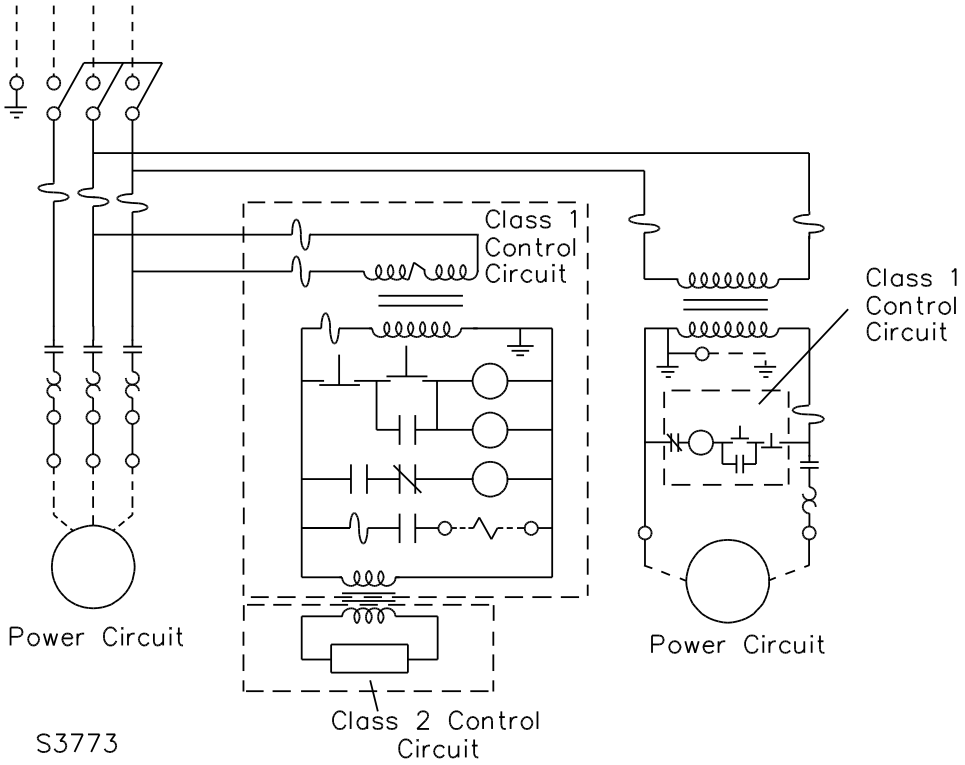
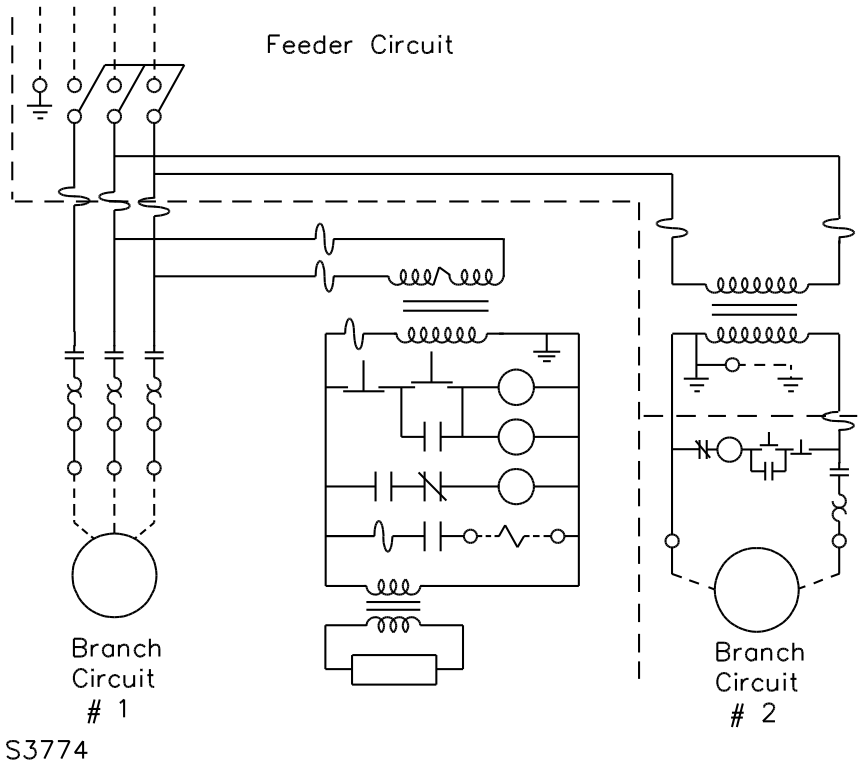


Figure 6.3

Description of branch circuits and feeder circuits



CONSTRUCTION

ALL PANELS

7 General

7.1 An industrial control panel shall:

a) Be constructed so that it complies with the rules for installation and use of such equipment as given in the National Electrical Code, ANSI/NFPA 70; and

b) Employ materials and components that are determined to be usable in the application.

8 Protection Against Corrosion

8.1 Iron and steel parts shall be protected against corrosion by enameling galvanizing, plating, or other equivalent means. This applies to all springs and other parts required for proper mechanical operation.

Exception: This requirement does not apply to:

a) Bearings, thermal elements, sliding surfaces of a hinge, shaft, or similar part, where such protection is impracticable;

b) Small parts of iron or steel, such as washers, screws, bolts, or similar parts, when the parts are not current carrying or relied upon to support or maintain the relative position of uninsulated live parts or components; and

c) Parts made of stainless steel.

9 Support and Securement of Live Parts

9.1 Provisions shall be made for securely mounting components to a supporting surface. A bolt, screw, or other part used to secure a part of a component shall not also be used to secure the component to the supporting surface.

9.2 A live screwhead or nut on the underside of an insulating base shall be prohibited from loosening by means of a star or lock washer and shall be insulated from the mounting surface by an insulating barrier that complies with Section 12, Insulating Barriers, or by through air and over surface spacings specified in Section 10, Spacings.

9.3 An uninsulated live part, including a terminal, or a component with uninsulated live parts shall be secured to its supporting surface by a method other than friction so that it is prohibited from turning or shifting in position. Turning or shifting of a live part is able to be prohibited by the use of:

a) Two or more screws or rivets securing the component or part to the mounting surface;

b) Non-circular shoulders or mortises that abuts an adjacent part or mechanical stop member such as a mounting rail;

c) Non-circular shoulders or mortises that fit through an opening of the same shape cut into the mounting surface for a panel-mounted component or part;

d) A dowel, pin, lug, or offset that mates with a hole, recess or offset in the mounting surface; or

e) A connecting strap or clip fitted into an adjacent part.

9.4 For a live part or a component with uninsulated live parts that are secured by means other than as in 9.3, the part or component shall comply with the following:

a) The mounting screw or nut, when provided, is loosened (one component or part at a time) to allow movement;

b) Is subjected to typical operation of the device, such as switch operation, relamping operation or fuse replacement operation, or rotated to the extent limited by the mounting screw or other means; and

c) As a result of (a) and (b), the spacings between the uninsulated live parts shall not be reduced below the requirements in Section 10, Spacings, and the internal wiring shall not be damaged or strain transmitted to the terminals due to operation or rotation.

10 Spacings

10.1 Other than as required by 9.2, 9.4, 10.8, 12.1, 13.2, Exception to 21.3.4, 28.2.1(a), 28.2.2(a), 29.2.2(a), 29.3.7, 29.3.9, and 36.2.3, spacings at and within a component or device shall be investigated based on the requirements for that component or device.

10.2 Unless otherwise specified in this standard, spacings between uninsulated live parts of adjacent components, between uninsulated live parts of components and grounded or accessible dead-metal parts, between uninsulated live parts of components and the enclosure, and at field wiring terminals, shall be:

a) According to Table 10.1 or Table 10.1A for the following:

1) Field wiring terminals of a feeder tap terminating in a branch circuit protective device in a remote subpanel included on the panel schematic;

2) Field wiring terminals of a branch circuit, control circuit (including the control circuits of power circuit components), or an instrumentation circuit;

3) Factory wired terminals of feeder circuits, feeder tap circuits, branch circuits, control circuits, and instrumentation circuits;

4) Bus bars in a branch circuit constructed and rated according to the requirements in 29.6.2 or Appendix D of this standard.

b) According to Table 10.2 for the following:

1) Field wiring terminals for input or output of feeder circuits, except for voltages of 251 – 1000V, a 12.7mm (1/2 in) spacing through air to grounded parts is permitted; and

2) Bus bars in a feeder circuit constructed and rated according to the requirements in 29.6.2 or Appendix D of this standard.

Exception: Spacings at field wiring terminals for the supply connection to an industrial control panel, where the branch circuit protective device, protecting a branch circuit in the panel, is omitted and provided by the installer in accordance with 60.1, shall be permitted to comply with Table 10.1.

Table 10.1
Minimum required spacings in branch and control circuits

Potential involved in volts rms ac or dc		Minimum spacing, inch (mm)					
		A			B		C
		General industrial control equipment			Devices having limited ratings[a]		All circuits[d]
		51 – 150	151 – 300	301 – 600	51 – 300	301 – 600	0 – 50
Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[f,g]	Through air or oil	1/8[b] (3.2)	1/4 (6.4)	3/8 (9.5)	1/16[b] (1.6)	3/16[b] (4.8)	1/16[b] (1.6)
	Over surface	1/4 (6.4)	3/8 (9.5)	1/2 (12.7)	1/8[b] (3.2)	3/8 (9.5)	1/16[b] (1.6)
Between any uninsulated live part and the walls of a metal enclosure including fittings for conduit or armored cable[c,e]	Shortest distance	1/2 (12.7)	1/2 (12.7)	1/2 (12.7)	1/4 (6.4)	1/2 (12.7)	1/4 (6.4)

NOTES –

1 A slot, groove, or similar gap, 0.013 inch (0.33 mm) wide or less in the contour of insulating material is to be disregarded for the purpose of measuring over surface spacings.

2 An air space of 0.013 inch (0.33 mm) or less between a live part and an insulating surface is to be disregarded for the purpose of measuring over surface spacings.

[a] See 10.5.

[b] The spacing between field wiring terminals of opposite polarity and the spacing between a field wiring terminal and a grounded dead metal part shall be at least 1/4 inch (6.4 mm) when short-circuiting or grounding of such terminals results from projecting strands of wire. For circuits involving no potential greater than 50 volts rms ac or dc, spacings at field wiring terminals are able to be 1/8 inch (3.2 mm) through air and 1/4 inch (6.4 mm) over surface.

Table 10.1 Continued on Next Page

Table 10.1 Continued

Potential involved in volts rms ac or dc		Minimum spacing, inch (mm)					
		A			B		C
		General industrial control equipment			Devices having limited ratings[a]		All circuits[d]
		51 – 150	151 – 300	301 – 600	51 – 300	301 – 600	0 – 50

[c] For the purpose of this requirement, a metal piece or component attached or mounted to the enclosure is evaluated as a part of the enclosure when deformation of the enclosure reduces the spacings between uninsulated live parts or between uninsulated live parts and metal parts.

[d] Spacings do not apply within a low-voltage limited energy circuit or a Class 2 circuit.

[e] Applicable to devices with sheet metal enclosures regardless of wall thickness and cast metal enclosures with a wall thickness of less than 1/8 inch (3.2 mm).

[f] These spacings are also applicable between any uninsulated live parts and the walls of a cast metal enclosure with a wall thickness of minimum 1/8 inch (3.2 mm) for devices with a limited rating complying with 10.5.

[g] These spacings are also applicable between an insulated live part and the wall of a metal enclosure to which the component is mounted. Deformation of the enclosure shall not reduce spacings.

Table 10.1A
Minimum required spacings in branch circuits rated 601 – 1000 V

Voltage, V rms ac or dc	Minimum Spacing, in (mm)			
	Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal		Between any uninsulated live part and the walls of a metal enclosure including fittings for conduit or armored cable	
	Through Air	Over Surface	Through Air	Over Surface
601 – 1000	0.55 (14.0)	0.85 (21.6)	0.80[a] (20.3)[a]	1.00 (25.4)

[a] The through-air spacing shall not be less than 1/2 inch between live parts of a circuit breaker or fusible disconnecting means and grounded metal.

Table 10.2
Spacings in feeder circuit

Voltage involved	Minimum spacing, inch (mm)		
	Between live parts of opposite polarity		Between live parts and grounded metal parts, through air and over surface
	Through air	Over surface	
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 – 1000	1 (25.4)	2 (50.8)	1[a] (25.4)[a]

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

[a] The through-air spacing shall not be less than 1/2 inch between live parts of a circuit breaker or fusible disconnecting means and grounded metal, and between grounded metal and the neutral of an industrial control panel rated 277/480 volt, 3-phase, 4-wire.

10.3 Spacings between isolated circuits at different potentials shall be in accordance with those required for the higher potential circuit.

10.4 A through air spacing of 5/8 inch (15.9 mm) shall be provided between the terminals of an oil-filled capacitor and any uninsulated live part at opposite polarity, of a different (isolated) circuit, or to grounded metal parts. The spacing shall be measured in a direction perpendicular to the end cap.

10.5 The spacings specified in column B of Table 10.1 are applicable to equipment:

a) Rated 1 horsepower (746 W output) or equivalent FLA, or less, 720 volt-amperes break pilot duty or less; or not more than 15 amperes at 51 – 150 volts, 10 amperes at 151 – 300 volts, or 5 amperes at 301 – 600 volts.

b) Of the type described in (a) which controls more than one load when the total load connected to the line at one time does not exceed 2 horsepower (1492 W output), 1440 volt-amperes, or have a current rating greater than 30 amperes at 51 – 150 volts, 20 amperes at 151 – 300 volts, or 10 amperes at 301 – 600 volts.

10.6 The spacings between live parts and metal parts that are intended to be grounded, such as the heads of mounting screws that pass through an insulating panel, shall be evaluated as grounded parts within an enclosure.

10.7 For an enclosed panel without conduit openings or knockouts, spacings not less than the minimum specified in 11.1 shall be provided between uninsulated live parts and a conduit bushing installed at any location intended to be used during installation. A permanent marking on the enclosure, a template, or a full-scale drawing furnished with the equipment is able to be used to identify such locations as in 53.6.

10.8 The spacings for a discrete fuseholder shall be as follows:

a) A fuseholder used for fuses providing required branch circuit protection or feeder circuit protection shall comply with the spacings specified in column A of Table 10.1;

b) A fuseholder used for fuses providing supplementary protection within the branch circuit shall comply with the spacings specified in Table 10.1.

10.9 The spacings for connectors, receptacles, attachment plugs, inlets and cable assemblies described in 28.2.5, 28.6.1, 28.6.6 and 28.7.1 provided in a feeder circuit, branch circuit or control circuit and rated 600V or less shall be a minimum 3/64 inch (1.2 mm) for a device rated 250 V or less, and a minimum 1/8 inch (3.2 mm) for a device rated more than 250 V, between the following:

a) Uninsulated live parts of opposite polarity;

b) An uninsulated live part and a dead-metal part that is likely to be grounded or exposed to contact by persons when the device is installed as intended, including a metal surface on which the device is mounted in the intended manner or a metal face plate used with a flush receptacle.

11 Conduit Bushings

11.1 An enclosure with openings for wiring systems, where provided, shall have a flat surrounding surface for proper seating of a conduit bushing. Each opening shall be so located that installation of a bushing having dimensions as specified in Table 11.1 does not result in spacings between uninsulated live parts and the bushing of less than the minimum requirement. When multiple size knockouts are provided, spacings shall be determined using the largest bushing size accommodated unless the equipment is marked to specify maximum usable size.

Table 11.1
Dimensions of bushings

Trade size of conduit, inches	Bushing dimensions, inches (mm)			
	Overall diameter		Height	
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	(140.7)	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)

12 Insulating Barriers

12.1 When an insulating material is used as a barrier in order to comply with the required over surface or through air spacings, or both, the required spacings in Section 10, Spacings, shall be applied by tracing over the surface of the insulator and through air to the edges of the insulator.

12.2 Insulating material used as specified in 12.1 shall comply with the following requirements:

a) The material shall be:

1) An insulating material described in Table 12.1; or

2) Tubing or sleeving complying with 29.2.3 and rated for the voltage involved;

b) The material is able to be in direct contact with uninsulated live parts; and

c) The material does not serve to physically support or maintain the position of an uninsulated live part.

Exception: A material that does not comply with 12.2 shall be investigated as an insulating barrier in accordance with the requirements in the Standard for Industrial Control Equipment, UL 508.

Table 12.1
Generic materials for use as barriers

Generic material	Minimum thickness	
	inches	(mm)
Aramid Paper	0.010	(0.25)
Electrical Grade Paper	0.028	(0.71)

Table 12.1 Continued on Next Page

Table 12.1 Continued

Generic material	Minimum thickness	
	inches	(mm)
Epoxy	0.028	(0.71)
Mica	0.006	(0.15)
Mylar (PETP)	0.007	(0.18)
RTV	0.028	(0.71)
Silicone Rubber	0.028	(0.71)
Vulcanized Fiber	0.028	(0.71)

13 Insulating Materials

13.1 An insulating material that is used for the direct support of an uninsulated live part, such as a standoff or insulating base for a bus bar, current shunt, or terminal, shall comply with 13.2. A material is in direct support of an uninsulated live part when:

a) It is in direct physical contact with the uninsulated live part; and

b) It serves to physically support or maintain the relative position of the uninsulated live part.

Exception: A material in direct contact only with uninsulated live parts of a low-voltage limited energy circuit or a Class 2 circuit is not required to comply with 13.1.

13.2 Insulating material used as specified in 13.1 shall comply with the following requirements:

a) The material shall be an insulating material described in Table 13.1; and

b) The dimensions of the insulating material shall comply with the required spacings of Section 10, Spacings.

Exception: A material that does not comply with 13.2 shall be investigated as an insulating material in accordance with the requirements in the Standard for Industrial Control Equipment, UL 508.

Table 13.1
Generic materials for direct support of uninsulated live parts

Generic material	Minimum thickness	
	inches	(mm)
Diallyl phthalate	0.028	(0.71)
Epoxy	0.028	(0.71)
Melamine	0.028	(0.71)
Melamine-phenolic	0.028	(0.71)
Phenolic	0.028	(0.71)
Unfilled nylon	0.028	(0.71)
Unfilled polycarbonate	0.028	(0.71)
Urea formaldehyde	0.028	(0.71)
Ceramic, porcelain, and slate	no limit	no limit
Beryllium oxide	no limit	no limit

14 Grounding – General

14.1 An industrial control panel shall have provision for grounding all noncurrent carrying metal parts that are exposed or that are able to be contacted by persons during normal operation or adjustment of the equipment and that are able to become energized due to a breakdown of insulation, loose wiring connection, or electrical disturbance. Grounding (bonding) braids shall be listed according to UL 467 and sized according to 15.1.

14.2 An industrial control panel shall be provided with a field wiring terminal for the connection of an equipment grounding conductor. The terminal shall comply with:

a) The component requirements of a field wiring terminal in accordance with Section 28, Field Wiring; or

b) The requirements in the Standard for Grounding and Bonding Equipment, UL 467.

14.3 The equipment grounding terminal shall have electrical continuity with all metal parts of the enclosure, or subpanel for open type equipment, by means of metal-to-metal contact or by means of an internal bonding conductor that complies with 15.2.

14.4 An industrial control panel that is not intended to be permanently connected to the building power supply shall be provided with a flexible cord that:

a) Complies with 28.5;

b) Contains a grounding conductor that is connected to the grounding prong of the attachment plug; and

c) Has the grounding conductor connected to the enclosure as in 14.1 and 14.2 and terminated with wiring methods described in 29.3.1 – 29.3.9.

15 Grounding – Size of Terminal or Bonding Conductor

15.1 A field wiring terminal for connection of an equipment grounding conductor shall accommodate the conductor size required by Table 15.1 based upon the overcurrent protection provided for field wiring conductors supplying panel that is:

a) The rating of the branch circuit protection marked on the industrial control panel, or wiring diagram, or as calculated from the requirements in Section 31, Branch Circuit Protection, when branch circuit protection is not provided in the panel; or

b) An ampere rating equal to the ampacity of the anticipated field wiring size calculated from Section 28, Field Wiring, when the branch circuit and/or feeder protection is provided in the panel.

Exception: The terminal for the equipment grounding conductor is not required to retain a wire larger than the field wiring conductors supplying the panel.

Table 15.1
Size of equipment grounding conductor terminal

Maximum ampere rating of overcurrent protection for field wiring conductors supplying panel, see 15.1	Size of equipment grounding or bonding conductor, minimum			
	Copper		Aluminum	
	AWG or kcmil	(mm^2)	AWG or kcmil	(mm^2)
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	1/0	(53.5)	3/0	(85.0)
1000	2/0	(67.4)	4/0	(107.2)
1200	3/0	(85.0)	250 kcmil	(127)
1600	4/0	(107.2)	350	(177)
2000	250 kcmil	(127)	400	(203)
2500	350	(177)	600	(304)
3000	400	(203)	600	(304)
4000	500	(253)	800	(405)
5000	700	(355)	1200	(608)
6000	800	(506)	1200	(608)

15.2 The size of an internal bonding conductor shall not be less than the size specified in Table 15.1 or the size of the field wiring conductor supplying the industrial control panel, whichever is smaller.

Exception: Where an internal over-current device is installed to protect control circuit conductors for door mounted equipment, the ampere rating of this over-current device can be used to size the bonding conductor for enclosure doors.

16 Transformer and Power Supply Secondary Grounding

16.1 A secondary circuit that contains field wiring terminals and is supplied from a power transformer, control transformer, or power supply shall have the secondary grounded under any of the following conditions:

a) When the secondary voltage is less than 50 volts; and

1) The supply to the primary is over 150 volts to ground; or

2) The supply to the primary at any voltage is ungrounded;

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

c) When the secondary is a 3-phase, 4-wire, wye connected in which the center point of the wye is used as a circuit conductor; or

d) When the secondary is a 3-phase, 4-wire, delta connected in which the midpoint of one phase winding is used as a circuit conductor.

16.2 For a transformer or power supply that is required to be grounded in accordance with 16.1, the secondary circuit shall be factory connected by a system bonding jumper to the enclosure and the grounding electrode conductor terminal. The size of the system bonding jumper shall be as specified in 75.1.4, based on the secondary rating. A grounding electrode conductor terminal sized to retain the required grounding electrode conductor in accordance with 75.1.4, based on the secondary rating, shall be provided in the enclosure containing the transformer or power supply and marked as specified in 54.10.

Exception No. 1: When the transformer or power supply is rated not more than 1000 volt-amperes and supplies only control circuits, the grounding electrode conductor terminal is able to be omitted and the system bonding jumper shall not be smaller than a 14 AWG (2.1 mm^2) copper conductor. The jumper is not otherwise required to be larger than the phase conductors connected to the transformer secondary.

Exception No. 2: Where multiple separately derived systems are provided within the same industrial control panel enclosure, a single grounding electrode conductor terminal suitable for a 3/0 AWG conductor is able to be supplied in the industrial control panel as the field wiring connection for the common grounding electrode conductor.

16.3 When components marked with a slash voltage rating, such as 120/240V, 480Y/277V, or 600Y/347V, are provided on the secondary side of a power transformer or power supply, the secondary shall be grounded as in 16.1(b), 16.1(c), or at the center point of the wye for a 3 phase, 3 wire secondary circuit, and 16.2.

16.4 For a power circuit or control circuit supplied from a secondary circuit voltage that is not required to be grounded as in 16.1 and is rated 100 V or more, the secondary circuit shall be provided with monitoring devices to provide an audible or visual indication when a ground fault occurs in any ungrounded conductor, such as a panel mounted indicator light or display, or one that interrupts the circuit in the event of a ground fault, such as a ground fault protective device. For a monitoring device that does not interrupt the circuit, a ground fault shall not result in the bypassing of safety shutdown devices.

Exception: A control circuit supplied from a control transformer or power supply with secondary circuit voltage rated 100 V or more that has no provisions for field wiring connections is not required to comply with 16.4.

16.5 An industrial control panel that contains a transformer or power supply with a 3-phase, 4-wire delta secondary, as described in 16.1(d), and provided with field wiring terminals for loads to be connected between a phase and the neutral, shall comply with 29.3.14.

17 Identification of Grounding and Grounded Circuit Conductors and Terminals

17.1 A pressure wire connector intended for connection of a field-installed equipment grounding conductor shall be marked in accordance with 54.5.

17.2 A wire-binding screw terminal intended for connection of a field-installed equipment grounding conductor not larger than 10 AWG (5.3 mm^2) shall be colored green or marked in accordance with 54.5.

17.3 Insulated grounding and bonding conductors shall be identified by the color green with or without one or more yellow stripes and no other conductor shall be so identified.

Exception No. 1: Insulated conductors sized 4 AWG (21.2 mm^2) or larger and having insulation colored other than as in 17.3, and insulated conductors that are not manufactured in this color, shall be identified at each termination point by a green marking, such as tape wrapped around the conductor.

Exception No. 2: Integral leads of components are not required to meet this requirement.

17.4 Insulated grounded circuit conductors connected to the grounded side of a transformer secondary circuit containing field wiring terminals as in Section 16, Transformer and Power Supply Secondary Grounding, shall be identified by the color white or gray or by three continuous white stripes on other than green insulation along its entire length.

Exception No. 1: Insulated conductors sized 4 AWG (21.2 mm^2) or larger and having insulation colored other than as in 17.4, and insulated conductors that are not manufactured in this color, shall be identified at each termination point by a white marking, such as tape wrapped around the conductor.

Exception No. 2: Integral leads of components are not required to meet this requirement.

Exception No. 3: Insulated conductors of a multi-conductor cable colored other than as in 17.4 shall be identified at each termination point by a white marking, such as tape wrapped around the conductor.

17.5 Where more than one grounded circuit conductor is identified within an industrial control panel, each grounded circuit conductor shall be:

a) Identified by:

1) A means that complies with 17.4; or

2) An outer covering of white or gray with a colored stripe other than green running along the length of the insulation; and

b) Identified by means in (a) that is different than the grounded circuit conductors of another system and no other conductors in the industrial control panel shall be so identified.

17.6 A grounded circuit conductor of a flexible cord shall be identified by one of the following means:

a) A white or gray outer finish;

b) A braid with an outer finish colored white or gray; or

c) A white or gray tracer woven into the braid of contrasting color and no other conductor in the cord having a tracer.

ENCLOSED PANELS

18 Enclosures

18.1 An open industrial control panel intended to be installed completely within an enclosure in the field shall comply with the requirements in Sections 7 – 17 and Sections 28 – 61. Portions of an open industrial control panel that serve to complete an ultimate enclosure after installation shall additionally comply with Sections 18 – 27 and 62 – 64.

18.2 Two or more open type industrial control panels having partial enclosures intended to be assembled together in the field in order to form a completely enclosed industrial control panel shall be evaluated as an

enclosed device and comply with Sections 18 – 27. Each open type section shall be marked in accordance with 53.4.

18.3 An enclosed industrial control panel shall comply with Sections 18 – 27 and the enclosure shall comply with:

a) The requirements in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50, and the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E; or

b) The industrial control panel enclosure requirements in Sections 62 – 64.

18.4 A door shall be provided on an enclosure that contains:

a) Power circuit fuses;

b) Circuit breakers located within power circuits which require renewal or resetting from inside the enclosure;

c) Motor overload protective devices which require renewal or resetting from inside the enclosure; or

d) Devices, such as timers or chart recorders, for which servicing or resetting is required.

Exception: A door is not required for an enclosure:

a) To which access is required only in the event of a burnout of a current element or similar component on short circuit;

b) In which the only fuse enclosed is a control-circuit fuse, when the fuse and control-circuit load are within the same enclosure; or

c) In which a means is provided for resetting all overload-protective devices from outside the enclosure.

d) When the removable cover is flanged and is interlocked with the external operating handle of the disconnecting means so that power is removed from all components in the enclosure before the cover can be removed in order to replace fuses or to reset overload protective devices.

18.5 The enclosure shall be constructed so that all doors are able to be opened to a minimum of 90 degrees from the closed position.

19 Enclosure Openings

19.1 All openings provided for conduit connections in the field shall be of standard dimensions. When provided, conduit fittings shall comply with the Standard for Conduit, Tubing, and Cable Fittings, UL 514B. For enclosures other than Type 1, as noted in column 1 of Table 19.1, the conduit openings and fittings shall additionally comply with the requirements specified in column 2 of Table 19.1.

Exception: A conduit fitting that does not comply with Table 19.1 is able to be evaluated to the performance requirements in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, corresponding to the required enclosure type rating.

Table 19.1
Openings for conduit connections in enclosures with environmental rating other than Type 1

Enclosure type (Column 1)	Conduit instructions (Column 2)
2, 3R, 3RX	a) All holes for conduit shall be below all uninsulated live parts; or b) Conduit openings above the lowest uninsulated live parts shall be provided with conduit fittings having an environmental rating that complies with Table 19.2; or c) The enclosure shall be marked as in 53.2 with instructions for the installer to apply fittings complying with (a) or (b).
3, 3S, 3SX, 3X, 4, 4X, 5, 12, 12K	d) All holes for conduit shall be provided with conduit fittings having an environmental rating that complies with Table 19.2 or as specified by the enclosure manufacturer; or e) The enclosure shall be marked as in 53.3 with instructions to apply fittings complying with (d).
6, 6P	f) All holes for conduit shall be provided with conduit fittings having an environmental rating that complies with Table 19.2.
13	g) All holes for conduit shall be provided with conduit fittings having an environmental rating that complies with Table 19.2; or h) No conduit openings shall be provided.

19.2 Openings for wireways shall be provided with a cover plate or supplied with the wireway. When provided, wireway shall comply with the Standard for Wireways, Auxiliary Gutters, and Associated Fittings, UL 870.

19.3 Openings provided in enclosures for mounting components shall be covered with components intended for such mounting. Openings provided for components, including ventilation openings, or observation windows, shall be closed with components that have been evaluated for one of the enclosure Types in the heading of column 2 of Table 19.2. The assembled enclosure is derated to the enclosure type rating indicated in the table corresponding to the type rating of the empty enclosure from column 1 and the type rating of the component from column 2 that results in the lowest rating.

Exception: A component that does not comply with Table 19.2 is able to be evaluated to the performance requirements in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, corresponding to the required enclosure type rating.

Table 19.2
Enclosure rating/derating table

Enclosure Type (Column 1)	Component rating (Column 2)										
	1	**2**	**3R**	**Wet Loc**		**RainTight**	**RainProof**	**Weather Proof**	**3RX**	**3**	**3S**
1	1	1	1	1		1	1	1	1	1	1
2	2 or 1[a]	2	2	2		2	1	1	2	2	2
3R	1	2	3R	3R		3R	3R[b]	3R[b]	3R	3R	3R
3RX	1	2	3R	3R		3R	3R[b]	3R[b]	3RX	3R	3R
3	1	2	3R[e]	3R[e]		3R[e]	3R[b,e]	3R[b,e]	3R	3	3
3S	1	2	3R[e]	3R[e]		3R[e]	3R[b,e]	3R[b,e]	3R	3[c]	3S
3SX	1	2	3R[e]	3R[e]		3R[e]	3R[b,e]	3R[b,e]	3RX	3	3S
3X	1	2	3R[e]	3R[e]		3R[e]	3R[b,e]	3R[b,e]	3RX	3	3S[c]
4	1	2	3R[e]	3R[e]		3R[e]	3R[b,e]	3R[b,e]	3R	3	3
4X	1	2	3R[e]	3R[e]		3R[e]	3R[b,e]	3R[b,e]	3RX	3	3
4X Indoor Use Only	1	2	5[f]	5[f]		5[f]	1	1	5[f]	5[f]	5[f]
5	1	2	5	5		5	1	1	5	5	5
6	1	2	3R[e]	3R[e]		3R[e]	3R[e]	3R[e]	3R[e]	3	3
6P	1	2	3R[e]	3R[e]		3R[e]	3R[e]	3R[e]	3RX[e]	3	3
12	1	2	5[f]	5[f]		5[f]	1	1	5[f]	5[f]	5[f]
12K	1	1	1	5[f]		5[f]	1	1	1	5[f]	5[f]
13	1	1	1	5[f]		5[f]	1	1	1	5[f]	5[f]
	3SX	**3X**	**4**	**4X**	**4X Indoor Use Only**	**5**	**6**	**6P**	**12**	**12K**	**13**
1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2
3R	3R	3R	3R	3R	1	1	3R	3R	1	1	1
3RX	3RX	3RX	3R	3RX	1	1	3R	3RX	1	1	1
3	3	3	3	3	5[f]	5[f]	3	3	1	1	1
3S	3S	3S[c]	3S[c]	3S[c]	5[f]	5[f]	3S[c]	3S[c]	1	1	1
3SX	3SX	3SX[d]	3[d]	3SX[d]	5[d,f]	5[d,f]	3S[c,d]	3SX[c,d]	1	1	1
3X	3X	3X	3	3X	5[f]	5[f]	3	3X	1	1	1

Table 19.2 Continued on Next Page

Table 19.2 Continued

Enclosure Type (Column 1)	Component rating (Column 2)										
4	3	3	4	4	5[f]	5[f]	4	4	1	1	1
4X	3RX	3RX	4	4X	4X Indoor Use Only	5[f]	4	4X	1	1	1
4X Indoor Use Only	5[f]	5[f]	5[f]	4X Indoor Use Only	4X Indoor Use Only	5[f]	5[f]	4X Indoor Use Only	1	1	1
5	5	5	5	5	5	5	5	5	5	5	5
6	3	3	4	4	5[f]	5[f]	6	6	1	1	1
6P	3X	3X	4	4X	4X Indoor Use Only	5[f]	6	6P	1	1	1
12	5[f]	5[f]	5[f]	5[f]	5[f]	5[f]	5[f]	5[f]	12	12	12
12K	1	1	5[f]	5[f]	5[f]	5[f]	5[f]	5[f]	12K	12K	12K
13	1	1	5[f]	5[f]	5[f]	5[f]	5[f]	5[f]	12	12	13

[a] Type 1 Components, ventilation openings, or windows under a drip shield are allowed to be used as Type 2.

[b] Components marked Weatherproof, or Rainproof are allowed to be installed below all other live parts in enclosure.

[c] Components with external operating mechanisms must be Type 3S or 3SX for use on 3S, otherwise rating becomes Type 3.

[d] Components with external operating mechanisms must be Type 3SX for use on 3SX, otherwise rating becomes Type 3.

[e] Must add drain, and locking mechanism or require tool entry.

[f] Must add locking mechanism or require tool entry.

19.4 *Deleted*

Table 19.3
Alternate enclosure ratings
Table deleted

19.5 No covering is required across the bottom of a floor-mounting enclosure when the lower edge of the enclosure is within 6 inches (152 mm) of the floor and when exposed live parts within the device are at least 6 inches above the highest portion of the lower edge of the enclosure.

19.6 Enclosures intended for use with conduit hubs, closure plates and other equipment intended to be field installed shall be marked or provided with instructions that identify the equipment necessary to maintain the environmental integrity of the enclosure. This may be accomplished by identifying the necessary environmental type designation or by identifying the specific manufacturer and models of the field installed equipment.

20 Accessibility of Live Parts

20.1 The minimum distance specified in Table 20.1 shall be provided between an opening in an enclosure and:

a) Uninsulated live parts of components inside of the enclosure where the circuit voltage is greater than 30 V ac or 42.4 V dc; and

b) Moving parts of components inside of the enclosure, such as a fan blade. The distance is measured in a straight line from any point around the edge of the opening to uninsulated live parts or moving parts.

Exception: A construction as described in 19.5 is not required to comply with this requirement.

Table 20.1
Minimum distance from an opening to a part involving risk of electric shock or personal injury

Minor dimension of opening[a]		Minimum distance from opening to uninsulated live part or moving part	
inches	(mm)	inches	(mm)
Less than 1/8	(Less than 3.18)	1/2	(12.7)
1/2	(12.7)	4	(101.6)
1[b]	(25.4)	6-1/2[b]	(165.0)
1-1/2[b]	(38.1)	8-3/8[b]	(212.7)
2[b]	(50.8)	11-5/8[b]	(295.3)
over 2 and not more than 3[b]	(over 50.8 and not more than 76.2)	30[b]	(762.0)

[a] The minor dimension of an opening is the diameter of the largest cylindrical probe having a hemispherical tip that is able to be inserted through the opening. The opening is evaluated without removable filters.

[b] Interpolation shall be used to determine intermediate distances between the table requirement and the previous entry specified in this table. Where the intermediate distance = (distance for previous entry) + (difference between intermediate minor dimension and minor dimension of previous entry) × (difference between required distance and distance of previous entry) / (difference between required minor dimension and minor dimension of previous entry).

Example: To find required distance for 3/4 inch opening (minor dimension) between 1/2 inch (12.7 mm) and 1 inch (25.4 mm) table values

Required distance = 4 inches + (3/4 − 1/2) × (6-1/2 − 4) / (1 − 1/2) = 5.25 inches

21 Ventilation Openings

21.1 General

21.1.1 A ventilation opening provided in an enclosure shall comply with the construction requirements in 21.3.1 – 21.3.5, and shall be evaluated as a Type 1 component with respect to 19.3. A ventilation opening that is an integral part of an enclosure or an accessory kit for an enclosure that complies with 18.3 complies with 21.3.1 – 21.3.5.

Exception: A ventilation opening for use in an enclosure with a Type 2 or 3R enclosure shall be evaluated to the performance requirements in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, for the environmental rating.

21.1.2 The location of a ventilation opening with respect to components inside of the enclosure shall comply with 21.2.1 – 21.2.4.

21.2 Location of ventilation opening

21.2.1 A ventilation opening in the top of the enclosure shall be covered by a hood or protective shield spaced above the opening when there are uninsulated live components below the opening.

Exception: A hood or protective shield is not required over ventilation openings to a compartment of an industrial control panel where no uninsulated live parts are present.

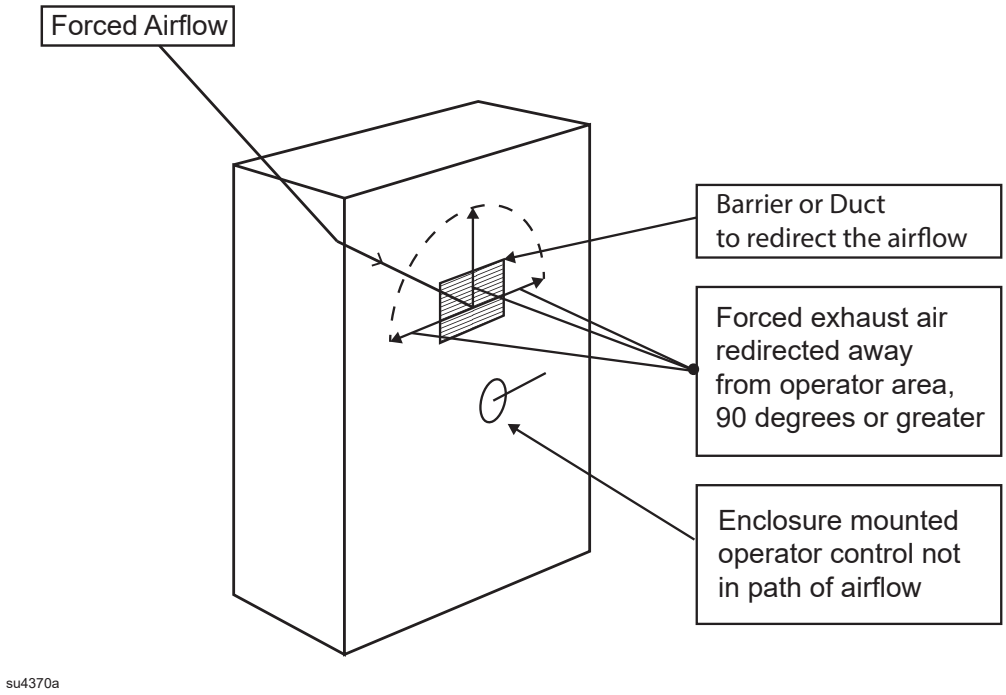
21.2.2 A ventilation opening that serves as an air outlet of exhaust air from a forced ventilation system shall not direct air at the area occupied by the equipment operator. The area occupied by the operator in front of the industrial control panel shall be 30 inches wide (horizontal) centered on any operator control, display, or disconnect handle over the entire (vertical) height of the enclosure for wall mounted equipment or up to 6-1/2 feet above the floor for floor mounted equipment.

Exception No. 1: When an air outlet from a forced ventilation system is directed at the area occupied by an operator, a barrier or duct shall be provided to redirect the airflow by 90 degrees or greater so that the exhaust air is directed away from the operator area. See Figure 21.1 for permitted air directions. If a barrier is used, it shall be provided in addition to the barrier that may be required per 22.1. Redirecting airflow upward is only permitted if the construction ensures that water and/or solid objects cannot enter the enclosure.

Exception No. 2: Air filters which baffle the airflow are permitted, provided they meet the requirements in 22.4.

Figure 21.1

Enclosure with forced exhaust air redirected away from the operator area



21.2.3 An industrial control panel with a ventilation opening that contains power-circuit switches, circuit breakers, fuses, contactors, or overload relays shall additionally comply with Section 22, Barriers Used with Ventilation Openings.

21.2.4 An industrial control panel with a ventilation opening shall comply with Section 20, Accessibility of Live Parts.

21.3 Construction

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

21.3.2 The area of an opening covered by a louver, a perforated or an expanded-metal mesh panel that is thinner than the enclosure, shall not exceed 200 square inches (0.129 m^2).

21.3.3 The diameter of the wires of a screen covering a ventilation opening shall be at least 0.051 inch (1.30 mm) when the screen openings are 0.500 square inch (322 mm^2) or less in area, and shall be at least 0.081 inch (2.06 mm) for larger screen openings.

21.3.4 Perforated sheet steel employed for an expanded-metal mesh panel covering a ventilation opening shall be at least 0.042 inch (1.07 mm) thick for mesh openings or perforations 0.500 square inch (322 mm^2) or less in area, and shall be at least 0.080 inch (2.03 mm) thick for larger openings.

Exception: Where the indentation of a guard or enclosure does not alter the clearance between uninsulated, movable, live parts and grounded metal so as to adversely affect the performance or reduce

the spacings below the minimum value specified in Table 10.1, expanded-metal mesh of steel not less than 0.20 inch (5 mm) thick is able to be employed when:

a) The exposed mesh on any one side or surface of the device has an area not more than 72 square inches (464 cm^2) and has no dimension greater than 12 inches (305 mm); or

b) The width of the opening protected is not greater than 3.50 inches (88.9 mm).

21.3.5 A ventilation opening provided in the top of an enclosure shall comply with 21.2.1.

22 Barriers Used with Ventilation Openings

22.1 Unless a ventilation opening is located at least 12 inches (305 mm) from an arcing part, a barrier of metal or of a material such as those specified in 22.4 shall be interposed between the ventilation opening and a possible source of arcing, such as a power-circuit disconnect switch, the vent openings of a circuit breaker, a contactor, or an overload relay.

22.2 A barrier shall be of such dimension and so located that any straight line drawn from any arcing part past the edge of the barriers intersects a point in the ventilation opening plane that is at least 0.25 inch (6.35 mm) outside the edge of the ventilation opening. A barrier shall be secured in place by mechanical means, such as mechanical fasteners. See Figure 22.1.

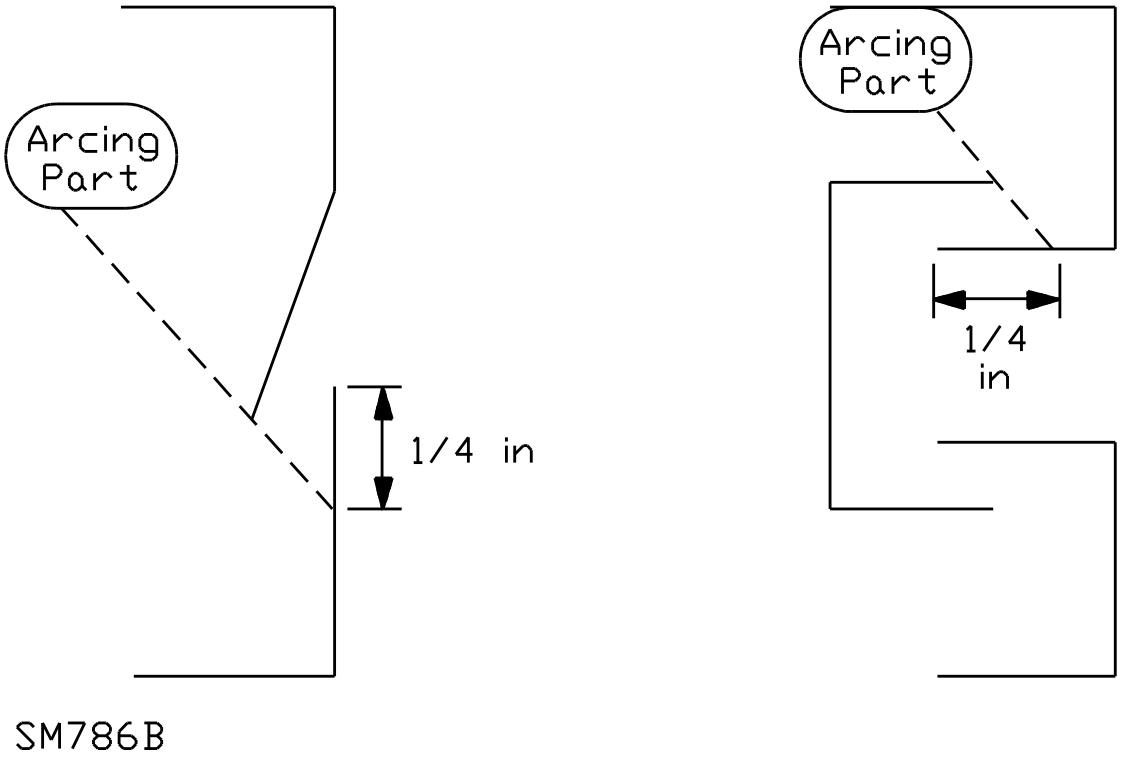
22.3 A sheet-metal barrier shall be at least 0.053 inch (1.35 mm) thick when steel or 0.075 inch (1.9 mm) thick when aluminum.

22.4 A barrier of polycarbonate shall be at least 0.125 inch (3.2 mm) thick. A nonmetallic barrier other than polycarbonate shall be at least 0.25 inch (6.35 mm) thick.

22.5 A barrier constructed other than as in 22.3 and 22.4 shall be evaluated to the requirements of the Standard for Industrial Control Equipment, UL 508.

Figure 22.1

Barriers for ventilation openings



23 Observation Windows

23.1 An observation window constructed as described in 23.2 – 23.6 shall be evaluated as a Type 1 component with respect to 19.3. An observation window that is an integral part of or an accessory for an enclosure that complies with 18.3 complies with 23.2 – 23.6.

Exception: An observation window for use in an enclosure with a Type designation other than Type 1 shall be evaluated to the performance requirements in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, for the environmental rating.

23.2 Glass covering an observation opening and forming a part of the enclosure shall be:

a) Not more than 4 inches (102 mm) in any dimension (including the diagonal) and shall not be less than 0.055 inch (1.40 mm) thick; or

b) Not more than 12 inches (305 mm) in any dimension (including the diagonal) and shall not be less than 0.115 inch (2.92 mm) thick.

23.3 A polymeric material covering an observation opening and forming a part of the enclosure shall be a polycarbonate material not less than 1/8 inch (3.2 mm) thick, having a flammability rating of 5VA at the use thickness, and having an area not more than 380 square inches (2452 cm^2).

23.4 An observation window constructed other than as described in 23.2 or 23.3 shall comply with the requirements for Observation Windows or Polymeric Parts of Enclosures in the Standard for Industrial Control Equipment, UL 508.

23.5 An observation window shall be secured to the enclosure by mechanical means, such as mechanical fasteners.

23.6 When an adhesive is used to secure an observation window to the enclosure, the assembly shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

24 Bonding

24.1 An enclosure made of insulating material, either wholly or in part, shall have a bonding means to provide continuity of grounding between all conduit openings. The bonding means shall be:

a) Completely assembled on the product; or

b) Provided as separate parts or available as an accessory for field installation and marked in accordance with 53.7 and 55.5.

Exception: A bonding means is not required for the enclosure of a pushbutton station or a selector switch that is intended to be connected to a single conduit and is marked in accordance with 53.5.

24.2 A separate bonding conductor shall comply with the requirements in Section 14, Grounding – General.

25 Wire Bending Space

25.1 The distance between the end of a pressure wire connector or terminal block for connection of a field installed wire, and the wall of the enclosure toward which the wire is to be directed, shall not be less than that indicated in Table 25.1.

Table 25.1
Wire bending space at field wiring terminals

Size of wire		Minimum bending space, terminal to wall, inches (mm)							
		Wires per terminal[a]							
AWG or MCM	(mm^2)	1		2		3		4 or more	
14 – 10	(2.1 – 5.3)	Not specified		a		a		a	
8 – 6	(8.4 – 13.3)	1-1/2	(38)	a		a		a	
4 – 3	(21.2 – 26.7)	2	(51)	a		a		a	
2	(33.6)	2-1/2	(64)	a		a		a	
1	(42.4)	3	(76)	a		a		a	
1/0	(53.5)	5	(127)	5	(127)	7	(178)	–	
2/0	(67.4)	6	(152)	6	(152)	7-1/2	(191)	–	
3/0	(85.0)	7	(178)	7	(178)	8	(203)	–	
4/0	(107.2)	7	(178)	7	(178)	8-1/2	(216)	–	
250	(127)	8	(203)	8	(203)	9	(229)	10	(254)
300	(152)	10	(254)	10	(254)	11	(279)	12	(305)
350	(177)	12	(305)	12	(305)	13	(330)	14	(356)
400	(203)	12	(305)	12	(305)	14	(356)	15	(381)
500	(253)	12	(305)	12	(305)	15	(381)	16	(406)

Table 25.1 Continued on Next Page

Table 25.1 Continued

Size of wire		Minimum bending space, terminal to wall, inches (mm)							
		Wires per terminal[a]							
AWG or MCM	(mm^2)	1		2		3		4 or more	
600	(304)	14	(356)	16	(406)	18	(457)	19	(483)
700	(355)	14	(356)	16	(406)	20	(508)	22	(559)
750 – 800	(380 – 405)	18	(457)	19	(483)	22	(559)	24	(610)
900	(456)	18	(457)	19	(483)	24	(610)	24	(610)
1000	(506)	20	(508)	–		–		–	
1250	(633)	22	(559)	–		–		–	
1500 – 2000	(760 – 1013)	24	(610)	–		–		–	

NOTE: "–" indicates no value established

[a] Conductors smaller than 1/0 AWG shall not be connected in parallel.

25.2 Upon leaving the lug or connector, the distance specified in 25.1 shall be measured in a straight line from the center of the opening in the connector, in the direction in which the wire leaves the terminal, perpendicular to the enclosure wall.

25.3 When a wire is restricted by barriers or other means from being bent where it leaves the connector, the distance required by Table 25.1 shall be measured from the end of the barrier.

25.4 The required bending space is dependent on the size of the anticipated field wire to be connected to the connector or terminal in accordance with Section 28, Field Wiring.

26 Enclosure Environmental Control Devices

26.1 General

26.1.1 A fan, air conditioner, or heater mounted to the industrial control panel for the purpose of conditioning air within the control panel shall comply with the requirements for general construction and power circuits in addition to the requirements in 26.2 – 26.6.

Exception: A fan that complies with 26.2.1, an air conditioner that complies with 26.3.1, and a heater that complies with 26.4.1 are able to be supplied from the isolated secondary of a control transformer or power supply and comply with the requirements for control circuits.

26.2 Enclosure fans

26.2.1 A fan or blower shall have provisions for permanent installation within electrical equipment and shall comply with the Standard for Electric Fans, UL 507.

26.2.2 A fan motor shall comply with the requirements in the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1.

26.2.3 A fan incorporated into an accessory intended for use with industrial control panels shall comply with the requirements for accessories in the Standard for Industrial Control Equipment, UL 508.

26.2.4 Each fan or motor shall incorporate one of the following forms of locked rotor protection:

a) Thermal protection complying with the Standard for Thermally Protected Motors, UL 1004-3, where the motor is marked "thermally protected" or "T.P."; or

b) Impedance protection complying with the Standard for Impedance Protected Motors, UL 1004-2, where the motor is marked "Impedance Protected" or "Z.P."; or

c) Motor overload protection in accordance with Section 34, Overload Protection of Motor Loads.

26.3 Enclosure air conditioner

26.3.1 An air conditioner shall be identified as a special-purpose type, intended for mounting to an electrical enclosure and complying with the Standard for Room Air Conditioners, UL 484 or the Standard for Heating and Cooling Equipment, UL 1995.

26.3.2 For an air conditioner as described in 26.3.1 that is marked with an “interface” environmental rating, such as Type 1 enclosure with Type 12 interface, the “interface” type rating marked on the component is used as the basis for compliance with Table 19.1.

26.4 Enclosure heater

26.4.1 An electric heater including a heater where the metal sheath is mounted to grounded metal and a heater enclosed in a polymeric material, such as silicone rubber, shall comply with the Standard for Electric Heating Appliances, UL 499.

26.4.2 A heater incorporated into an accessory intended for use with industrial control panels shall comply with the requirements for accessories in the Standard for Industrial Control Equipment, UL 508.

26.4.3 A heater shall be mounted 2 inches (50.8 mm) or more from polymeric insulating materials of components and wiring, other than the internal wiring connected to the heater.

26.4.4 Internal wiring connecting to a sheath-type heater shall have a temperature rating of 200°C (392°F) or more.

Exception: Internal wiring rated less than 200°C (392°F) is able to be used with a heater provided with a disc thermostat mounted to the sheath and set for a temperature lower than the temperature rating of the internal wiring.

26.5 Air filters

26.5.1 Air filters shall be provided over ventilation openings in enclosures containing power conversion equipment, programmable controllers, power supplies, and information technology equipment.

Exception: An air filter is not required over ventilation openings when fans are not provided in the enclosure or an integral part of any component in the enclosure.

26.6 Enclosure thermal insulation

26.6.1 Thermal insulation provided on the inside of the cabinet walls shall:

a) Be supported by mechanical means, not adhesives only, such that the insulation does not contact uninsulated live parts within the enclosure; and

b) Be 1/2 inch (12.7 mm) or more from uninsulated live parts and 12 inches (305 mm) or more from arcing parts.

26.6.2 An adhesive used to secure thermal insulation to the inside of the cabinet walls shall be evaluated for the intended use.

27 Enclosure Maintenance Lighting

27.1 General

27.1.1 The requirements in this section apply to maintenance lighting provided on the inside of an industrial control panel.

27.2 Component requirements

27.2.1 A lampholder for an incandescent lamp shall comply with the Standard for Lampholders, UL 496.

27.2.2 A fluorescent lighting fixture shall comply with the requirements in the Standard for Luminaires, UL 1598.

27.2.3 An incandescent lampholder or flourescent lighting fixture incorporated into an accessory intended for use with industrial control panels shall comply with the requirements for accessories in the Standard for Industrial Control Equipment, UL 508.

27.3 Circuit requirements

27.3.1 The lighting circuit voltage for an incandescent lamp shall not exceed 150 volts between conductors. The screwshell of the lampholder shall be connected to the grounded circuit conductor.

27.3.2 The maintenance lighting circuit shall comply with the requirements for a power circuit in Sections 28 – 36.

Exception No. 1: A 120-volt lighting circuit located on the inside of the industrial control panel is able to be supplied from the isolated secondary of a control transformer and comply with the requirements for control circuits in Section 37 – 44.

Exception No. 2: LED luminaires are able to comply with the requirements for control circuits in Section 37 – 44.

27.3.3 A lighting fixture provided with a receptacle for an attachment plug shall:

a) Comply with 31.5 when provided in a power circuit; or

b) Comply with 40.3.5 when located in a control circuit.

POWER CIRCUITS

28 Field Wiring

28.1 General

28.1.1 A terminal, such as a pressure wire connector or wire-binding screw, shall be provided for connection of each conductor intended to be installed in the industrial control panel in the field.

Exception: Bus bars complying with 29.2.2 with provisions for field installation of pressure wire connectors, cable lugs or similar termination devices that comply with 28.2.2 for connection of field wiring, are not required to be supplied with terminals when the control panel is marked in accordance with 60.4.

28.1.2 A field wiring terminal shall be located so that:

a) It is accessible for examination; and

b) Connection is able to be tightened or wires removed without loosening any screws that secure internal (factory) wiring, bus bars, or components (such as circuit breakers, switches, and fuseholders).

28.1.3 A field wiring terminal shall be for use with copper or aluminum conductors or both and marked in accordance with 54.11.

28.1.4 A plug-in circuit breaker installed in a panelboard, that is intended to be back-fed by means of a field wired supply conductor connected to its load terminal, shall be secured in place by an additional fastener that requires other than a pull to release the device from the mounting means on the panelboard. This securing means shall comply with UL 67 as an accessory to the panelboard.

28.2 Component requirements

28.2.1 A pressure wire connector of a terminal block shall comply with the requirements contained in the Standard for Terminal Blocks, UL 1059. In addition a terminal block shall:

a) Have electrical spacings that comply with Section 10, Spacings; and

b) Have been investigated for connection of field wiring.

28.2.2 A pressure wire connector of a component other than a terminal block shall:

a) Comply with the requirements 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; and

b) Have electrical spacings at field wiring terminals that comply with Section 10, Spacings.

28.2.3 A wire binding screw, other than one on a terminal block or a component, shall comply with the following:

a) A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.030 inch (0.76 mm) thick for a 14 AWG (2.1 mm^2) or smaller wire, and not less than 0.050 inch (1.27 mm) thick for a wire larger than 14 AWG (2.1 mm^2). There shall be at least two full threads in the plate; and

Exception: Two full threads are not required if fewer threads result in a secure connection in which the threads will not strip upon application of a 20 pound-inch (2.3 N·m) tightening torque.

b) A terminal plate formed from stock having the required thickness specified in (a) is able to have the metal extruded at the tapped hole for the binding screw to provide two full threads; and

c) A wire-binding screw shall thread into metal; and

d) A wire-binding screw shall be No. 8 (4.2 mm diameter) or larger screw for securing a 10 AWG (5.3 mm^2) or smaller conductor, or a No. 6 (3.5 mm diameter) screw for securing a 14 AWG (2.1 mm^2) conductor only.

28.2.4 A power distribution block shall comply with the requirements contained in:

a) The Outline of Investigation for Power Distribution Blocks, UL 1953, for use in branch or feeder circuits; or

b) 28.2.1.

28.2.5 Single and multipole connectors, intended for factory assembly to copper or copper alloy conductors or printed wiring boards shall:

a) Comply with the requirements in the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977; and

b) Comply with the spacing requirements of 10.9.

28.3 Sizing

28.3.1 The required size of the field wiring terminal shall not be less than 14 AWG (2.1 mm^2) and shall be determined by:

a) Calculating the required ampacity per 28.3.2 – 28.3.6; and

b) Determining the minimum field wiring conductor size from Table 28.1 having a corresponding ampacity that is equal to or greater than the required ampacity from (a).

Table 28.1
Ampacities of insulated conductors

Wire size		60°C (140°F)		75°C (167°F)	
AWG	(mm^2)	Copper	Aluminum	Copper	Aluminum
14	(2.1)	15	–	15	–
12	(3.3)	20	15	20	15
10	(5.3)	30	25	30	25
8	(8.4)	40	30	50	40
6	(13.3)	55	40	65	50
4	(21.2)	70	55	85	65
3	(26.7)	85	65	100	75
2	(33.6)	95	75	115	90
1	(42.4)	110	85	130	100
1/0	(53.5)	–	–	150	120
2/0	(67.4)	–	–	175	135
3/0	(85.0)	–	–	200	155
4/0	(107.2)	–	–	230	180
250 kcmil	(127)	–	–	255	205
300	(152)	–	–	285	230
350	(177)	–	–	310	250
400	(203)	–	–	335	270
500	(253)	–	–	380	310

Table 28.1 Continued on Next Page

Table 28.1 Continued

Wire size		60°C (140°F)		75°C (167°F)	
AWG	(mm^2)	Copper	Aluminum	Copper	Aluminum
600	(304)	–	–	420	340
700	(355)	–	–	460	375
750	(380)	–	–	475	385
800	(405)	–	–	490	395
900	(456)	–	–	520	425
1000	(506)	–	–	545	445
1250	(633)	–	–	590	485
1500	(760)	–	–	625	520
1750	(887)	–	–	650	545
2000	(1013)	–	–	665	560

NOTES –

1 For multiple-conductors of the same size (1/0 AWG or larger) at a terminal, the ampacity is equal to the value in this table for that conductor multiplied by the number of conductors that the terminal is able to accommodate.

2 These values of ampacity apply only when not more than three conductors are intended to be field-installed in the conduit. When four or more conductors, other than a neutral that carries the unbalanced current, are intended to be installed in a conduit (occurring because of the number of conduit hubs provided in outdoor equipment, the number of wires necessary in certain polyphase systems, or other reasons), the ampacity of each of the conductors is: 80 percent of these values if 4 – 6 conductors are involved, 70 percent of these values if 7 – 24 conductors, 60 percent of these values if 25 – 42 conductors, and 50 percent of these values if 43 or more conductors.

28.3.2 For motors, fixed electrical space heating loads and lighting loads, the anticipated field wiring shall have an ampacity of 125 percent of the full-load current rating of the load involved.

Exception No. 1: A terminal of a component with a marked horsepower rating, such as a motor starter, is determined to be capable of retaining field wiring having an ampacity of 125 percent of the full-load current corresponding to the horsepower rating from Table 50.1.

Exception No. 2: A terminal for connection of a heater load provided with individual branch circuit protection that is greater than 125 percent of the heater current, shall be capable of retaining field wiring having an ampacity not less than the rating of the branch circuit protective device.

28.3.3 For terminals intended to carry current from a combination of one or more motors, or one motor and one or more other loads, the field wiring shall have an ampacity of 125 percent of the largest motor full-load current rating of the group plus 100 percent of all remaining loads.

28.3.4 For terminals intended to carry current from a dc motor load operating from a rectified single phase power supply (not a variable-speed drive or speed control), the field wiring shall have an ampacity of:

a) 190 percent of the full-load motor current where a rectifier bridge of the single phase half-wave type is used; or

b) 150 percent of the full-load motor current where a rectifier bridge of the single phase full-wave type is used.

28.3.5 For terminals that will carry the input current to power conversion equipment or a solid-state motor speed controller in which the input current is different from the motor full-load current, the field wiring shall have an ampacity of 125 percent of the input current rating of the device.

28.3.6 For terminals intended to carry the load current from a wye-delta starter, the ampacity of the field wiring shall be:

a) In accordance with 28.3.2; and

b) Based on a load current equal to 58 percent of the motor full-load current.

28.3.7 Field wiring terminals intended to carry the current of a part winding motor, where half of the motor winding is energized during starting and the remaining half of the motor winding is subsequently energized for the running condition, the ampacity of the field wiring shall be:

a) In accordance with 28.3.2; and

b) Based upon the FLA from the respective part or half winding being energized instead of the full motor FLA (both halves).

28.3.8 For industrial process heating employing electric resistance or electrode heating technology including boilers, electrode boilers, duct heaters, strip heaters, immersion heaters, process air heaters, or other fixed electric equipment used for industrial process heating the field wiring shall have an ampacity of 100 percent of the full-load current rating of the load involved.

28.3.9 For dielectric heating, induction heating, induction melting, and induction welding equipment and accessories for industrial and scientific applications the field wiring shall have an ampacity of 100 percent of the full-load current rating of the load involved.

28.4 Separation of circuits

28.4.1 An industrial control panel shall be constructed so that a field-installed conductor of any circuit is segregated as specified in 28.4.2 or separated by a barrier from:

a) A field-installed conductor connected to any other circuit unless:

1) Both circuits are Class 2 or both circuits are other than Class 2; and

2) The conductors of both circuits are intended to be insulated for the maximum voltage of either circuit.

b) An uninsulated live part of any other circuit.

c) A factory-installed conductor connected to any other circuit, unless the conductors of both circuits will be insulated for the maximum voltage of either circuit.

Exception: The field-installed conductors are not required to be segregated or separated by a barrier when specific installation instructions are included that explain the proper procedure to be followed to install the equipment to achieve required separation as specified in 54.8.

28.4.2 Field-installed conductors are able to be segregated from each other and from uninsulated live parts or factory-installed conductors of the industrial control panel connected to different circuits by arranging the location of openings in an enclosure for the various field-installed conductors with respect to the terminals or other uninsulated live parts and factory- or field-installed conductors so that a minimum permanent 1/4 inch (6.4 mm) separation is provided. Field installed conductors of a Class 2 circuit shall be segregated from field and factory installed conductors and uninsulated live parts of other circuits operating at over 150 volts to ground so that a minimum permanent 2 inch (50.8 mm) separation is maintained.

28.5 Cord-connected equipment

28.5.1 An industrial control panel intended to be portable (by hand) or as free-standing stationary equipment (movable by hand truck or fork lift) and having no provisions for conduit or permanent connection to a building, is able to be cord-connected to the power supply, load or both.

28.5.2 At the point at which the cord passes through the enclosure wall, a strain relief bushing shall be provided to prohibit cord abrasion. The strain relief bushing shall comply with the Standard for Conduit, Tubing, and Cable Fittings, UL 514B.

Exception: A strain relief means that complies with the requirements in the Standard for Industrial Control Equipment, UL 508.

28.5.3 The cord shall comply with the Standard for Flexible Cords and Cables, UL 62, and be one of the following types: S, SE, SEO, SEOO, SJ, SJE, SJEO, SJEOO, SJO, SJOO, SJT, SJTO, SJTOO, SO, SOO, ST, STO, STOO, or portable power cable type G, PPE, or W power cable.

28.5.4 A cord, used on equipment having a:

a) Type 3, 3R, 3S, 4, 4X, 6, or 6P enclosure shall be marked:

1) "Outdoor," or

2) "W;"

b) Type 6 or 6P enclosure shall be marked "water resistant;" and

c) Type 12, 12K, or 13 enclosure shall be oil resistant and designated by the letter "O" in the cord type (such as SO, SJO, or STO).

28.5.5 The required conductor size of a cord shall be determined by:

a) Calculating the required ampacity per 28.3.2 – 28.3.6; and

b) Determining minimum conductor size from Table 28.2 or Table 28.3 having a corresponding ampacity that is not less than (a).

28.5.6 Cable assemblies and flexible cords provided for interconnection between sections of equipment or between units of a system shall comply with 28.5.1 – 28.5.5, 28.5.7, and 28.5.8. A multi-pin connector attached to the cable assembly shall comply with the requirements for receptacles in 28.6.

Table 28.2
Ampacity of flexible cord

Conductor size, AWG	Amperes	
	Two conductors	Three conductors[a]
18	10	7
16	13	10
14	18	15
12	25	20
10	30	25
8	40	35

Table 28.2 Continued on Next Page

Table 28.2 Continued

Conductor size, AWG	Amperes	
	Two conductors	Three conductors[a]
6	55	45
4	70	60
2	95	80

[a] Where more than three current-carrying conductors are provided, the ampacity of each of the conductors shall be: 80 percent of these values for 4 – 6 conductors; 70 percent of these values for 7 – 9 conductors; 50 percent of these values for 10 – 20 conductors; 45 percent of these values for 21 – 30 conductors; 40 percent of these values for 31 – 40 conductors; and 35 percent of these values for 41 or more conductors.

Table 28.3
Ampacity of portable power cable

Conductor size, AWG	Number of current-carrying conductors		
	1	2	3[a]
8	60	55	48
6	80	72	63
4	105	96	84
3	120	113	99
2	140	128	112
1	165	150	131
1/0	195	173	151
2/0	225	199	174
3/0	260	230	201
4/0	300	265	232
250	340	296	259
300	375	330	289
350	420	363	318
400	455	392	343
500	515	448	392

[a] Where more than three current-carrying conductors are provided, the ampacity of each of the conductors shall be: 80 percent of these values for 4 – 6 conductors; 70 percent of these values for 7 – 9 conductors; 50 percent of these values for 10 – 20 conductors; 45 percent of these values for 21 – 30 conductors; 40 percent of these values for 31 – 40 conductors; and 35 percent of these values for 41 or more conductors.

28.5.7 When either or each end of an external interconnecting cable terminates in a connector external to the enclosure on which there are one or more exposed contacts, risk of electric shock shall not exist between earth ground and any contact that is exposed on either the connector or its receptacle mounted on an enclosure surface while the connector is out of its receptacle.

28.5.8 In reference to 28.5.7, an interlock circuit in the cable to de-energize the exposed contacts whenever an end of the cable is disconnected meets the intent of the requirement.

28.6 Receptacles

28.6.1 A general-use grounding type receptacle and a multi-pin type receptacle shall comply with the requirements in the Standard for Attachment Plugs and Receptacles, UL 498 or the Standard for Appliance Couplers for Household and Similar General Purposes – Part 1: General Requirements, UL 60320-1.

28.6.2 A multi-pin receptacle mounted through an enclosure wall shall additionally:

a) Be provided with a metal housing or comply with the polymeric enclosure requirements in the Standard for Industrial Control Equipment, UL 508;

b) Be a female type;

c) Comply with 28.5.8 and 28.5.8; and

d) Be marked in accordance with 59.2 and 59.4.

28.6.3 A general-use receptacle or a multi-pin receptacle of the type where the mating part is intended to be connected to a flexible cord shall be provided only for connection of loads which:

a) Are portable; or

b) Require frequent interchange.

28.6.4 A receptacle provided for the permanent connection of a load shall be of a type where the mating part will have provision for connection of conduit.

28.6.5 A general-use receptacle rated more than 20 amperes or a multi-pin type receptacle of any rating shall have mechanical means to secure the connection(s). The receptacle shall be marked in accordance with 59.4.

28.6.6 Class A ground fault circuit interrupter protection complying with the requirements in the Standard for Ground-Fault Circuit-Interrupters, UL 943, shall be provided for all 120-volt, single-phase, 15- or 20-ampere receptacles used in an industrial control panel marked as having a Type 3R or 3RX enclosure or otherwise intended for outdoor use.

28.7 Cable assemblies and fittings

28.7.1 Cable assemblies, male and female cable fittings, panel-mounted fittings and fittings intended for use in power circuits shall comply with 28.5.6, 28.6.2, 28.6.3 and the requirements in one of the following:

a) The Outline of Investigation for Multi-Point Interconnection Power Cable Assemblies for Industrial Machinery, UL 2237;

b) The Standard for Cable Assemblies and Fittings for Industrial Control and Signal Distribution, UL 2238.

29 Internal Wiring

29.1 General

29.1.1 All internal wiring conductors or bus bars shall be made of copper.

29.1.2 All internal wiring shall have insulation rated for the maximum voltage involved.

Exception: The voltage rating of conductors connected to a dc circuit, such as a dc bus or dc motor circuits supplied from power conversion equipment, shall be the peak equivalence of the rms voltage (rated voltage of the conductor multiplied by the square root of 2) marked on the conductor.

29.1.3 *Deleted*

29.2 Conductor requirements

29.2.1 All internal wiring of power circuits shall have a temperature rating of 90°C (194°F) minimum and shall be one of the following:

a) Machine tool wire that complies with the Standard for Machine-Tool Wire and Cables, UL 1063. Flexing or Class K type machine tool wires and cables shall be installed in accordance with 29.3.12;

b) Thermoset insulated wire that complies with the Standard for Thermoset-Insulated Wires and Cables, UL 44;

c) Thermoplastic insulated wire that complies with the Standard for Thermoplastic-Insulated Wires and Cables, UL 83;

d) Appliance wiring material that complies with the Standard for Appliance Wiring Material, UL 758; or

e) Welding cable installed in accordance with 29.3.12.

Exception: A power supply cord that is integral to a component is not required to comply with this requirement when its attachment plug is intended for connection to a receptacle that complies with the Standard for Attachment Plugs and Receptacles, UL 498 or the Standard for Appliance Couplers for Household and Similar General Purposes – Part 1: General Requirements, UL 60320-1.

29.2.2 Bus bars are able to be used for internal connections in a power circuit when:

a) The bus bars comply with the Standard for Industrial Control Equipment, UL 508, and having spacings that comply with Table 10.1 or Table 10.2, as appropriate; or

b) The bus bars are evaluated according to 29.2.2(b)(1) and 29.2.2(b)(2) below:

1) Spacings are maintained in accordance with Section 13, Insulating Material, and Table 10.1 or Table 10.2; and

2) They are constructed in accordance with 29.3.10 and 29.3.11 and sized as specified in 29.6.2.

Exception: This requirement does not apply to bus bars integral to a component.

29.2.3 Additional insulation, when used, shall be rated 90°C (194°F) minimum and shall be one of the following:

a) Insulating sleeving that complies with the Standard for Coated Electrical Sleeving, UL 1441;

b) Insulating tubing that complies with the Standard for Extruded Insulating Tubing, UL 224; or

c) A wrapping of not less than two layers of insulating tape that complies with the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510.

Exception: Additional insulation used only for physical protection of the wire and not to comply with 29.4.4(a) is not required to comply with this requirement.

29.3 Wiring methods

29.3.1 All internal wiring terminations shall be mechanically secured, shall provide electrical continuity, and shall comply with 29.3.2 – 29.3.7.

29.3.2 A soldered joint shall be mechanically secured before soldering by being:

a) Wrapped at least halfway (180 degrees) around a terminal;

b) Provided with at least one right angle bend when passed through an eyelet or opening; or

c) Twisted with other conductors.

29.3.3 A connection to a wire-binding screw shall be made as follows such that no loose strands protrude from the connection:

a) Solid wire formed into a loop at least three-quarters (270 degrees) around the terminal; or

b) Stranded wire that is:

1) Soldered;

2) Connected to a terminal provided with upturned ends;

3) Connected to a terminal provided with a cup washer; or

4) Connected to a crimped pressure terminal connector or eyelet;

29.3.4 A connection to a terminal of a component shall be made by:

a) Wire inserted directly into a pressure wire terminal of the component;

b) Quick-connect terminal of the component, where the mating part is provided with a dimple, depression, or spring-type connection such that a mechanical snap-action connection is made that does not rely solely upon friction between the two parts;

c) Crimped-on pressure terminal connector or closed-loop eyelet;

d) Solder terminal specified in 29.3.2;

e) Wire-binding screw specified in 29.3.3;

f) Open-type eyelet specified in 29.3.5; or

g) Wiring ferrule specified in 29.3.6.

29.3.5 An open-type eyelet shall have:

a) Upturned ends that engage the terminal screw head;

b) Fork- or crimp-type ends that engage the terminal screw shank; or

c) A flat terminal that supports the wire such that loosening of a terminal screw does not result in the conductor disengaging from the intended connection.

29.3.6 A wiring ferrule shall be:

a) Used with stranded copper wire(s) only;

b) Terminated in a connector rated for copper wire and rated for the number and size of wire(s) crimped to the ferrule;

c) Crimped with an appropriate tool as recommended by the ferrule manufacturer before terminating in a terminal of a component;

d) Sized in diameter appropriate for the number of wires and wire size(s) as recommended by the ferrule manufacturer; and

e) Crimped to the wires such that the length of the uninsulated portion of the wires does not result in the reduction of electrical spacings when the ferrule is installed.

29.3.7 Multiple conductors secured to a single termination point shall result in a reliable electrical and mechanical connection made without loose, unretained, or severed stranding, and without a reduction in the electrical spacings required in Section 10, Spacings.

29.3.8 Internal wiring connected to earth ground or the grounded secondary side of a transformer shall comply with 17.3 and 17.4.

29.3.9 A splice shall be provided with additional insulation complying with 29.2.3 or an insulated crimp-on splice connector that complies with the Standard for Splicing Wire Connectors, UL 486C. The splice insulation shall overlap the wire insulation or be mechanically supported such that it complies with Section 10, Spacings.

29.3.10 A bus bar shall be supported by insulators that comply with Section 13, Insulating Materials, and that are rated 90°C (194°F) minimum.

29.3.11 The surfaces of bus bars intended to carry over 600 amperes and that are bolted together shall be plated with tin, silver, or nickel.

29.3.12 Flexible conductors, including welding cable and machine tool wire identified as “Flexing” or “Class K”, shall be retained by terminals that have been evaluated to the Standard for Wire Connectors, UL 486A-486B for the size and type of conductors involved.

29.3.13 Unless otherwise marked, the intended phase arrangement on 3-phase horizontal and vertical buses shall be A, B, C from front to back, top to bottom, or left to right, as viewed from the front of the industrial control panel; and on 3-phase, 4-wire, delta-connected systems, the B phase shall be that phase having the higher voltage to ground. Where the intended bus bar phase arrangement differs from the above convention, each bus bar shall be marked to identify the intended phase at each termination point.

29.3.14 An industrial control panel constructed specifically for connection to a 3-phase, 4-wire delta supply, such as shown in Figure 75.7 and Figure 75.8, and provided with internal components connected between a phase and neutral, or an industrial control panel that contains a transformer or power supply with a 3-phase, 4-wire delta secondary, as described in 16.1(d), and provided with field wiring terminals for loads to be connected between a phase and the neutral, shall have the internal conductor or bus bar connected to the phase having the higher voltage to ground to be identified by the color orange at each termination point.

29.4 Routing of internal wiring

29.4.1 A hole through which insulated wires pass in a sheet metal wall within the enclosure of the equipment shall be provided with a smooth, well-rounded bushing or shall have smooth, well-rounded surfaces upon which the wires are able to bear to reduce the risk of abrasion of the insulation.

29.4.2 Wires shall be routed away from sharp edges, screw threads, burrs, fins, moving parts, drawers, and similar parts, that are able to abrade the wire insulation. Wires shall also be routed away from heat-producing components, such as heat sinks of power circuit components, power supplies, transformers, cabinet heaters, and power circuit resistors.

29.4.3 Clamps, guides, spiral wrap, wire ties, and wiring troughs, either metallic or nonmetallic, used for routing stationary internal wiring shall be provided with smooth, well-rounded edges. The clamping action and bearing surface shall be such that abrasion or cold flow of the insulation is not able to occur. Auxiliary nonconducting mechanical protection shall be provided under a metallic clamp that exerts pressure on a conductor having thermoplastic insulation less than 1/32 inch (0.8 mm) thick and having no overall braid.

29.4.4 Wiring that is subject to movement, flexing, handling, or manipulation during its intended use, or during mechanical maintenance such as wiring from a stationary part to a part mounted on a hinged cover or door, shall be:

a) Stranded-type conductors;

b) Cabled, routed, secured, and protected so that the wire is not damaged during opening and closing of the door or cover.

Wiring intended for flexing duty, flexible cord, machine tool wire that is 8 AWG (8.4 mm^2) or larger, machine tool wire that is 18 – 10 AWG (0.8 – 5.3 mm^2) designated as "Flexing" or "Class K", or welding cable complies with this requirement.

29.5 Separation of circuits

29.5.1 A factory-installed conductor shall be separated by a barrier or by additional insulation complying with 29.2.3, or shall be segregated as specified in 29.5.2 from:

a) A factory-installed conductor used in a different circuit unless the conductors of both circuits are insulated for the maximum voltage of either circuit; and

b) An uninsulated live part connected to a different circuit.

29.5.2 Segregation of a conductor shall be accomplished by clamping, routing, or equivalent means that provides permanent separation from a conductor or an uninsulated live part of a different circuit.

29.5.3 A conductor shall be provided with strain relief in accordance with 28.5.2 when stresses on the conductor cause the conductor to move such that compliance with 29.5.1 is not maintained.

29.6 Sizing

29.6.1 Internal wiring of a power circuit shall not be smaller than 14 AWG (2.1 mm^2) and shall be determined by:

a) Calculating the required ampacity by adding the full-load current ratings of all external loads being carried by the conductor based on the marked load ratings of the industrial control panel. For motor loads rated in horsepower, the equivalent full-load current rating shall be determined from Table 50.1 or Table 50.2; and

b) Determining the minimum internal wiring conductor size from Table 28.1, having a corresponding ampacity not less than the required ampacity from (a).

The wire temperature rating(s) marked on the component or in the instructions shall be used to select the appropriate column(s) from Table 28.1 as follows:

1) For a 60°C component marking : A conductor with a temperature rating of 90°C or higher shall be used but the conductor size shall be determined using the ampacities in the 60°C column;

2) For a 75°C component marking : A conductor with a temperature rating of 90°C or higher shall be used but the conductor size shall be determined using the ampacities in the 75°C column;

3) For a 60°C / 75°C component marking : A conductor with a temperature rating of 90°C or higher shall be used but the conductor size shall be determined using the ampacities in the 60°C column or the 75°C column.

4) If the component markings or instructions do not specify a wire temperature rating, the conductor size shall be determined using the ampacities in the 60°C column in Table 28.1 when the component is rated 100 amps or less, and the 75°C column in Table 28.1 when the component is rated greater than 100 amps.

If the wire temperature ratings marked on components at both ends of the conductor differ, the more restrictive wire temperature rating shall be used.

Exception: Lead wires integral to a component, such as a transformer, are not required to comply with this requirement.

29.6.2 The required size of bus bars used for internal connections of a power circuit shall:

a) Be determined by calculating the required ampacity by adding the full-load current ratings of all external loads being carried by the conductor, based on the marked load ratings of the industrial control panel. For motor loads rated in horsepower, the equivalent full-load current rating shall be determined from Table 50.1 or Table 50.2; and

b) Have a current rating not less than current determined in 29.6.2(a) based on the marked current rating of a bus bar that complies with 29.2.2(a) or the current density not exceeding 1000 amperes per square inch (per 6.45 cm^2) of cross-sectional area (minimum width of bus bar multiplied by minimum thickness of bus bar) of the copper bus bar.

30 Disconnect Switches

30.1 Component requirements

30.1.1 An inverse-time or instantaneous-trip circuit breaker shall comply with the requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489.

30.1.2 A molded-case switch shall comply with the requirements in the Standard for Molded-Case Circuit-Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489.

30.1.3 A switch unit, an open-type switch or enclosed switch shall comply with the requirements in the Standard for Enclosed and Dead-Front Switches, UL 98.

30.1.4 A manual motor controller marked "Suitable as Motor Disconnect" shall comply with the requirements in the Standard for Industrial Control Equipment, UL 508.

30.1.5 A self-protected combination motor controller shall comply with the requirements in the Standard for Industrial Control Equipment, UL 508, and shall be provided with all accessory parts required by the product marking.

30.1.6 Disconnect handles and operating mechanisms shall comply with the requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489, or the Standard for Enclosed and Dead-Front Switches, UL 98, or the Standard for Industrial Control Equipment, UL 508, for use with the disconnecting device involved.

30.1.7 A pullout switch shall comply with the requirements contained in the Standard for Pullout Switches, UL 1429.

30.1.8 A fused disconnect switch with provisions for a fuse rated greater than 600A shall comply with 30.1.3 or the requirements contained in the Standard for Fused Power-Circuit Devices, UL 977.

30.1.9 A power circuit breaker shall comply with the requirements contained in the Standard for Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures, UL 1066.

30.2 Sizing of disconnect switch

30.2.1 An inverse-time or instantaneous-trip circuit breaker shall not carry a full-load current of more than 80 percent of its nominal ampere rating.

Exception: An inverse-time circuit breaker that is marked for continuous use up to 100 percent of its rating or an instantaneous trip circuit breaker, or a power circuit breaker is able to carry a full-load current equivalent to its ampere rating.

30.2.2 A molded-case switch, a switch unit, a fused power circuit switch, a pullout switch, and an open or enclosed switch shall have:

a) For control of one or more non-motor loads:

1) An ampere rating not less than 100 percent of the rated full-load current of the load(s) for a non-fused switch; and

2) The full-load current of the loads shall not be more than 80 percent of the rating of the fuses for an enclosed, open, molded case, pullout switch or switch unit with an integral fuseholder;

b) For control of a single motor load:

1) A horsepower rating not less than the motor load rating; or

2) An ampere rating not less than 115 percent of the motor full-load current rating in accordance with Table 50.1 or the input current rating of a variable speed drive; or

c) For one or more motors or for one motor and any other load(s), an ampere rating or a horsepower rating with an equivalent full-load current:

1) Not less than 115 percent of the full load current ratings of all motors, in accordance with Table 50.1 or the input current rating of a variable speed drive plus the full-load currents of all other loads; and

2) The rated locked-rotor current of the switch shall not be less than the sum of the locked-rotor currents of all motors, plus the full-load currents of all other loads. For single-phase motors, the locked rotor current is 6 times the full load current rating as in Table 50.1. For three-phase motors, the locked rotor current is as in Table 50.3 for motor designs B, C and D, and 6 times the full load current rating as in Table 50.1 for other motor designs or motors without a motor design designation. For dc motors the locked rotor current is 10 times the full load current rating as in Table 50.2.

30.2.3 A self-protected combination motor controller shall be sized at 100 percent of its full-load current rating for disconnection of a single motor load.

30.2.4 A manual motor controller marked “Suitable as Motor Disconnect" shall have a rating that complies with 30.2.2(b) or 30.2.2(c).

30.3 Location

30.3.1 A disconnecting means shall be provided for each incoming supply circuit.

Exception: A disconnecting means is not required when the industrial control panel is marked in accordance with 60.1.

30.3.2 The disconnecting means shall open each ungrounded conductor of the supply circuit.

30.3.3 A manual motor controller marked "Suitable as motor disconnect" shall be installed only on the load side of the branch circuit protective device.

30.3.4 A manual motor controller marked, "Suitable as Motor Disconnect" is able to be installed on the line side of semiconductor fuses protecting power conversion equipment, as in 31.1.3, when separate branch circuit protective devices are also installed on the line side of the manual motor controller as in 30.3.3. In this case, the branch circuit protective devices on the line side of the manual motor controller shall comply with 31.3, as they serve as the branch circuit protection, and the semiconductor fuses are considered as supplementary protection.

30.3.5 When two or more disconnects are provided for multiple supply circuits, they shall be grouped in one location on the industrial control panel. Each disconnect shall be legibly marked to indicate the equipment it disconnects.

Exception: Two or more disconnects provided for multiple supply circuits are not required to be grouped in one location on the industrial control panel provided a marking is installed at each supply circuit disconnect location denoting the location of all other supply circuit disconnects.

30.3.6 The supply connections to a disconnecting means shall not be “back-fed” or reversed, with the load side.

Exception No. 1: An inverse-time circuit breaker that is not marked "Line" and "Load", is able to be back-fed. The industrial control panel shall be marked as in 57.3.

Exception No. 2: A manual self-protected combination motor controller is able to be back-fed only when marked on the device. The industrial control panel shall be marked as in 57.3.

Exception No. 3: A disconnect switch as described in 30.1.3 and having contacts that simultaneously open the line and load side of an integral fuseholder is able to be back-fed. The industrial control panel shall be marked as in 57.3.

30.4 Mechanical operating mechanism

30.4.1 When the handle of a main disconnect switch is operated vertically rather than rotationally or horizontally, the "up" position of the handle shall be the "on" position.

30.4.2 The disconnecting means shall have an indicator to indicate whether it is in the open ("off") or closed ("on") position.

30.4.3 The operating handle of the disconnecting means shall be capable of being locked in the "off" or open position.

30.4.4 The center of the grip of an operating handle for the disconnecting means provided in a floor-mounting controller, when in its highest position, shall not be more than 79 inches (201 cm) above the floor bottom of the enclosure.

31 Branch Circuit Protection

31.1 Component requirements

31.1.1 An inverse-time or instantaneous-trip circuit breaker shall comply with the requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489. An instantaneous-trip circuit breaker, in combination with the motor controller and motor overload device, shall additionally comply with the requirements for combination motor controllers in the Standard for Industrial Control Equipment, UL 508.

31.1.2 A branch circuit fuse shall comply with the Standard for Low-Voltage Fuses – Part 1: General Requirements, UL 248-1, and the applicable parts of the UL 248 series. A branch circuit fuse intended to be located in a direct-current circuit shall be marked with a dc voltage rating. A special purpose fuse that meets the applicable performance requirements of the UL 248 series of standards for a branch circuit fuse are able to be used as branch circuit protection based on the specified fuse class.

31.1.3 A semiconductor fuse that complies with the Standard for Low-Voltage Fuses – Part 13: Semiconductor Fuses, UL 248-13 is able to be used for branch circuit protection of a motor circuit containing a variable speed drive whose installation instructions recommend its use.

31.1.4 A self-protected combination motor controller or a manual self-protected combination motor controller shall comply with the Standard for Industrial Control Equipment, UL 508, and shall be provided with all accessory parts required by the product marking. Manual self-protected combination motor controllers shall be used with the motor controllers required by the product marking. A self-protected combination motor controller or a manual self-protected combination motor controller shall be used only as branch circuit protection for single motor circuits.

31.1.5 A discrete fuseholder, not an integral part of a disconnect switch, for a branch circuit fuse other than Class L shall comply with the Standard for Fuseholders – Part 1: General Requirements, UL 4248-1, and the applicable Part from the UL 4248 series.

31.1.6 A discrete fuseholder, not an integral part of a disconnect switch, rated more than 600A for use with a Class J, L, or T branch circuit fuse shall comply with the requirements in the Standard for Fused Power-Circuit Devices, UL 977.

31.1.7 The following shall not be relied upon to provide branch circuit protection:

a) A supplementary protector that complies with the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077;

b) Miscellaneous, miniature, and micro fuses that comply with the Standard for Low-Voltage Fuses – Part 14: Supplemental Fuses, UL 248-14; and

c) A manual motor controller provided with an instantaneous-trip overcurrent mechanism that complies with the Standard for Industrial Control Equipment, UL 508.

31.1.8 An industrial control panel that contains a circuit breaker rated 1000 amperes or more or a fuseholder that accepts a fuse rated 1000 amperes or more shall additionally comply with the requirements for ground-fault protection in 75.6.

Exception: This requirement does not apply to a panel marked in accordance with 60.1.

31.2 Location

31.2.1 A branch circuit protective device shall be installed in each ungrounded conductor to the load(s) involved.

Exception No. 1: An industrial control panel that is intended to be installed on the load side of branch circuit protection provided in the field and marked in accordance with 60.1 is not required to comply with this requirement. Also see 31.2.2.

Exception No. 2: Branch circuit fuses are not required to be provided in a branch circuit fuseholder having a pole for each ungrounded conductor where the fuseholder is sized to accept the branch circuit fuse required in 31.3 – 31.8. See 60.1.

31.2.2 When an industrial control panel is intended to be installed on the load side of branch circuit protection provided in the field and the required branch circuit protection is to be sized based on a component restriction as specified in 31.3.1(b) or 31.3.2 or based on motor grouping as described in 31.4, the field installed component marking of 60.1 shall include the required size and type of branch circuit protection.

31.2.3 A fuseholder within a power circuit shall be located so that when the disconnect switch contacts are open:

a) The fuses are readily accessible; and

b) The operator is able to replace the fuse without contacting live parts.

31.2.4 The handle of a circuit breaker that is operable from outside the industrial control panel and that operates vertically rather than rotationally or horizontally shall be located so that the "up" position of the handle is the "on" position.

31.3 Sizing of branch circuit protection for single motor circuit

31.3.1 The ampere rating and type of branch circuit protection for a single motor circuit, other than covered in 31.3.2 and 31.3.3, shall be determined based on the smaller of:

a) Sizing in accordance with Table 31.1, by:

1) Determining the full-load current rating corresponding to the motor horsepower rating from Table 50.1 or Table 50.2;

2) Determining the maximum percentage of full-load current rating corresponding to the type of branch circuit device selected from Table 31.1; and

3) Multiplying (1) and (2);

b) Sizing based on component restrictions, as indicated by markings on components, the heater table of an overload relay, or in the instructions provided with components. In this case, the branch circuit protection selected shall be coordinated with all power circuit components on the load side of the protective device and shall:

1) Have an ampere rating not exceeding the manufacturers maximum specified rating; and

2) Be the same type of device specified by the manufacturer.

When used in instructions for a component, heater tables, or instruction manuals, the term "fuse" shall refer to a branch-circuit type fuse and "circuit breaker" shall refer to an inverse-time circuit breaker.

31.3.2 The branch circuit protection for a single-motor circuit provided with a variable-speed drive shall be of the type and size specified by the manufacturer's instructions provided with the drive. Lower sizes, of the same type, can be used. When the instructions do not specify the type and size, a branch-circuit fuse or inverse-time circuit breaker shall be used and shall be sized in accordance with 31.3.1(a) based upon the full-load motor output current rating of the drive.

Exception No. 1: Additional branch circuit protection is not required for a drive provided with integral inverse-time circuit breaker, branch-circuit, or semiconductor fuses in all ungrounded input conductors.

Exception No. 2: Unless specified in the installation instructions for a variable-speed drive, a "common bus" drive is not required to have individual branch circuit protective devices installed in the dc input conductors. See 31.4.2 for branch circuit protection for the power supply converter unit supplying dc bus power to the "common bus" inverter sections.

31.3.3 Additional branch circuit protection is not required for a self-protected combination motor controller or a manual self-protected combination motor controller supplying a single motor load. The adjustable range of the self-protected combination motor controller shall be capable of being set for the motor full load current rating as determined from 50.1. The cautionary markings in 55.7 shall be provided.

31.3.4 Additional branch circuit protection is not required to be provided when an instantaneous-trip circuit breaker and all of the load side power components have been evaluated as a combination motor controller as specified in 31.1.1 and supply a single motor load. The adjustable range of the instantaneous-trip circuit breaker shall be able to be set for the rating determined from 31.3.1. The cautionary markings of 55.6 shall be provided.

31.3.5 A fuseholder shall be sized to accept a fuse in accordance with 31.3.1. The fuseholder shall be provided with the replacement fuse marking of 56.1 when:

a) The fuseholder accepts a fuse with an ampere rating greater than specified in 31.3.9;

b) The fuseholder accepts a fuse with an ampere rating that exceeds a component restriction as specified in 31.3.1(b); or

c) The fuseholder is intended for a semiconductor fuse.

31.3.6 The branch circuit protective device(s) provided in an industrial control panel for a multi-speed motor having two or more windings or a part winding motor shall have:

a) Individual branch circuit protection for each winding that complies with 31.3.1 based on the full load current rating of the protected winding; or

b) A single branch circuit protective device or set of branch circuit protective devices supplying all windings that complies with 31.3.1 based on the full load current rating of the smallest winding.

Table 31.1
Maximum rating of motor branch circuit device percent of full load current rating

Type of Branch Circuit Protective Device	Ampere Rating	Nominal rating of motor branch circuit protective device, percent of full load current rating	Notes
Nontime delay fuse	0 – 600	300	See 31.3.7, 31.3.8, 31.3.9(a)
Nontime delay fuse	Over 600	300	See 31.3.7, 31.3.8, 31.3.9(b)
Dual element fuse (time delay) except Class CC	All	175	See 31.3.7, 31.3.8, 31.3.9(c)
Class CC Dual element fuse (time delay)	0 – 30	300	See 31.3.7, 31.3.8, 31.3.9(a)
Inverse-time circuit breaker	0 – 100	250	See 31.3.7, 31.3.8, 31.3.9(d)
Inverse-time circuit breaker	Over 100	250	See 31.3.7, 31.3.8, 31.3.9(e)
Instantaneous-trip circuit breaker	All	800	See 31.3.4, 31.3.9(f)
Self-protected Combination Motor Controller	All	100	See 31.3.3
Manual Self-protected Combination Motor Controller	All	100	See 31.3.3

31.3.7 When the calculated ampere rating of the branch circuit protection as specified in 31.3.1(a) does not correspond to a standard size fuse or circuit breaker, the next higher size fuse or inverse-time circuit breaker as specified in 31.3.8 shall be used.

Exception No. 1: When the calculated ampere rating of the branch circuit protection specified in 31.3.1(b) does not correspond to a standard size fuse or circuit breaker, the next lower standard size shall be used.

Exception No. 2: When a circuit breaker is used as branch circuit protection of a motor circuit that is rated 3.75 amperes or less in accordance with 31.3.1, a 15-ampere circuit breaker is able to be used.

31.3.8 Standard ampere ratings for fuses and inverse-time circuit breakers are 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000. Additional ratings for fuses include 1, 3, 6, and 10.

31.3.9 Where the starting current of the motor opens the branch circuit protective device specified based on 31.3.1(a), the maximum rating or setting of the branch circuit protective device shall not exceed:

a) 400 percent of full-load motor current for a non-time delay fuse or a Class CC time delay fuse not exceeding 600 amperes;

b) 300 percent of full-load motor current for a non-time delay fuse rated 601 amperes or greater;

c) 225 percent of full-load motor current for a time delay (dual element) fuse;

d) 400 percent of full-load motor current for an inverse-time circuit breaker not exceeding 100 amperes;

e) 300 percent of full-load motor current for an inverse-time circuit breaker rated more than 100 amperes; or

f) 1300 percent of full-load motor current for an instantaneous-trip circuit breaker or 1700 percent of motor full load current for an instantaneous trip circuit breaker used with a high–efficiency Design B motor.

31.4 Sizing of branch circuit protection for motor groups

31.4.1 A group of loads, consisting of two or more motors, or one or more motors and other loads, are able to be protected by a single set of branch circuit fuses or inverse – time circuit breaker as specified in (a), (b), or (c):

a) When the branch circuit protection does not exceed 20 A, 125 V or 15 A, 1000 V or less; and

1) The full load current rating of each motor does not exceed 6 A; and

2) The rating and type of the branch circuit protection is coordinated with component restrictions in 31.3.1(b); and

3) The rating and type of the branch circuit protection is coordinated with the requirements for other loads in 31.4.4;

b) When the rating and type of the branch circuit protective device complies with 31.3.1 for each motor circuit in the group, the tap conductors comply with 31.4.3, and the rating and type of the branch circuit protection is coordinated with the requirements for other loads in 31.4.4; or

c) When each power circuit device included on the load side of the branch circuit protection is either (a) intended for group installation, as determined by a marking on the component, the heater table of an overload relay, or on instructions provided with the components, or (b) selected such that the rating and type of the branch circuit protective device complies with 31.3 for that individual motor circuit, the tap conductors comply with 31.4.3, and the rating and type of the branch circuit protection is coordinated with the requirements for other loads in 31.4.4 and the size of the branch circuit protection does not exceed the rating determined by (1) or (2), whichever is smaller:

1) Size of branch circuit protection is determined by determining the size required for the largest motor in the group, in accordance with 31.3.1(a) and adding the full-load current ratings of all remaining motors and the current ratings of all other non-motor loads in the grouping; or

2) Size of branch circuit protection is chosen so as not to exceed the ampere rating specified in the group installation marking of all power components and the type of protective device is the type specified in the group installation marking. For the purpose of making this determination, the term "fuse" refers to a branch-circuit type fuse and the term "circuit breaker" refers to an inverse-time circuit breaker.

31.4.2 For power conversion equipment consisting of two or more "common bus" inverter sections that are supplied from a single power supply converter, all sections shall comply with 33.1.2 and shall be protected by a single set of branch protective devices installed in the line side of the converter section. The branch circuit protective devices shall be sized according to (a) or (b), whichever is smaller:

a) The maximum usable branch circuit protection specified in 31.3.1 for the largest motor in the group plus the full-load current ratings of all remaining motors and other loads in the group: or

b) The maximum specified branch circuit protection of the converter section.

31.4.3 The ampacity of the tap conductors, the internal conductors to individual loads, shall be:

a) Not less than 1/3 the ampacity of the branch circuit conductor, calculated as in 28.3.3; or

b) Not less than 1/10 the ampere rating of the branch circuit protection for the group for each motor circuit provided with a manual motor controller marked “Suitable as tap conductor protection in group installations ” and complies with the Standard for Industrial Control Equipment, UL 508. The

conductors on the load side of the manual motor controller shall have an ampacity not less than calculated in 28.3.2.

31.4.4 For a group that includes other (non-motor) loads, additional branch circuit fuses or inverse time circuit breakers shall be provided in each circuit in accordance with 31.5 – 31.8.

Exception: Where the ampere rating of the branch circuit protection determined in 31.4.1 does not exceed the applicable branch circuit protection requirements in 31.5 – 31.8 for a non-motor load in the group, additional branch circuit protection is not required.

31.5 Receptacles

31.5.1 A single general-use receptacle shall be protected by a branch circuit protective device having an ampere rating not more than the ampere rating of the receptacle.

31.5.2 A duplex receptacle or two or more receptacles connected to the same branch circuit shall be protected by a branch circuit protective device having an ampere rating not more than the ampere rating of the receptacle.

Exception No. 1: A 20-ampere branch circuit protective device is able to be used with a receptacle rated 15 amperes.

Exception No. 2: Branch circuit protective devices having a rating that is smaller than the rating of the receptacle are able to be used with a receptacle intended for use only with a specific piece of equipment and marked in accordance with 59.1.

31.6 Sizing of branch circuit protection for heater loads

31.6.1 Fixed electric space-heating equipment shall be provided with branch circuit protection sized:

a) Not larger than 60 amperes; and

b) Not larger than the ampacity of the field wiring to the heater load.

Exception: For heaters used for industrial furnaces, pipelines and vessels or outdoor de-icing and snow melting where the heater is not able to be subdivided into circuits less than 48 amperes, the branch circuit protective device is required to be sized in accordance with 31.6.1(b).

31.6.2 The maximum branch circuit protective device shall be 150 amperes for resistive heating element loads contained in a water heater or steam boiler having an ASME rated and stamped vessel. The load rating shall comply with 50.5.

31.6.3 Branch circuit protection for industrial process heating employing electric resistance or electrode heating technology including boilers, electrode boilers, duct heaters, strip heaters, immersion heaters, process air heaters, or other fixed electric equipment used for industrial process heating shall be sized based on the ampacity of the field wiring conductors supplying this equipment.

31.6.4 Branch circuit protection for dielectric heating, induction heating, induction melting, and induction welding equipment and accessories for industrial and scientific applications shall be sized based on the ampacity of the field wiring conductors supplying this equipment.

31.7 Sizing of branch circuit protection for appliance loads

31.7.1 For a single non-motor-operated appliance load, the branch circuit protective device shall be sized:

a) Based on the required branch protection as marked on the appliance;

b) Not more than 20 amperes for an appliance rated less than 13.3 amperes and not marked with a required branch circuit protective device rating; or

c) 150 percent of the ampere rating of an appliance rated more than 13.3 amperes and not marked with a required branch circuit protective device rating.

Exception No. 1: An appliance provided with a power supply cord and attachment plug is not required to comply with this requirement. See 31.5.1 and 31.5.2.

Exception No. 2: Where the branch circuit protective device calculated in accordance with (c) does not correspond to a standard size overcurrent device, the next larger size is able to be used.

31.7.2 For a single motor-operated appliance, the branch circuit protective device shall be sized based on:

a) The required branch protection as marked on the appliance;

b) 31.3.1 or 31.4.1; or

c) 31.5.1 and 31.5.2 for an appliance provided with a power supply cord and attachment plug.

31.8 Sizing of branch circuit protection for lighting loads

31.8.1 The branch circuit protection of a circuit supplying standard-duty incandescent lampholders or fluorescent ballasts shall not exceed 20 amperes and shall not exceed the ampacity of the anticipated field wiring.

31.8.2 The branch circuit protection of a circuit supplying lampholders marked "heavy duty" for use with incandescent or infrared lamps shall not exceed 50 amperes and shall not exceed the ampacity of the anticipated field wiring.

32 Overcurrent Protection of Feeder

32.1 Component requirements

32.1.1 An inverse-time circuit breaker shall comply with 31.1.1.

32.1.2 A branch-circuit type fuse shall comply with 31.1.2.

32.1.3 A manual motor controller and a combination motor controller that complies with the Standard for Industrial Control Equipment, UL 508, shall not be located in the feeder circuit and shall not be relied on to provide overcurrent protection of the feeder.

32.2 Location

32.2.1 The overcurrent devices specified in 32.1.1 and 32.1.2 shall be provided in each ungrounded conductor.

Exception: This requirement does not apply to units intended to be provided with overcurrent devices in the field.

32.3 Sizing of overcurrent protection

32.3.1 The size of the overcurrent protection shall not exceed the ampere value determined from (a) and (b), whichever is larger:

a) The rating of the largest branch circuit protective device in the circuit plus 125 percent of all heater loads plus the full-load currents of all other motors or other loads in the group that could be in operation at the same time; or

b) The ampacity of the conductors or bus bars on the load side of the overcurrent device.

Exception No. 1: Where one or more instantaneous trip circuit breakers or motor short-circuit protectors are used for motor branch-circuit short-circuit and ground-fault protection, the procedure specified above for determining the maximum rating of the protective device for the circuit supplying the industrial control panel shall apply with the following provision: for the purpose of the calculation, each instantaneous trip circuit breaker or motor short-circuit protector shall be assumed to have a rating not exceeding the maximum percentage of motor full-load current permitted by Table 31.1 for the type of control panel supply circuit protective device employed.

32.4 Feeder taps for non-motor loads

32.4.1 Conductors shall be permitted to be tapped, without overcurrent protection at the tap, to a feeder as specified in 32.4.2 – 32.4.4.

32.4.2 Taps Not over 3 m (10 ft) Long. If the length of the tap conductors does not exceed 3 m (10 ft) and the tap conductors comply with all of the following:

a) The ampacity of the tap conductors is:

1) Not less than the combined calculated loads on the circuits supplied by the tap conductors; and

2) Not less than the rating of the equipment containing an overcurrent device(s) supplied by the tap conductors or not less than the rating of the overcurrent protective device at the termination of the tap conductors.

Exception: Where equipment, such as a surge protective device(s) [SPD(s)], is provided with specific instructions on minimum conductor sizing, the ampacity of the tap conductors supplying that equipment shall be permitted to be determined based on the manufacturer's instructions.

b) The tap conductors do not extend beyond the industrial control panel.

32.4.3 Taps Not over 7.5 m (25 ft) Long. Where the length of the tap conductors does not exceed 7.5 m (25 ft) and the tap conductors comply with all the following:

a) The ampacity of the tap conductors is not less than one-third of the rating of the overcurrent device protecting the feeder conductors;

b) The tap conductors terminate in a single circuit breaker or a single set of fuses that limit the load to the ampacity of the tap conductors. This device shall be permitted to supply any number of additional overcurrent devices on its load side; and

c) The tap conductors are protected from physical damage by being enclosed in a raceway or by other means.

32.4.4 Taps Supplying a Transformer [Primary Plus Secondary Not over 7.5 m (25 ft) Long]. Where the tap conductors supply a transformer and comply with all the following conditions:

a) The conductors supplying the primary of a transformer have an ampacity at least one-third the rating of the overcurrent device protecting the feeder conductors; and

b) The conductors supplied by the secondary of the transformer shall have an ampacity that is not less than the value of the primary-to-secondary voltage ratio multiplied by one-third of the rating of the overcurrent device protecting the feeder conductors.

32.5 Feeder taps for motor loads

32.5.1 Feeder tap conductors shall begin and end within the panel, shall have an ampacity not less than that required by 29.6.1, shall terminate in a branch-circuit protective device, and, in addition, shall meet one of the following requirements:

a) Be not more than 3.0 m (10 ft) in length;

b) Have an ampacity of at least one-third that of the feeder conductors and be not more than 7.5 m (25 ft) in length; or

c) Have an ampacity not less than the feeder conductors.

33 Load Controllers

33.1 Component requirements

33.1.1 A load controller, including a magnetic or manual motor controller, definite purpose motor controller, combination motor controller, reduced voltage starter, and solid-state relay or controller (a control containing a solid-state switching device, such as a triac or SCR, controlling the power circuit load), shall comply with the requirements contained in the Standard for Industrial Control Equipment, UL 508.

33.1.2 A variable speed drive, including individual converter and inverter sections, shall comply with the requirements in the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1.

33.1.3 A motor controller and a mechanical interlocking mechanism used as part of a reversing motor controller shall additionally comply with the overload and endurance test requirements for reversing contactors contained in the Standard for Industrial Control Equipment, UL 508.

33.2 Sizing/rating of load controllers

33.2.1 A load controller, other than specified in 33.2.2 shall:

a) Have a voltage rating not less than the rated voltage of the circuit;

b) Have an current rating not less than the sum of the current ratings of loads controlled with horsepower ratings converted to a full-load current rating in accordance with Table 50.1 and Table 50.2; and

c) Be rated for the type of load controlled as specified in Table 33.1.

Table 33.1
Required controller ratings for various load types

Controller rating		Usable load types
Type	Units	
ac heater or resistive	ac amperes	ac heater loads
dc heater or resistive	dc amperes	dc heater loads
ac amperes, general-purpose or general-use	ac amperes	ac non-motor-operated appliance or ac heater loads, ac power transformer for non-motor loads
dc amperes, general-purpose or general-use	dc amperes	dc non-motor-operated appliance or dc heater loads
ac tungsten	ac amperes or watts	ac lighting load, ac heater load
dc tungsten	dc amperes or watts	dc lighting load, dc heater load
ac definite-purpose motor	FLA and LRA	ac hermetic refrigerant compressor motor, ac non-motor-operated appliance, or ac heater loads
dc definite-purpose motor	FLA and LRA	dc hermetic refrigerant compressor motor, dc non-motor-operated appliance, or dc heater loads
ac motor, Design B, C, or D	horsepower	ac motor, ac motor-operated appliance, ac non-motor-operated appliance, ac heater loads, ac fluorescent ballast load, ac power transformer for motor loads
dc motor	horsepower	dc motor, dc motor-operated appliance, dc non-motor-operated appliance, or dc heater loads

33.2.2 A switching device located on the line side of a variable speed drive and intended to be operated under load shall comply with 33.2.1, except the ampere rating shall be based on the input current rating of the variable speed drive. See 33.2.3 for manually-operated switches located on the line side of a variable speed drive and not intended to be operated under load.

33.2.3 A manually-operated switch located on the line side of a variable speed drive and not intended to be operated under load shall:

a) Have an ampere rating based on the input current rating of the variable speed drive;

b) Have:

1) An ac voltage rating not less than the rated ac input voltage of the variable speed drive; or

2) An ac voltage rating multiplied by the square root of 2 or a dc voltage rating that is not less than the rated dc input voltage of the variable speed drive; and

c) Have a marking as specified in 57.2 located next to the operating handle of the switch.

33.3 Location

33.3.1 A load controller marked with the words "break all lines" or having a diagram illustrating a break all lines configuration shall have contacts in each conductor to the load. Other controllers, not marked "break all lines" shall be configured with contacts in one conductor to a single-phase load and in two conductors to a three-phase load.

33.4 Reversing motor controllers

33.4.1 A reversing motor controller shall consist of two controllers that comply with 33.1.3 and shall additionally be provided with one or more of the following means to prohibit energization of both controllers simultaneously:

a) Electrically interlocked coils via control circuitry; or

b) Mechanically interlocked by a device that complies with 33.1.3.

33.5 Wye-delta motor controllers

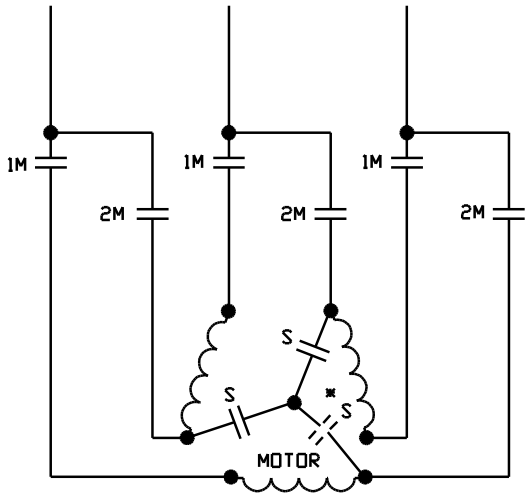
33.5.1 A motor controller intended to be used in an open or closed transition wye-delta starter shall have a locked rotor and full-load current rating not less than the "make" and "break" currents shown in Table 33.2, respectively, for its position in the circuit, as illustrated in Figure 33.1. The rated full-load current rating for a contactor and a motor load rated in horsepower shall be determined from Table 50.1, and the corresponding locked-rotor amperes shall be six times the full-load current rating or rated locked rotor current. When standard size contactors are used and motor locked rotor current does not exceed six times the full-load current rating, the contactor size and resulting wye-delta motor rating shall be as specified in Table 33.3. The minimum horsepower ratings corresponding to standard size contactors are shown in Table 33.4.

33.5.2 The contactor sequencing shall be as shown in Figure 33.1 with the coils electrically or mechanically interlocked to prohibit simultaneous energization.

Figure 33.1

Contactor sequencing

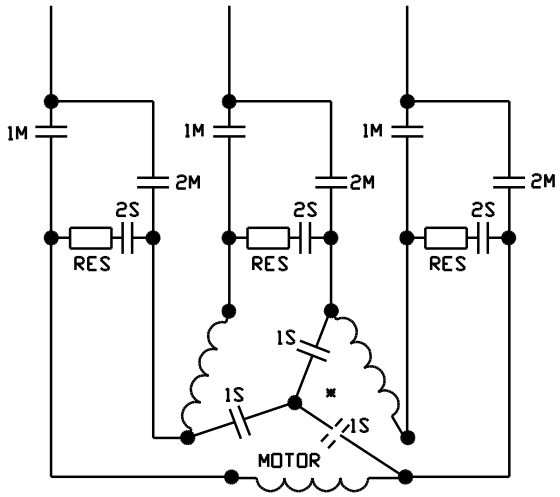
OPEN-CIRCUIT TRANSITION



* ALTERNATE METHOD

CONTACTOR SEQUENCE				
CON-TACTOR	START		TRAN-SITION	RUN
1M		X	X	X
2M				X
S	X			

CLOSED-CIRCUIT TRANSITION



* ALTERNATE METHOD

CONTACTOR SEQUENCE						
CON-TACTOR	START		TRANSITION			RUN
			1	2	3	
1M		X	X	X	X	X
2M					X	X
1S	X		X			
2S			X	X	X	

SM1261

Table 33.2
Contactor sizing for wye-delta controller

Contactor designation	Required contactor current rating	
	"make" current, LRA	"break" current, FLA
1M	0.33 multiplied by motor LRA	0.577 multiplied by motor FLA
2M	0.577 multiplied by motor LRA	0.577 multiplied by motor FLA
1S	No current	0.33 multiplied by motor LRA
2S	a	a

[a] Rating of contactor shall be determined based on the impedance provided.

Table 33.3
Horsepower ratings of wye-delta controllers using standard size contactors

Size of controller	Size of contactor[a]		3-phase horsepower			
			60 Hz	60 Hz	50 Hz	60 Hz
	M1 and M2	S	200 volts	230 volts	380 volts	460 or 575 volts
1YD	1	1	10	10	15	15
2YD	2	2	20	25	40	40
3YD	3	3	40	50	75	75
4YD	4	4	60	75	150	150
5YD	5	5	150	150	250	300
6YD	6	6	300	350	500	700
7YD	7	6	500	500	800	1000
8YD	8	7	750	800	1000	1500
9YD	9	8	1500	1500	2000	3000

NOTE – For motors having locked rotor currents greater than 6 times the full-load current, use Table 33.2.

[a] See Table 33.4 for horsepower ratings corresponding to standard size contactors.

Table 33.4
Horsepower ratings for standard size full-voltage magnetic motor controllers

Size of controller	3-phase horsepower			
	60 Hz	60 Hz	50 Hz	60 Hz
	200 volts	230 volts	380 volts	460 or 575 volts
1	7-1/2	7-1/2	10	10
2	10	15	25	25
3	25	30	50	50
4	40	50	75	100
5	75	100	150	200
6	150	200	300	400
7	–	300	–	600
8	–	450	–	900
9	–	800	–	1600

NOTE – For motors having locked-rotor currents greater than 6 times the full-load current, use Table 33.2.

33.6 Controllers for multi-speed and part winding motors

33.6.1 A controller provided for a winding of a multi-speed motor or a part winding motor shall comply with 33.2.1 based on the full-load current rating of the winding.

33.7 Autotransformer- and resistor-type reduced voltage motor controllers

33.7.1 For an autotransformer- type or resistor-type reduced voltage motor controller shall comply with the requirements in the Standard for Industrial Control Equipment, UL 508.

34 Overload Protection of Motor Loads

34.1 Component requirements

34.1.1 An overload relay, including a mechanically- or electrically-operated type a solid-state motor controller with integral overload protection, a manual motor starter and an overload unit of a self-protected combination motor controller shall comply with the requirements in the Standard for Industrial Control Equipment, UL 508.

34.1.2 Power conversion equipment that includes a solid-state motor overload protection function shall comply with the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1. Instructions provided with the power conversion equipment shall indicate the adjustable range and means for adjustment. Instructions provided with power conversion equipment that is not provided with a motor overload function or where the motor overload function has not been evaluated shall indicate that a separate overload device is required, as specified in 34.1.1, 34.1.3, or 34.3.4.

34.1.3 Overload protection provided by a thermal device integral to the motor shall comply with 34.3.3.

34.1.4 A motor protection circuit breaker that includes motor overload protection function shall comply with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489. Instructions provided with the motor protection circuit breaker shall indicate the adjustable range and means for adjustment.

34.2 Sizing of overload relay

34.2.1 An overload relay with replaceable units shall be capable of receiving a heater element that has an ampere trip rating that includes 115 percent of the motor full-load amperes.

34.2.2 An overload relay with a mechanical or electronic adjustment shall be capable of being set at an ampere rating of 115 percent of the motor full-load amperes.

34.3 Location

34.3.1 Motor overload protection shall be provided for each individual motor circuit.

Exception No. 1: Branch circuit protection complying with 34.3.4 is not required to comply with this requirement.

Exception No. 2: A panel having a field wiring diagram marked in accordance with 60.1 to indicate that required protection is to be provided in the field is not required to comply with this requirement.

Exception No. 3: Individual motor circuits intended to supply field installed thermally, impedance, or electronically protected motors and marked in accordance with 50.4 are not required to comply with this requirement.

34.3.2 The minimum number of poles and location of overload units shall be in accordance with Table 34.1.

Table 34.1
Overload units

Kind of motor	Supply system	Number and location of overload units, such as trip coils, relays or thermal cutouts[a]
1 phase ac or dc	Two wire, 1 phase ac or dc ungrounded	One in either conductor
1 phase ac or dc	Two wire, 1 phase ac or dc one conductor grounded	One in ungrounded conductor
1 phase ac or dc	Three wire, 1 phase ac or dc, grounded-neutral	One in either ungrounded conductor
2 phase ac	Three wire, 2 phase ac, ungrounded	Two, one in each phase
2 phase ac	Three wire, 2 phase ac one conductor grounded	Two in ungrounded conductors
2 phase ac	Four wire, 2 phase ac grounded or ungrounded	Two, one per phase in ungrounded conductors
2 phase ac	Five wire, 2 phase ac grounded neutral or ungrounded	Two, one per phase in any ungrounded phase wire
3 phase ac	Any 3 phase	Three, one in each phase

[a] When using a 3-pole overload relay for a 1-phase or 2-phase circuit, manufacturer's instructions shall be referenced for handling of additional poles.

34.3.3 Motor overload protection provided by a thermal device, such as a thermostat, integral to the motor winding shall have provision for the leads to be connected directly to the ungrounded conductor of the motor controller coil circuit. The industrial control panel shall be marked to indicate the location where the thermal device is intended to be connected into the motor control circuit in accordance with 50.4 and 52.2. Motor overload protection provided by a thermal device integral to the motor winding with no connection to the motor control circuit shall be indicated by a marking on the industrial control panel in accordance with 50.4 and 60.1.

34.3.4 Branch circuit protection complying with 34.3.2 and sized with not more than 115 percent of the motor full-load current rating provides required motor overload protection as well as required branch circuit protection. A marking shall be located next to the fuseholder in accordance with 56.1.

34.3.5 An intermittent-duty motor that is not able to be operated continuously due to the inclusion of limit switches or timers is not required to be provided with motor overload protection.

34.3.6 An overload relay provided as part of a wye-delta controller shall be located on the load side of contactor M1 and shall be sized in accordance with 34.2.1 or 34.2.2, based on 0.577 multiplied by the motor full-load current. The starting time of the motor shall be coordinated with the overload relay class, Class 20 (20 s). For starting times greater than 60 seconds, where the motor is manually started and the start switch is not able to be left in the "on" position, the overload relay elements are able to be shunted out during the starting period.

34.3.7 An overload relay shall be provided for each winding of a multi-speed motor or a part winding motor based on the full-load current rating of the winding.

35 Power Transformers

35.1 Component requirements

35.1.1 A general purpose transformer shall comply with the requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2.

35.1.2 A dry-type general purpose or power transformer shall comply with the Standard for Dry Type General Purpose and Power Transformers, UL 1561.

35.2 Sizing of overcurrent protection for power transformer

35.2.1 Overcurrent protection of power transformer primary side only

35.2.1.1 The primary winding shall be provided with a set of branch circuit fuses or an inverse-time circuit breaker rated at not more than Table 35.1.

Table 35.1
Sizing of primary winding only branch circuit protection

Power transformer primary current, amperes	Rating of branch circuit protection maximum percentage of primary current
9 or more	125[a]
2 – 8.99	167
less than 2	300

[a] Where the calculated size of the branch circuit protection does not correspond to a standard size fuse or nonadjustable inverse-time circuit breaker, the next larger size is able to be used. See 31.3.8 for standard sizes of branch circuit protection.

35.2.1.2 The secondary conductors of a power transformer having branch circuit protection located on the primary side only, as in 35.2.1.1, and with:

a) A two-wire single voltage secondary; or

b) A three-wire 3-phase single voltage secondary with both primary and secondary sides connected in a delta configuration

shall be sized with an ampacity in accordance with Table 28.1, not less than the rating of the primary branch circuit protection multiplied by the primary to secondary transformation ratio. A power transformer, other than as specified in this requirement, shall comply with 35.2.2.

35.2.2 Overcurrent protection of power transformer primary and secondary

35.2.2.1 A set of branch circuit fuses or an inverse-time circuit breaker provided for both the primary and secondary sides of a power transformer shall be sized in accordance with Table 35.2. A transformer with multiple secondary windings shall be provided with a set of branch circuit fuses or an inverse-time circuit breaker for each secondary sized in accordance with Table 35.2.

Table 35.2
Sizing of primary and secondary branch circuit protection of a power transformer

Primary winding		Secondary winding	
Rated amperes	Branch circuit protection, percent of rated amperes	Rated amperes	Branch circuit protection, percent of rated amperes
9 or more	250	9 or more	125[a]
2 – 8.99	250	less than 9	167
less than 2	300	–	–

[a] Where the calculated size of the branch circuit protection does not correspond to a standard size fuse or nonadjustable inverse-time circuit breaker, the next larger size is able to be used. See 31.3.8 for standard sizes of branch circuit protection.

35.2.2.2 The overcurrent protection provided in the secondary of the power transformer shall consist of:

a) A single set of branch circuit fuses or an inverse-time circuit breaker sized in accordance with Table 35.2; or

b) More than one set of branch circuit fuses or an inverse-time circuit breaker, each supplying a parallel circuit, where the sum of the ampere ratings of the overcurrent protective devices does not exceed the maximum specified rating from Table 35.2.

35.3 Location

35.3.1 Branch circuit protection shall be located in each ungrounded conductor of the primary winding or primary and secondary winding.

Exception: Individual branch circuit protection, carrying only the primary current, is not required to be provided where the upstream primary overcurrent protection provides the required protection.

35.4 Low-voltage limited energy circuits

35.4.1 General

35.4.1.1 A low-voltage limited energy circuit shall comply with 43.1.2 and shall be supplied from a power transformer that complies with 35.1.1 or 35.1.2. The secondary winding shall be grounded so that the voltage to ground at each conductor supplying the low-voltage limited energy circuit is within the voltage limits of 43.1.2.

35.4.1.2 The overcurrent protection provided in the secondary of the power transformer shall consist of a set of branch circuit fuses or an inverse-time circuit breakers sized in accordance with Table 43.1.

35.4.2 Secondary side requirements

35.4.2.1 Components and wiring located entirely within the low-voltage limited energy circuit are not required to be investigated.

35.4.2.2 Internal wiring shall comply with the separation of circuits requirements of 29.5 and, where routed with conductors of other circuits, shall comply with 38.1.

35.4.2.3 Field wiring terminals of a low-voltage limited energy circuit shall comply with 37.3.1.

36 Other Circuit Components

36.1 Capacitors

36.1.1 A capacitor employing a liquid medium more combustible than askarel shall comply with the protected oil-filled capacitor requirements in the Standard for Capacitors, UL 810, and shall comply with 36.1.2 – 36.1.5. See 10.4 for spacing requirements.

36.1.2 An oil-filled motor start or run capacitor in series with a motor winding shall have an available fault current (AFC) marking of not less than 5,000 amperes for a motor load rated less than 50 horsepower (37.3 kW). The capacitor AFC rating shall be included in the determination of the short circuit current rating of an industrial control panel that is marked in accordance with the requirements in Supplement SB.

36.1.3 An oil-filled capacitor connected across-the-line, without other impedances in series, shall have an available fault current (AFC) rating of not less than 10,000 amperes. The capacitor AFC rating shall be included in the determination of the short circuit current rating for an industrial control panel marked in accordance with the requirements in Supplement SB.

36.1.4 An oil-filled capacitor in series with other components shall have an available fault current rating not less than the current obtained by dividing the rated circuit voltage by the impedance of the other components.

36.1.5 A dry-type or an oil-filled capacitor shall have a voltage rating not less than the rated circuit voltage.

36.1.6 A dry-type capacitor connected across-the-line, without other impedances in series, shall comply with the Dielectric Voltage Withstand Test in the Standard for Industrial Control Equipment, UL 508.

36.2 Resistors

36.2.1 A resistor shall comply with the Standard for Industrial Control Equipment, UL 508.

36.2.2 A resistor, including a motor braking resistor or a resistor in a closed transition wye-delta motor starter, shall be used within its wattage rating.

36.2.3 When evaluating spacings in Section 10, Spacings, the body of a resistor is an uninsulated live part.

Exception: A resistor embedded in a metal sheath and mounted to grounded metal that complies with the Dielectric Voltage Withstand Test in the Standard for Industrial Control Equipment, UL 508, is not required to be evaluated to this requirement.

36.2.4 Insulating materials and internal wiring shall not contact a resistor body.

36.2.5 The ampacity of conductors to a resistor that is not for continuous duty shall be sized in accordance with Table 28.1 based on the motor full-load current multiplied by the derating factor (percentage) from Table 36.1. Circuits with "on" and "off" times different from those in Table 36.1 shall be sized using the percent "on" time.

Exception: A resistor that is part of a product covered by this standard is not required to comply with 36.2.

Table 36.1
Conductor rating factor for power resistors

Time, seconds		"On" time, percent	Ampacity of conductors in percent of motor full-load current
On	Off		
5	75	6.25	35
10	70	12.50	45
15	75	16.67	55
15	45	25.00	65
15	30	33.33	75
15	15	50.00	85

36.3 Reactors

36.3.1 A reactor shall comply with one of the following:

a) The Standard for Industrial Control Equipment, UL 508;

b) The Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2;

c) The Standard for Dry-Type General Purpose and Power Transformers, UL 1561; or

d) The Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical Thermal and Energy, UL 61800-5-1.

36.3.2 A reactor shall be used within its voltage, frequency, and current or horsepower ratings.

Exception: A reactor that is part of a product covered by this standard is not required to comply with 36.3.

36.4 Surge protective devices (SPDs)

36.4.1 An SPD shall comply with the requirements in the Standard for Surge Protective Devices, UL 1449.

36.4.2 The normal operating voltage rating and MCOV SPD shall not be less than the rated circuit Line-to-Line (full phase) voltage.

36.4.3 Where provided, a SPD shall be connected to each ungrounded conductor. The conductors used to connect the SPD to line and to ground shall not be longer than required and shall not have more bends than required by the construction. Line and ground connecting conductors to a SPD shall not be smaller than 14 AWG (2.1 mm^2).

36.4.4 An SPD marked with a slash voltage rating shall only be used in a circuit where the source is solidly grounded as noted in 16.3 when voltage is from transformer or power supply provided within the industrial control panel, or by marking the slash voltage rating on the industrial control panel nameplate in accordance with 49.6(a), as appropriate. An SPD marked for use on a delta system, such as "600V delta", can be used on either a wye or a delta system.

36.5 Line filters

36.5.1 An electromagnetic interference (EMI) or radio frequency interference (RFI) filter shall comply with the Standard for Electromagnetic Interference Filters, UL 1283 or the Standard for Passive Filter Units

for Electromagnetic Interference Suppression – Part 3: Passive Filter Units for Which Safety Tests are Appropriate, UL 60939-3.

36.5.2 An active or passive harmonic filter shall comply with the Standard for Industrial Control Equipment, UL 508, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1.

36.5.3 A line filter, as described in 36.5.1 and 36.5.2, shall have a voltage rating not less than the rated circuit voltage, and have a current rating that is not less than the sum of the current ratings of all connected loads or not less than the ampacity of the internal wiring conductors.

CONTROL CIRCUITS

37 Field Wiring Terminals

37.1 Component requirements

37.1.1 A field wiring terminal for connection to a control circuit shall comply with 28.2.1 – 28.2.3, 28.2.5 or 28.7.

Exception: A terminal that complies with 37.4.1 or the Exception to 37.3.1 is not required to comply with this requirement.

37.2 Sizing

37.2.1 The required size of a field wiring terminal for a control circuit shall not be less than 14 AWG (2.1 mm^2) conductor minimum and shall be determined by the ampere rating of the upstream overcurrent protective device outside the panel, at the input terminals inside the panel for power input, or on the rating of the secondary winding of a control transformer or overcurrent protection inside the panel for all other connections.

Exception: The required size of a field wiring terminal rated for 10 amperes or less shall comply with Table 37.1.Where Table 37.1 specifies use of a marking, the field wiring diagram shall be marked to indicate the required size of field wiring (see 54.9).

Table 37.1
Ampacities of field wiring conductors smaller than 14 AWG (2.1 mm^2)

Maximum control circuit terminal ampacity, amperes	Minimum terminal wire range		Marking required
	AWG	(mm^2)	
10	16	(1.3)	yes
10	16 – 14	(1.3 – 2.1)	no
7	18	(0.82)	yes
7	18 – 14	(0.82 – 2.1)	no
5	20 – 18	(0.52 – 0.82)	yes
5	20 – 14	(0.52 – 2.1)	no
3	22 – 18	(0.32 – 0.82)	yes
3	22 – 14	(0.32 – 2.1)	no

Table 37.1 Continued on Next Page

Table 37.1 Continued

Maximum control circuit terminal ampacity, amperes	Minimum terminal wire range		Marking required
	AWG	(mm^2)	
2	24 – 18	(0.20 – 0.82)	yes
2	24 – 14	(0.20 – 2.1)	no
1	26 – 18	(0.13 – 0.82)	yes
1	26 – 14	(0.13 – 2.1)	no
0.8	28 – 18	(0.08 – 0.82)	yes
0.8	28 – 14	(0.08 – 2.1)	no
0.5	30 – 18	(0.05 – 0.82)	yes
0.5	30 – 14	(0.05 – 2.1)	no

37.3 Field wiring terminals of a low-voltage limited energy circuit

37.3.1 A terminal for a field wiring connection to a low-voltage limited energy circuit that is not segregated from other circuits as in 37.5.1 shall comply with 37.1 and 37.2 and shall be marked to use Class 1 wiring for these circuits as indicated in 54.6.

Exception: A field wiring terminal for a low-voltage limited energy circuit that is segregated from other Class 1 and power circuit terminals and also from Class 2 circuit terminals is not required to comply with 37.1 and 37.2.

37.4 Field wiring terminals of Class 2 circuits

37.4.1 A terminal for a field wiring connection to a Class 2 circuit is not required to comply with 37.1 and 37.2. Such a terminal shall comply with the segregation of circuits requirements in 37.5.1 and shall be marked to use Class 2 wiring for these circuits as specified in 54.7.

37.5 Separation of circuits

37.5.1 A field wiring terminal intended to be connected to a Class 2 circuit and field wiring terminals of a low-voltage limited energy circuit that does not comply with 37.1 and 37.2 shall comply with 28.4.1 and 28.4.2.

37.6 Receptacles

37.6.1 Receptacles for field wiring connection of a control circuit shall comply with 28.6.

Exception: A receptacle intended for connection to a Class 2 circuit or a low-voltage limited-energy circuit is not required to comply with this requirement.

37.7 Flexible cords

37.7.1 A cord for field wiring connection of a control circuit shall comply with 28.5.

Exception: A cord for connection to a Class 2 circuit or a low-voltage limited-energy circuit is not required to comply with this requirement.

37.8 Cable assemblies and fittings

37.8.1 Cable assemblies, male and female cable fittings, panel-mounted fittings and fittings intended for use in remote-control, signaling, and power-limited circuits shall comply with the requirements in the Standard for Cable Assemblies and Fittings for Industrial Control and Signal Distribution, UL 2238, or the Outline of Investigation for Multi-Point Interconnection Power Cable Assemblies for Industrial Machinery, UL 2237.

Exception: Cable assemblies and fittings for connection to a Class 2 circuit or a low-voltage limited-energy circuit are not required to comply with this requirement.

38 Internal Wiring

38.1 Component requirements

38.1.1 Internal wiring of a control circuit shall comply with 29.1.1, 29.1.2, and one of the following:

a) As specified in 29.2.1, except for conductors 16 AWG (1.3 mm^2) or smaller, the minimum temperature rating shall be 60°C (140°F);

b) Requirements for power limited cable in the Standard for Power-Limited Circuit Cables, UL 13, for use in Class 2 or low-voltage limited energy circuits only and where separated from internal wiring of other circuits as specified in 29.5; or

c) Requirements for communication cable in the Standard for Communications Cables, UL 444, for use in Class 2 or low-voltage limited energy circuits only and where separated from internal wiring of other circuits as specified in 29.5.

38.2 Sizing of internal control circuit conductors

38.2.1 The required size of internal wiring in a control circuit shall be determined by:

a) The ampere rating of overcurrent protection for the control circuit or the ampere rating of the secondary of a transformer or power supply; and

b) Determining the minimum wire size corresponding to the required ampacity based on:

1) Table 28.1; or

2) Table 38.1.

Table 38.1
Ampacities of control circuit conductors

Ampacity, amperes	Conductor size	
	AWG	(mm^2)
10	16	(1.3)
7	18	(0.82)
5	20[b]	(0.52)
3	22[b]	(0.32)
2	24[b]	(0.20)

Table 38.1 Continued on Next Page

Table 38.1 Continued

Ampacity, amperes	Conductor size	
	AWG	(mm^2)
1	26[b]	(0.13)
0.8	28[a, b]	(0.08)
0.5	30[a, b]	(0.05)

[a] Where these conductors are contained in a jacketed multi-conductor cable assembly or for jumpers or special wiring applications.

[b] These sizes of conductors are only for connection of electronic control input/output and control devices.

38.3 Wiring methods, wire routing, and separation of circuits for internal wiring of a control circuit

38.3.1 Internal wiring of a control circuit shall comply with 29.3, 29.4, and 29.5.

39 Disconnecting Means

39.1 A control circuit intended to be supplied from a separate source shall be provided with a disconnecting means that complies with Section 30, Disconnect Switches.

40 Overcurrent Protection

40.1 Component requirements

40.1.1 A branch circuit fuse shall comply with 31.1.2 or an inverse-time circuit breaker complying with 31.1.1.

40.1.2 A miscellaneous or miniature type fuse shall comply with the Standard for Low-Voltage Fuses – Part 14: Supplemental Fuses, UL 248-14.

40.1.3 An overcurrent trip-type supplementary protector shall comply with the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077. A supplementary protector that is connected to the load side of a branch circuit protective device (not in an isolated secondary circuit) shall be additionally evaluated as to its performance under fault conditions.

40.1.4 A fuseholder shall comply with the Standard for Fuseholders – Part 1: General Requirements, UL 4248-1, and the applicable Part from the UL 4248 series.

40.1.5 Where a branch circuit fuse, inverse-time circuit breaker, miscellaneous or miniature type fuse, or supplemental protector is applied in a dc circuit with a voltage above 32 V, it must be evaluated in accordance with the appropriate product standard to have a dc voltage rating equal to or greater than the circuit voltage.

40.1.6 A manual motor controller marked “suitable for tap conductor protection” that is used to provide supplementary overcurrent protection for a control transformer or power supply on the load side of a motor branch circuit protective device shall comply with the requirements in UL 508, Standard for Industrial Control Equipment or UL 60947-4-1, Low Voltage Switchgear and Controlgear, Part 4-1 Electromechanical Contactors and Starters.

40.2 Location of overcurrent protective devices

40.2.1 A branch circuit protective device complying with 40.1.1 shall be installed in each ungrounded conductor to a control circuit that is supplied from a separate source voltage (not an isolated secondary).

Exception: An industrial control panel intended to be connected to the load side of a branch circuit protective device installed in the field shall be marked with the required size and type of branch circuit protection sized in accordance with 40.3.1. See 60.2 for marking.

40.2.2 An overcurrent protective device, either branch circuit or supplementary type, shall be installed in each ungrounded conductor of the control circuit on the load side of the branch circuit protection in the power circuit or as specified in 40.2.1 to protect smaller tap conductors where they receive their supply and sized in accordance with 40.3.2.

40.2.3 A manual motor controller marked “suitable for tap conductor protection” providing supplementary overcurrent protection for a control transformer or power supply shall be installed with one or more poles in each ungrounded circuit conductor supplying the control transformer. The manual motor controller shall be connected so that all poles carry current, unless otherwise specified in the manufacturer’s instructions.

40.3 Sizing of overcurrent protection

40.3.1 Branch circuit protective devices provided in accordance with 40.2.1 shall not be rated more than 20 amperes.

40.3.2 Overcurrent protection shall be sized based on:

a) The ampacity of the control circuit conductor;

b) The source of the control circuit voltage in accordance with Section 41, Sizing of Overcurrent Protection – Control Circuits (Common), Section 42, Overcurrent Protection – Control Circuits (Isolated Secondary), Section 43, Low-Voltage Limited Energy Circuits, or Section 44, Class 2 Circuits; or

c) A component requirement, as specified in 40.3.3.

40.3.3 Additional overcurrent protective devices shall be provided to protect conductors having an ampacity less than required in 38.2.1(a) and individual components or circuits according to instruction provided with the component.

Exception No. 1: A component, such as an output module of a programmable controller, which is provided with a protective device that complies with 40.3.2, is not required to be provided with additional overcurrent protective devices.

Exception No. 2: Direct leads, such as leads integrally attached to a component, measuring a maximum of 12 inches (305 mm) long or printed wiring board assemblies of components having no connection external to the industrial control panel do not require additional overcurrent protection.

40.3.4 A fuseholder shall be sized to accept a fuse sized in accordance with 40.3.1 or 40.3.2. The fuseholder shall be marked with the replacement fuse marking of 56.1.

Exception: A fuseholder for a branch circuit fuse that does not accept a fuse having a greater current rating is not required to be marked with a fuse replacement marking.

40.3.5 A general-use receptacle provided in a control circuit shall:

a) Have overcurrent protection not exceeding the rating of the receptacle; and

b) Be restricted to use with programming and diagnostic devices.

The receptacle shall be marked in accordance with 59.3.

40.3.6 The overcurrent protection provided by a supplementary protector shall be sized as specified in 40.3.2 based on the tripping current designated on the manufacturer's trip curve for the device. The rated current to be carried by the supplementary protector shall not exceed the nominal ampere rating of the device.

40.3.7 A manual motor controller marked “suitable for tap conductor protection” providing supplementary overcurrent protection for a control transformer or power supply shall be adjusted so that the tripping current is not greater than the maximum current determined from Table 42.1 or Table 42.2.

41 Sizing of Overcurrent Protection – Control Circuits (Common)

41.1 The conductors of a control circuit tapped off the load side of the branch circuit protective device shall have overcurrent protection sized in accordance with the ampacity of the control circuit conductor as specified in Table 28.1 or Table 38.1.

Exception No. 1: When the control circuit is tapped off a motor branch circuit protective device and the control wires do not leave the industrial control panel enclosure (such as when a start-stop button is provided on the enclosure cover) the motor branch circuit protective device provides the required overcurrent protection when its rating does not exceed that specified in Table 41.1.

Exception No. 2: When the control circuit is tapped off a motor branch circuit protective device and the control wires leave the industrial control panel enclosure (such as when a start-stop button is field connected as a remote control device) the motor branch circuit protective device provides the required protection when its rating does not exceed that specified in Table 41.2.

Table 41.1
Motor branch circuit protection of common control circuit without remote control devices

Control circuit wire size		Maximum protective device rating, amperes
AWG	(mm^2)	
22	(0.32)	12
20	(0.52)	20
18	(0.82)	25
16	(1.3)	40
14	(2.1)	100
12	(3.3)	120

Table 41.2
Motor branch circuit protection of common control circuit with remote control devices

Control circuit wire size		Maximum protective device rating, amperes
AWG	(mm^2)	
22	(0.32)	3
20	(0.52)	5
18	(0.82)	7
16	(1.3)	10
14	(2.1)	45
12	(3.3)	60

42 Overcurrent Protection – Control Circuits (Isolated Secondary)

42.1 Control transformers

42.1.1 Component requirements

42.1.1.1 A control transformer shall comply with the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1 and the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2, or the Standard for Dry-Type General Purpose and Power Transformers, UL 1561.

42.1.2 Sizing of overcurrent protection of primary side only

42.1.2.1 The primary winding shall have individual overcurrent protection, carrying only the primary current, rated not more than specified in Table 42.1.

Exception: Individual overcurrent protection, carrying only the transformer primary current, is not required where the upstream primary overcurrent protection provides the required protection.

Table 42.1
Sizing of primary winding only overcurrent protection of a control transformer

Control transformer primary current, amperes	Rating of overcurrent protection, maximum percentage of primary current
9 or more	125[a]
2 – 8.99	167
less than 2	500

[a] Where the calculated size of the overcurrent protection, branch circuit or supplementary type, does not correspond to a standard size protective device, the next larger size is able to be used. See 31.3.8 for standard sizes of branch circuit protection.

42.1.2.2 The secondary conductors of a control transformer having overcurrent protection located on the primary side only, as described in 42.1.2.1, and with a two-wire single voltage secondary shall be sized with an ampacity in accordance with Table 28.1 or Table 38.1, that is not less than the rating of the primary side protective device multiplied by the primary to secondary transformation ratio. A control transformer, other than as noted in this requirement, shall require the secondary side to be protected as specified in 42.1.3.

42.1.3 Sizing of overcurrent protection of primary and secondary

42.1.3.1 Individual overcurrent protection on both the primary and secondary sides of a control transformer shall be sized in accordance with Table 42.2. A control transformer with multiple secondary windings shall have overcurrent protection in each secondary that is sized in accordance with Table 42.2.

Exception: Individual primary winding overcurrent protection, carrying only the primary winding current of the transformer, shall not be required when the upstream overcurrent protective device provides the required protection.

Table 42.2
Sizing of primary and secondary overcurrent protection of a control transformer

Primary winding		Secondary winding	
Rated amperes	Overcurrent protection percent of rated amperes	Rated amperes	Overcurrent protection percent of rated amperes
9 or more	250	9 or more	125[a]
2 – 8.99	250	less than 9	167
less than 2	500	–	–

[a] Where the calculated size of the overcurrent protection, branch circuit or supplementary type, does not correspond to a standard size protective device, the next larger size is able to be used. See 31.3.8 for standard sizes of branch circuit protection.

42.1.3.2 The overcurrent protection provided in the secondary of the control transformer shall consist of:

a) A single set of overcurrent protective devices specified in Table 42.2; or

b) More than one overcurrent protective device, where the sum of the ampere ratings does not exceed the maximum allowable rating from Table 42.2.

42.2 Power supplies

42.2.1 Component requirements

42.2.1.1 A power supply having an integral isolation transformer, including a linear or switch mode type power supply, shall comply with one of the following:

a) The Standard for Power Units Other Than Class 2, UL 1012;

b) The Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1;

c) The Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1;

d) The Standard for Industrial Control Equipment, UL 508; or

e) The Standard for Electrical Equipment for Measurement, Control, and Laboratory Use; Part 1: General Requirements, UL 61010-1, and the Standard for Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-201: Particular Requirements for Control Equipment, UL 61010-2-201.

42.2.1.2 A bridge rectifier that is mounted to a grounded metal heat sink shall comply with the Standard for Power Units Other Than Class 2, UL 1012, or the Standard for Electrically Isolated Semiconductor Devices, UL 1557.

42.2.2 Enclosure requirements

42.2.2.1 A power supply shall be installed in a non-ventilated enclosure, a ventilated enclosure where the ventilation is not fan-forced, or a fan-forced ventilated enclosure provided with filters over the ventilation openings.

Exception: A power supply that is encapsulated, in a hermetically sealed case, or provided with a non-ventilated housing, except for the terminals, is not required to comply with this requirement.

42.2.3 Sizing of power supply

42.2.3.1 A power supply or bridge rectifier shall be loaded at not more than 50 percent of the ampere rating of the device. Where the power supply has multiple secondaries, each secondary shall be loaded at not more than 50 percent of the secondary ampere rating.

Exception No. 1: An enclosed power supply having provisions for connection to conduit is able to be used for loading to 100 percent of the ampere rating of the power supply.

Exception No. 2: A power supply that complies with the Temperature Test in the Standard for Industrial Control Equipment, UL 508, or UL Standard for Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, UL 61010-2-201 is able to be used for loading to 100 percent of the ampere rating of the power supply.

42.2.3.2 Where the sum of the current ratings of all connected loads within the industrial control panel exceeds the maximum load current specified in 42.2.3.1, or where the secondary is intended for connection to external loads, each secondary circuit shall be protected by an overcurrent device sized in accordance with 42.2.3.1. The fuseholder shall be marked with the fuse replacement marking of 56.1.

42.2.3.3 A secondary conductor shall have an ampacity in accordance with Table 28.1 or Table 38.1, based on the secondary fuse rating or the rated current of the power supply secondary.

42.3 Other isolated secondary sources

42.3.1 Isolated secondary circuits that comply with the secondary circuits requirements in the Standard for Industrial Control Equipment, UL 508, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1, or the Standard for Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-201: Particular Requirements for Control Equipment, UL 61010-2-201, including the secondary circuit of a programmable controller or power conversion equipment, is not required to be provided with additional overcurrent protection. Conductors connected to these secondary circuits shall have an ampacity in accordance with Table 28.1 or Table 38.1, based on the secondary fuse rating or the rated current of the power supply secondary.

43 Low-Voltage Limited Energy Circuits

43.1 Component requirements

43.1.1 A low-voltage limited energy circuit shall comply with 43.1.2 and 43.1.3 and shall be supplied from one of the following isolated secondary sources:

a) A control transformer that complies with 42.1;

b) A power supply that complies with 42.2;

c) An isolated secondary source that complies with 42.3;

d) A sealed battery that complies with the Standard for Standby Batteries, UL 1989;

e) A lithium battery that complies with the Standard for Lithium Batteries, UL 1642;

f) A current transformer that complies with the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2; or

g) A current transformer with a 5-ampere secondary winding.

43.1.2 A low-voltage limited energy circuit shall have a maximum open-circuit secondary voltage of 30 volts ac rms, 42.4 volts peak, or 60 volts dc.

43.1.3 A low-voltage limited energy circuit shall have an overcurrent protection sized in accordance with Table 43.1.

Exception No. 1: A secondary circuit that complies with the Limited Voltage/Current Circuit Requirements for Secondary Circuits in the Standard for Industrial Control Equipment, UL 508, is not required to comply with this requirement.

Exception No. 2: A current transformer is not required to comply with this requirement.

Table 43.1
Overcurrent protection for a low-voltage limited energy circuit

Open-circuit secondary voltage, V	Maximum overcurrent device, amperes
0 – 20 (peak or dc)	5
20.1 – 42.4 (peak or dc)	100/V
42.5 – 60 (dc)	100/V
Where "V" is equal to the peak or dc open-circuit secondary voltage.	

43.2 Secondary side requirements

43.2.1 Components and wiring located entirely within the low-voltage limited energy circuit are not required to be investigated.

43.2.2 Internal wiring shall comply with the separation of circuits requirements of 29.5 and, where routed with conductors of other circuits, shall comply with 38.1.

43.2.3 Field wiring terminals of a low-voltage limited energy circuit shall comply with 37.3.1.

44 Class 2 Circuits

44.1 Component requirements

44.1.1 A Class 2 transformer shall comply with the requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3. A not inherently limited Class 2 transformer shall be provided with additional overcurrent protective devices in accordance with the manufacturer's instructions for the component.

44.1.2 A Class 2 power unit shall comply with the requirements in the Standard for Class 2 Power Units, UL 1310.

44.1.3 For the purposes of evaluating a circuit, a thermocouple is a Class 2 circuit.

44.1.4 Limited-power (limited energy) circuit supplied by a limited-power source for information technology equipment shall comply with the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, or the Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1.

44.2 Secondary side requirements

44.2.1 Components and internal wiring located entirely within a Class 2 circuit are not required to be investigated.

44.2.2 Internal wiring shall comply with the separation of circuits requirements in 29.5 and, where routed with conductors of other circuits, shall comply with 38.1.

44.2.3 Field wiring terminals shall comply with 37.4.1.

45 Switching Devices

45.1 Component requirements

45.1.1 Switching components of control circuit devices shall comply with one of the following:

a) An overload relay contact, pushbutton, plug-in dry-contact relay and relay socket, auxiliary contact, time-delay relay, and solid-state relay or timer, or programmable controller shall comply with the Standard for Industrial Control Equipment, UL 508, or the Standard for Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-201: Particular Requirements for Control Equipment, UL 61010-2-201, and shall be intended for general industrial use;

b) A snap or special-use switch, including a rocker, toggle, or pushbutton, shall comply with the Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1;

c) A clock-operated switch, such as a 24-hour timer, shall comply with the Standard for Clock-Operated Switches, UL 917;

d) A temperature controller shall comply with the requirements in the Standard for Temperature-Indicating and -Regulating Equipment, UL 873. Compliance with the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1, and/or the applicable Part 2 standard from the UL 60730 series fulfills these requirements; or

e) A process temperature controller shall comply with the applicable requirements for the product.

f) A emergency stop device, consisting of an actuator (providing mechanically held latching means) and contact block(s), and an emergency stop unit (that receives inputs from multiple emergency stop devices) shall comply with the requirements in the Standard for Low-voltage Switchgear and Controlgear – Part 5-5: Control Circuit Devices and Switching Elements – Electrical Emergency Stop Device with Mechanical Latching Function, UL 60947-5-5.

45.2 Sizing/ratings of control circuit switching devices

45.2.1 A switching device shall have:

a) A voltage rating not less than the rated load;

b) An ampere rating not less than the sum of the current ratings of the loads controlled; and

c) A rating corresponding to the type of load controlled, as specified in Table 45.1.

Table 45.1
Required controller ratings for various load types

Controller rating		Control circuit load types	Sizing
Type	**Units**		
ac resistive	ac amperes	ac control transformer, power supply, solid-state circuit device, pilot lamp or LED, annunciator or buzzer	up to 10 percent of ampere rating
ac general-use	ac amperes	ac non-motor-operated device-controlled transformer, power supply, ac solid-state circuit device, ac pilot lamp or LED, ac annunciator or buzzer	up to 100 percent of ampere rating
ac general-use	ac amperes	solenoid, valve, relay coil	up to 10 percent of ampere rating
dc general-use	dc amperes	dc non-motor operated device, dc solid-state circuit device, dc pilot lamp or LED	up to 100 percent of ampere rating
ac pilot duty	contact rating code,	ac relay or contactor coil,	VA rating per Table 45.2
	"light duty,"	control transformer,	125 VA
	"standard duty,"	solid-state circuit device,	360 VA
	"heavy duty,"	pilot lamp or LED,	720 VA
	horsepower	annunciator or buzzer	VA rating per Table 45.4
dc pilot duty	contact rating code	dc relay or contactor coil	VA rating per Table 45.3

Table 45.2
Rating codes for ac control circuit contacts at 50 and 60 hz

Contact rating code designation[a]	Thermal continuous test current, amperes	Maximum current, amperes[b, c]								Maximum volt-amperes	
		120 volts		240 volts		480 volts		600 volts			
		Make	Break	Make	Break	Make	Break	Make	Break	Make	Break
A150	10	60	6.0	–	–	–	–	–	–	7200	720
A300	10	60	6.0	30	3.0	–	–	–	–	7200	720
A600	10	60	6.0	30	3.0	15	1.5	12	1.2	7200	720
B150	5	30	3.0	–	–	–	–	–	–	3600	360
B300	5	30	3.0	15	1.5	–	–	–	–	3600	360
B600	5	30	3.0	15	1.5	7.5	0.75	6	0.60	3600	360
C150	2.5	15	1.5	–	–	–	–	–	–	1800	180
C300	2.5	15	1.5	7.5	0.75	–	–	–	–	1800	180
C600	2.5	15	1.5	7.5	0.75	3.75	0.375	3.0	0.30	1800	180
D150	1.3	3.6	0.60	–	–	–	–	–	–	432	72
D300	1.0	3.6	0.60	1.8	0.30	–	–	–	–	432	72
E150	0.5	1.8	0.30	–	–	–	–	–	–	216	36

[a] The numerical suffix designates the maximum voltage design values, which shall be 600, 300, 150 volts for suffixes 600, 300, and 150 respectively.

Table 45.2 Continued on Next Page

Table 45.2 Continued

Contact rating code designation[a]	Thermal continuous test current, amperes	Maximum current, amperes[b, c]								Maximum volt-amperes	
		120 volts		240 volts		480 volts		600 volts			
		Make	Break	Make	Break	Make	Break	Make	Break	Make	Break

[b] For maximum ratings at voltages between the maximum design value and 120 volts, the maximum make and break ratings are to be obtained by dividing the volt-amperes rating by the application voltage. For voltages below 120 volts, the maximum make current is to be the same as for 120 volts, and the maximum break current is to be obtained by dividing the break volt-amperes by the application voltage, but these currents are not to exceed the thermal continuous test current.

[c] Power factor 0.35 or less.

Table 45.3
Contact rating codes for dc control circuit contacts

Contact rating code designation[a]	Thermal continuous test current, amperes	Maximum make or break current, amperes[b, c]			Maximum make or break VA at 300 volts or less
		125 volts	250 volts	301 to 600 volts	
N150	10	2.2	–	–	275
N300	10	2.2	1.1	–	275
N600	10	2.2	1.1	0.40	275
P150	5.0	1.1	–	–	138
P300	5.0	1.1	0.55	–	138
P600	5.0	1.1	0.55	0.20	138
Q150	2.5	0.55	–	–	69
Q300	2.5	0.55	0.27	–	69
Q600	2.5	0.55	0.27	0.10	69
R150	1.0	0.22	–	–	28
R300	1.0	0.22	0.11	–	28

[a] The numerical suffix designates the maximum voltage design values which are to be 600, 300, and 150 volts for suffixes 600, 300, and 150, respectively.

[b] For maximum ratings at 300 volts or less, the maximum make and break ratings are to be obtained by dividing the volt-ampere rating by the application voltage, but the current values are not to exceed the thermal continuous test current.

[c] Inductive loads for control circuits specified in Section 46

Table 45.4
Conversion of horsepower to VA load ratings

Switch rating, horsepower	Corresponding volt-ampere rating, VA
1/10	144
1/8	182
1/6	211
1/4	278
1/3	345
1/2	470
3/4	662
1	768

45.3 Location

45.3.1 All control circuit contacts shall be arranged to open the ungrounded conductor to the coil.

Exception No. 1: Electrical interlock contacts on multi-speed motor controllers are not required to comply when the wiring to these contacts does not extend beyond the control enclosure.

Exception No. 2: Overload relay contacts are not required to comply when the wiring to these contacts does not extend beyond the control enclosure.

Exception No. 3: Contacts of multi-pole control circuit switching devices that simultaneously open both sides of the control circuit are not required to comply.

Exception No. 4: Ground test switching device contacts in ungrounded control circuits are not required to comply.

Exception No. 5: Solenoid test switching device contacts in ungrounded circuits are not required to comply.

Exception No. 6: Coils or contacts used in electronic control circuits are not required to comply.

Exception No. 7: "Run" pushbuttons for two hand operating are not required to comply when overcurrent protection is provided in each conductor.

45.4 Undervoltage protection

45.4.1 The control circuitry shall be arranged such that operation of motors or motor-operated appliances is not automatically re-started upon the return of power after an undervoltage condition, power failure, or motor overload relay cycling. The circuit shall directly control the motor controller, such as a three-wire momentary push to start circuit. The use of programmable components shall be permitted to be used as part of this circuit, when the operation provides equivalent protection.

Exception No. 1: Blower motors are not required to comply when moving parts are fully guarded.

Exception No. 2: Pump applications are not required to comply.

Exception No. 3: Lighting circuit applications are not required to comply.

46 Loads

46.1 Component requirements

46.1.1 A control circuit load shall comply with the following:

a) A pilot light shall comply with the Standard for Industrial Control Equipment, UL 508, and a miscellaneous lampholder shall comply with the Standard for Lampholders, UL 496;

b) An electrically-operated valve shall comply with the Standard for Electrically Operated Valves, UL 429;

c) A solenoid shall be evaluated for the intended use;

d) A time-indicating or time-recording device, including an hourmeter, or a synchronous motor shall comply with the Standard for Time-Indicating and -Recording Appliances, UL 863;

e) An electrically operated counter shall comply with the Standard for Time-Indicating and -Recording Appliances, UL 863;

f) An audible signal appliance, including a horn, bell, or buzzer, shall comply with the Standard for Audible Signaling Devices for Fire Alarm and Signaling Systems, Including Accessories, UL 464; and

g) A coil or input circuit to another control circuit switching device or to a load controller shall comply with other component requirements in this standard.

46.2 Location

46.2.1 All operating coils of electro-mechanical devices and indicator lamps, including the transformer primary winding of an indicator lamp, shall be directly connected to the grounded side of the control circuit.

Exception: A switching device that is provided within the industrial control panel as specified in the exceptions to 45.3.1 is able to be located between the coil and the grounded side of the control circuit.

46.3 Rating of control circuit load

46.3.1 The rating of a control circuit load, other than those specified in 46.3.2 or 46.3.3, shall be determined from the ampere, volt-ampere, or wattage rating of the device.

46.3.2 The volt-ampere rating of a coil of an electro-mechanical relay or contactor shall be:

a) As marked on the coil; or

b) As specified in Table 46.1 when the coil is unmarked.

46.3.3 The rating of a control circuit load that is intended to be field connected to the industrial control panel shall be:

a) As specified in Table 46.1 for each relay or contactor coil;

b) 30 volt-amperes for each load described in 46.1.1 other than a relay or starter coil; or

c) Rating marked on the field wiring diagram as in 51.1 and 52.2.

Table 46.1
Relay or contactor coil ratings

Relay or contactor maximum ampere rating of contacts	Coil, VA
10	30
30	30
50	75
100	100
150	100
300	125

47 Miscellaneous Devices

47.1 Surge protective devices SPDs

47.1.1 An SPD used for overvoltage protection shall comply with the requirements in the Standard for Surge Protective Devices, UL 1449.

47.1.2 The normal operating voltage rating and MCOV of the SPD shall not be less than the rated circuit Line-to-Line (full phase) voltage.

47.1.3 A protector for data communications and fire-alarm circuits shall comply with the Standard for Protectors for Data Communications and Fire-Alarm Circuits, UL 497B.

47.1.4 *Deleted*

47.1.5 A dry-type capacitor that is placed across the line, without other impedances in series, shall comply with the Dielectric Voltage Withstand Test in the Standard for Industrial Control Equipment, UL 508.

47.1.6 A capacitor, an axial lead diode, and a transient voltage surge suppressor shall have a rated voltage not less than the rated circuit voltage.

47.2 Resistors

47.2.1 A resistor, including a potentiometer or thumbwheel, shall comply with 36.2.2 – 36.2.4.

47.2.2 A potentiometer or thumbwheel shall not be accessible from outside the industrial control panel enclosure unless it is connected to an isolated secondary circuit rated not more than 30 Vac (42.4 Vdc).

47.3 UPS (Uninterruptible Power-Supply) Equipment

47.3.1 UPS equipment shall comply with the requirements in:

a) The Standard for Uninterruptible Power Systems, UL 1778; and

b) 47.3.2 and 47.3.3.

47.3.2 The industrial panel enclosure shall be ventilated unless the UPS equipment batteries are of a sealed type construction or provided with capacitors in lieu of batteries.

47.3.3 The industrial control panel enclosure containing the UPS equipment shall be marked in accordance with 55.8.

Exception: This marking shall not be required for UPS equipment with outputs operating at 50 volts or less.

47.4 Line filters

47.4.1 An electromagnetic interference (EMI) or radio frequency interference (RFI) filter shall comply with the Standard for Electromagnetic Interference Filters, UL 1283 or the Standard for Passive Filter Units for Electromagnetic Interference Suppression – Part 3: Passive Filter Units for Which Safety Tests are Appropriate, UL 60939-3.

47.4.2 An active or passive harmonic filter shall comply with the Standard for Industrial Control Equipment, UL 508, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1.

47.4.3 A line filter, as described in 47.4.1 and 47.4.2, shall have a voltage rating not less than the rated circuit voltage, and have a current rating that is not less than the sum of the current ratings of all connected loads or not less than the ampacity of the internal wiring conductors.

48 Pneumatic Switching Devices

48.1 A pneumatic control circuit switching device operating at pressures greater than 300 psi (2.07 MPa) shall comply with the requirements for pressure-operated switches in the Standard for Industrial Control Equipment, UL 508.

48.2 A pneumatic control circuit shall operate on compressed air.

RATING

49 Supply Ratings

49.1 The input terminals intended to be connected to each source of supply shall be rated in volts, total full-load current rating, full-load current or horsepower rating of the largest motor (when multiple loads are controlled), number of phases when other than single phase, and the frequency.

49.2 The full-load current rating of the panel shall, at a minimum, include the sum of the current ratings of all loads that are able to be operated simultaneously plus the primary current rating of all control transformers connected to the input voltage.

49.3 The largest motor rating shall be determined based upon the full-load current rating of the motor at the source voltage.

49.4 The full-load current of a motor connected to the secondary side of a power transformer and operating at a voltage different from the source voltage shall be determined based upon the full-load current rating of the motor divided by the primary to secondary transformation ratio.

49.5 Each set of input terminals in 49.1 supplying a power circuit shall have a short circuit current rating. The short circuit current rating shall be determined based upon the requirements in Supplement SB.

49.6 The voltage rating of an industrial control panel shall not exceed the voltage rating of any component connected to the source of supply. When an industrial control panel contains components marked with a slash voltage rating, such as 120/240, 480Y/277, or 600Y/347, the voltage rating of the industrial control panel shall be:

a) The complete slash voltage rating, when intended for connection to the higher voltage; or

b) Not more than the lower voltage rating.

50 Individual Load Ratings

50.1 The output terminals to each individual external motor load shall be rated in volts and amperes, or volts and horsepower. When an output is rated in horsepower, the output circuit of the panel shall be evaluated based on the FLC rating from Table 50.1 and Table 50.2. The output terminals to individual windings of a multi-speed motor or a part winding motor shall comply with this requirement for each individual winding. For motor loads rated over 500 hp and all motor loads rated over 600V, the motor load shall be rated in volts, full load amperes and locked rotor amperes.

Table 50.1
Full-load current rating in amperes corresponding to various a-c horsepower ratings

Horse power	110 – 120 Volts		200 Volts		208 Volts		220 – 240 Volts[a]		380 – 415 Volts		440 – 480 Volts		550 – 600 Volts	
	Single phase	Three phase	Single phase	Three phase	Single phase	Three phase	Single phase	Three phase	Single phase	Three phase	Single phase	Three phase	Single phase	Three phase
1/10	3.0	–	–	–	–	–	1.5	–	1.0	–	–	–	–	–
1/8	3.8	–	–	–	–	–	1.9	–	1.2	–	–	–	–	–
1/6	4.4	–	2.5	–	2.4	–	2.2	–	1.4	–	–	–	–	–
1/4	5.8	–	3.3	–	3.2	–	2.9	–	1.8	–	–	–	–	–
1/3	7.2	–	4.1	–	4.0	–	3.6	–	2.3	–	–	–	–	–
1/2	9.8	4.4	5.6	2.5	5.4	2.4	4.9	2.2	3.2	1.3	2.5	1.1	2.0	0.9
3/4	13.8	6.4	7.9	3.7	7.6	3.5	6.9	3.2	4.5	1.8	3.5	1.6	2.8	1.3
1	16.0	8.4	9.2	4.8	8.8	4.6	8.0	4.2	5.1	2.3	4.0	2.1	3.2	1.7
1-1/2	20.0	12.0	11.5	6.9	11.0	6.6	10.0	6.0	6.4	3.3	5.0	3.0	4.0	2.4
2	24.0	13.6	13.8	7.8	13.2	7.5	12.0	6.8	7.7	4.3	6.0	3.4	4.8	2.7
3	34.0	19.2	19.6	11.0	18.7	10.6	17.0	9.6	10.9	6.1	8.5	4.8	6.8	3.9
5	56.0	30.4	32.2	17.5	30.8	16.7	28.0	15.2	17.9	9.7	14.0	7.6	11.2	6.1
7-1/2	80.0	44.0	46.0	25.3	44.0	24.2	40.0	22.0	27.0	14.0	21.0	11.0	16.0	9.0
10	100.0	56.0	57.5	32.2	55.0	30.8	50.0	28.0	33.0	18.0	26.0	14.0	20.0	11.0
15	135.0	84.0	–	48.3	–	46.2	68.0	42.0	44.0	27.0	34.0	21.0	27.0	17.0
20	–	108.0	–	62.1	–	59.4	88.0	54.0	56.0	34.0	44.0	27.0	35.0	22.0
25	–	136.0	–	78.2	–	74.8	110.0	68.0	70.0	44.0	55.0	34.0	44.0	27.0
30	–	160.0	–	92	–	88	136.0	80.0	87.0	51.0	68.0	40.0	54.0	32.0
40	–	208.0	–	120	–	114	176.0	104.0	112.0	66.0	88.0	52.0	70.0	41.0
50	–	260.0	–	150	–	143	216.0	130.0	139.0	83.0	108.0	65.0	86.0	52.0
60	–	–	–	177	–	169	–	154.0	–	103.0	–	77.0	–	62.0
75	–	–	–	221	–	211	–	192.0	–	128.0	–	96.0	–	77.0
100	–	–	–	285	–	273	–	248.0	–	165.0	–	124.0	–	99.0
125	–	–	–	359	–	343	–	312.0	–	208.0	–	156.0	–	125.0
150	–	–	–	414	–	396	–	360.0	–	240.0	–	180.0	–	144.0
200	–	–	–	552	–	528	–	480.0	–	320.0	–	240.0	–	192.0
250	–	–	–	–	–	–	–	604	–	403.0	–	302.0	–	242.0
300	–	–	–	–	–	–	–	722	–	482.0	–	361.0	–	289.0
350	–	–	–	–	–	–	–	828	–	560.0	–	414.0	–	336.0
400	–	–	–	–	–	–	–	954	–	636.0	–	477.0	–	382.0
450	–	–	–	–	–	–	–	1030	–	–	–	515	–	412
500	–	–	–	–	–	–	–	1180	–	786.0	–	590.0	–	472.0

[a] To obtain full-load currents for 265 and 277 volt motors, decrease corresponding 220 – 240 volt ratings by 13 and 17 percent, respectively.

Table 50.2
Full-load current rating in amperes corresponding to various dc horsepower ratings

Horsepower	90 volts	110 – 120 volts	180 volts	220 – 240 volts	500 volts	550 – 600 volts
1/10	–	2.0	–	1.0	–	–
1/8	–	2.2	–	1.1	–	–
1/6	–	2.4	–	1.2	–	–

Table 50.2 Continued on Next Page

Table 50.2 Continued

Horsepower	90 volts	110 – 120 volts	180 volts	220 – 240 volts	500 volts	550 – 600 volts
1/4[a]	4.0	3.1	2.0	1.6	–	–
1/3	5.2	4.1	2.6	2.0	–	–
1/2	6.8	5.4	3.4	2.7	–	–
3/4	9.6	7.6	4.8	3.8	–	1.6
1	12.2	9.5	6.1	4.7	–	2.0
1-1/2	–	13.2	8.3	6.6	–	2.7
2	–	17	10.8	8.5	–	3.6
3	–	25	16	12.2	–	5.2
5	–	40	27	20	–	8.3
7-1/2	–	58	–	29	13.6	12.2
10	–	76	–	38	18	16
15	–	110	–	55	27	24
20	–	148	–	72	34	31
25	–	184	–	89	43	38
30	–	220	–	106	51	46
40	–	292	–	140	67	61
50	–	360	–	173	83	75
60	–	–	–	206	99	90
75	–	–	–	255	123	111
100	–	–	–	341	164	148
125	–	–	–	425	205	185
150	–	–	–	506	246	222
200	–	–	–	675	330	294

[a] The full-load current for a 1/4-horsepower, 32-volt dc motor is 8.6 amperes.

Table 50.3
Locked-rotor motor currents corresponding to various a-c horsepower ratings (3-phase)

	110 – 120 V	200 V	208 V	220 – 240 V	380 V – 415 V	440 – 480 V	550 – 600 V
	Motor designations	Motor designations	Motor designations	Motor designations	Motor designations	Motor designations	Motor designations
HP	B, C, D	B, C, D	B, C, D	B, C, D	B, C, D	B, C, D	B, C, D
1/2	40	23	22.1	20	20	10	8
3/4	50	28.8	27.6	25	20	12.5	10
1	60	34.5	33	30	20	15	12
1-1/2	80	46	44	40	27	20	16
2	100	57.5	55	50	34	25	20
3	128	73.6	71	64	43	32	25.6
5	184	105.8	102	92	61	46	36.8
7-1/2	254	146	140	127	84	63.5	50.8
10	324	186.3	179	162	107	81	64.8
15	464	267	257	232	154	116	93
20	580	334	321	290	194	145	116
25	730	420	404	365	243	183	146
30	870	500	481	435	289	218	174

Table 50.3 Continued on Next Page

Table 50.3 Continued

HP	110 – 120 V	200 V	208 V	220 – 240 V	380 V – 415 V	440 – 480 V	550 – 600 V
	Motor designations	Motor designations	Motor designations	Motor designations	Motor designations	Motor designations	Motor designations
	B, C, D	B, C, D	B, C, D	B, C, D	B, C, D	B, C, D	B, C, D
40	1160	667	641	580	387	290	232
50	1450	834	802	725	482	363	290
60	–	1001	962	870	578	435	348
75	–	1248	1200	1085	722	543	434
100	–	1668	1603	1450	965	725	580
125	–	2087	2007	1815	1207	908	726
150	–	2496	2400	2170	1441	1085	868
200	–	3335	3207	2900	1927	1450	1160
250	–	–	–	3650	–	1825	1460
300	–	–	–	4400	–	2200	1760
350	–	–	–	5100	–	2550	2040
400	–	–	–	5800	–	2900	2320
450	–	–	–	6500	–	3250	2600
500	–	–	–	7250	–	3625	2900

50.2 The output terminals to each individual external lighting and heater load shall be rated in volts and amperes, or volts and watts for incandescent lighting or heater loads.

50.3 The output terminals to each individual external appliance load shall be rated in volts and amperes.

50.4 For an industrial control panel that is designed to control a field-installed thermally-protected motor, or an electronically protected motor, or an impedance protected motor, the load rating of 50.1 shall be additionally marked with:

a) "Thermally protected" or "T.P." and location of field wiring connections of thermal protector to be connected to control circuit for a thermally protected motor;

b) "Impedance protected" or "Z.P." for an impedance protected motor; and

c) “Electronically protected” or “E.P.” for an electronically protected motor.

50.5 For an industrial control panel that is intended for control of a specific heating element load such as one contained in a water heater or steam boiler having an ASME rated and stamped vessel as specified in 31.6.2, one of the types in Exception No. 2 to 31.6.1, the load rating of 50.2 shall additionally be marked to identify the intended load, such as "Water Heater with ASME Vessel" or "Steam Boiler with ASME Vessel", “Pipeline heater”, “Industrial furnace”, or equivalent wording.

50.6 When a transformer is rated in volt-amperes, a heater load is rated in watts, a capacitor load is rated in VAR, the full-load current is to be determined as follows:

a) For a single phase load: amperes = (power, in VA, W, or VAR) / (rated voltage)

b) For a three phase load: amperes = (power, in VA, W or VAR) / [(sq. root of 3) x (rated voltage)].

51 Ratings for Control Circuit Outputs

51.1 The output terminals of a control circuit switching device for connection to an external control circuit load that is not defined on the schematic wiring diagram as a device type as specified in Table 45.1 shall be rated in volts and amperes, or volts and volt-amperes.

51.2 The output terminals of a control circuit switching device for connection of an external control circuit load that is defined on the schematic wiring diagram and complies with 46.3.3 (a) or (b) shall not require ratings to be assigned.

MARKINGS

52 General Markings

52.1 An industrial control panel shall be provided with a nameplate marking that includes the following:

a) Manufacturer's name or authorized designation;

b) Complete electrical rating of each source of supply as specified in 49.1;

c Short circuit current rating of industrial control panel as specified in 49.5;

d) Field wiring diagram number when required load ratings from 52.2 or field wiring information of 54.1 – 54.9, 60.1, or 60.2 is included only on the diagram;

e) Factory identification as specified in 52.5;

f) Enclosure Type rating (for enclosed panels only) as specified in 53.1; and

g) Ambient temperature rating for industrial control panels, evaluated for ranges other than 5°C to 40°C (41°F to 104°F).

52.2 An industrial control panel shall be provided with load ratings as specified in Section 50, Individual Load Ratings, and Section 51, Ratings for Control Circuit Outputs.

52.3 The location of required markings shall be in accordance with Table 52.1. All markings, other than those on a diagram, shall be located so that they are visible after installation of field wiring when a cover or door is opened. An open industrial control panel with a partial or incomplete enclosure, other than as in 18.2 and 53.4, shall comply with the marking requirements for open-type devices.

52.4 Markings required to be placed on an industrial control panel as specified in notes (a) – (d) and note (f) of Table 52.1 shall be made by die-stamping, silkscreening, or etching in metal or plastic or with an indelible ink on adhesive-backed label stock and permanently attached to the industrial control panel by rivets, screws, or adhesive.

Table 52.1
Locations of required markings

Paragraph	General description	Location categories (see notes)	
		Enclosed	Open
	General markings		
52.1	Nameplate stating: manufacturer, maximum voltage, Full Load Current rating (FLC), largest motor FLC rating, phase, frequency, field wiring diagram, environmental type rating, short circuit current rating	a or b	f
67.1.1	Nameplate stating: manufacturer, maximum voltage, Full Load Current rating (FLC), largest motor FLC rating, phase, frequency, field wiring diagram, environmental type rating, short circuit current rating	a	–
52.2	External load ratings	a, b, or e	e or f
	Enclosure markings		
53.1	Environmental type	a or b	–
53.2	Conduit hubs for Type 2, 3R or 3RX enclosures	a, b, or e	–
53.3	Conduit hubs for Type 3, 3S, 3SX, 3X, 4, 4X, 5, or 12 enclosures	a, b, or e	–
53.4	Modular enclosure marking, specifying interconnections	a or b	–
53.5	Single conduit entry, non-metallic enclosure only	a, b, or e	–
53.6	Location of conduit entry	a or b	–
53.7	Instructions for field installed bonding means	a, b, or e	–
53.8	Instructions for field installed equipment to maintain Type ratings	a, b or e	–
	Field wiring terminal markings		
54.1	Field wiring terminal identification	c	c
54.2 – 54.4, 54.11	Type of field wiring conductors, field wiring temperature rating (power circuit only), terminal tightening torque	b, c, or e	c, e, or f
54.5	Equipment grounding terminal identification	c	c
54.6	Class 1 markings	b, c, or e	c, e, or f
54.7	Class 2 markings	b, c, or e	c, e, or f
54.8	Routing of Class 1 and Class 2 conductors	b, c, or e	c, e, or f
54.9	Control circuit wire size [less than 14 AWG (2.1 mm^2)]	b, c, or e	c, e, or f
54.10	Connect secondary neutral to grounding electrode conductor	b, c, or e	c, e, or f
54.12	Slash voltage rating	a, b, or e	e or f
	Cautionary markings		
55.4	Multiple disconnect marking	a	d
55.5	Polymeric enclosure with multiple conduit entries	b	–
55.6	Instantaneous trip circuit breaker used as branch circuit protection for a combination motor controller	a, b, or c	c or d
55.7	Self-protected combination motor controller, including manual type	a, b, or c	c or d
55.8	UPS equipment outputs remain live with main disconnect in off position	a	d
	Fuseholders		
56.1	Fuse replacement marking	b or c	c or d
	Switches		

Table 52.1 Continued on Next Page

Table 52.1 Continued

Paragraph	General description	Location categories (see notes)	
		Enclosed	Open
57.1	Disconnect handle, "on" and "off"	c	–
57.2	Manual switch, not to operate under load	c	c
57.3	Reverse fed disconnecting means	a	d
	Overload Relay Heater Tables		
58.1	Overload relay heater element table	b or c	c or d
	Receptacles		
59.1	General use receptacle in power circuit	c	c
59.2	Multi-pin receptacle, identification of load connection	c	c
59.3	General use receptacle in control circuit	c	c
59.4	Receptacle not to operate under load	c	c
	Field provided components		
60.1, 60.2	Disconnect switch, branch circuit protection and/or overload relay to be provided by installer	e	e
60.3	Other devices to be provided by installer	e	e
60.4	Pressure wire connectors, cable lugs or terminal kit provided by installer for connection to busbars	e	e
	Schematic Wiring Diagrams		
61.1, 61.2	Complete schematic	e	e

NOTES

a) Marking shall be visible without opening the door or cover of the enclosure.

b) This marking is able to be provided on the door or cover of the enclosure or on the inside walls of the enclosure.

c) Marking shall be on or adjacent to the component in question. Fuse replacement markings are able to be on a chart displayed as specified in (b) when each fuseholder is marked with a distinctive designation, such as F1. For open panels, the chart is able to be supplied as described in (d).

d) Marking shall be shipped separately on a self-adhesive label with the device (this is intended to be placed on or in the ultimate enclosure).

e) Marking shall be on the field wiring diagram, prints, or instructions that are referenced on the panel nameplate and is to be shipped with the panel (either loosely, in the "print pocket," or adhered to the inside of the enclosure).

f) Marking shall be on the subpanel component mounting plate.

52.5 A manufacturer who assembles industrial control panels in more than one factory shall provide a distinctive marking which will identify the industrial control panel as a product of a particular factory.

52.6 Industrial Control Panels including control circuitry which limit output current to a marked maximum load may be marked to indicate suitability for use in load management applications.

53 Enclosure Markings

53.1 An enclosed industrial control panel shall be marked with the type designation determined from Section 19, Enclosure Openings.

53.2 An enclosed industrial control panel marked as Type 2, Type 3R or Type 3RX enclosure as specified in 53.1 and that is not provided with conduit hubs as specified in Table 19.1 shall be marked to indicate that raintight or wet location hubs that comply with the Standard for Conduit, Tubing, and Cable Fittings, UL 514B, or hubs having the same environmental rating as the enclosure shall be used.

53.3 An enclosed industrial control panel marked as Type 3, 3S, 3SX, 3X, 4, 4X, 5, or 12 enclosure as specified in 53.1 that is not provided with conduit hubs as specified in Table 19.1 shall be marked with instructions identifying the specific hub or fitting intended to be used or to use hubs or fittings with the same environmental rating as the enclosure.

53.4 An enclosed industrial control panel consisting of two or more sections intended to be connected together in the field shall have the following marking on each section, "Section ___ of ___, see diagram No. ___ for interconnections" or equivalent wording.

53.5 A pushbutton station or selector switch enclosure made of insulating material that has no means for continuity of grounding between conduit entries shall be marked to indicate that only one conduit shall be connected to the enclosure.

53.6 An enclosure with electrical spacings between live parts and conduit fittings that are less than required, as specified in 10.7, shall be marked to identify the area where conduit is able to enter.

53.7 An enclosure intended for field assembly of the bonding means as in 24.1(b) shall be provided with installation instructions that identifies the parts for bonding and specifies the method of installation.

53.8 Enclosures shipped with open holes, as specified in Section 19.6, are to be marked with the following or the equivalent: "To maintain the environmental rating of this enclosure, install in the openings only Listed or Recognized control devices with the same environmental rating as the enclosure in compliance with the installation instructions of the device." Alternately, the panel may identify the specific manufacturer and models of the field installed equipment.

54 Field Wiring Terminal Markings

54.1 All field wiring terminals shall be marked to indicate proper connections of supply, loads, and control circuit. A terminal marking consisting of an alphanumeric code shall correspond to markings on the field wiring diagram.

54.2 All field wiring terminals shall be marked with:

a) The required type of field wiring conductor in accordance with 54.11.

b) The required temperature rating of the field wiring conductors as specified in 54.3;

c) The required terminal tightening torque as determined from 54.4.

54.3 All field wiring terminals of the power circuit shall be marked for use with field wiring having one of the following temperature ratings corresponding to the size of the anticipated field wiring determined from 28.3.1 and Table 28.1:

a) 60°C (140°F) for terminals rated less than 100 amperes;

b) 75°C (167°F) for terminals rated less than 100 amperes and the do not accept the required 60°C conductor; or

c) 75°C (167°F) for terminals rated 100 amperes or more.

Exception: This marking is not required for field wiring terminals for connection of a non-motor load rated 15 amperes or less.

54.4 All field wiring terminals shall be marked with the tightening torque determined from:

a) The manufacturer's specifications, installation instructions, or markings on the product; or

b) Table 54.1, Table 54.2, or Table 54.3, where the marking shall be 90 – 100 percent of the value from the tables.

A component, such as a motor starter or fuseholder, that is provided with a tightening torque marking that is visible to the installer complies with this requirement.

Exception No. 1: A wire-binding screw is not required to be marked with a tightening torque.

Exception No. 2: A control circuit terminal that has a rated tightening torque of 7 inch-lb (0.8 N·m) is not required to be marked with a tightening torque.

Table 54.1
Tightening torque for screws

Test wire size installed in connector		Tightening torque, pound-inches (N·m)							
		Slotted head No. 10 and larger				Hexagonal head-external drive socket wrench			
		Slot width – 0.047 inch (1.2 mm) or less and slot length 1/4 inch (6.4 mm) or less		Slot width – over 0.047 inch (1/2 mm) or slot length – over 1/4 inch (6.4 mm)		Split-bolt connectors		Other connectors	
AWG or kcmil	(mm^2)								
18 – 10	(0.82 – 5.3)	20	(2.3)	35	(4.0)	80	(9.0)	75	(8.5)
8	(8.4)	25	(2.8)	40	(4.5)	80	(9.0)	75	(8.5)
6 – 4	(13.3 – 21.2)	35	(4.0)	45	(5.1)	165	(18.6)	110	(12.4)
3	(26.7)	35	(4.0)	50	(5.6)	275	(31.1)	150	(16.9)
2	(33.6)	40	(4.5)	50	(5.6)	275	(31.1)	150	(16.9)
1	(42.4)	–		50	(5.6)	275	(31.1)	150	(16.9)
1/0 – 2/0	(53.5 – 67.4)	–		50	(5.6)	385	(43.5)	180	(20.3)
3/0 – 4/0	(85.0 – 107.2)	–		50	(5.6)	500	(56.5)	250	(28.2)
250 – 350	(127 – 177)	–		50	(5.6)	650	(73.4)	325	(36.7)
400	(203)	–		50	(5.6)	825	(93.2)	375	(36.7)
500	(253)	–		50	(5.6)	825	(93.2)	375	(42.4)
600 – 750	(304 – 380)	–		50	(5.6)	1000	(113.0)	375	(42.4)
800 – 1000	(406 – 508)	–		50	(5.6)	1100	(124.3)	500	(56.5)
1250 – 2000	(635 – 1010)	–		–	–	1100	(124.3)	600	(67.8)

NOTE – For values of slot width or length not corresponding to those specified, the largest torque value associated with the conductor size shall be marked. Slot width is the nominal design value. Slot length shall be measured at the bottom of the slot.

Table 54.2
Tightening torque for slotted head screws smaller than No. 10 intended for use with 8 AWG (8.4 mm^2) or smaller conductors

Slot length of screw[a]		Tightening torque, pound-inches (N·m)			
		Slot width of screw[b], in (mm)			
inches	(mm)	Smaller than 0.047 (1.2)		0.047 (1.2) and larger	
Less than 5/32	(4)	7	(0.79)	9	(1.0)
5/32	(4)	7	(0.79)	12	(1.4)
3/16	(4.8)	7	(0.79)	12	(1.4)
7/32	(5.6)	7	(0.79)	12	(1.4)
1/4	(6.4)	9	(1.0)	12	(1.4)
9/32	(7.1)			15	(1.7)
Above 9/32	(7.1)			20	(2.3)

[a] For slot lengths of intermediate values, torques pertaining to next shorter slot length shall be utilized. For screws with multiple tightening means, the largest torque value associated with the conductor size shall be marked. Slot length shall be measured at the bottom of the slot.

[b] Slot width is the nominal design value.

Table 54.3
Tightening torque for socket head screws

Socket size across flats		Tightening torque	
inches	(mm)[a]	Pound-inches	(N·m)
1/8	(3.2)	45	(5.1)
5/32	(4.0)	100	(11.3)
3/16	(4.8)	120	(13.6)
7/32	(5.6)	150	(16.9)
1/4	(6.4)	200	(22.6)
5/16	(7.9)	275	(31.1)
3/8	(9.5)	375	(42.4)
1/2	(12.7)	500	(56.5)
9/16	(14.3)	600	(67.8)

[a] For screws with multiple tightening means, the largest torque value associated with the conductor size shall be marked. Slot length shall be measured at the bottom of the slot.

54.5 The equipment grounding conductor terminal shall be identified by one of the following methods:

a) With a green, not readily removable terminal screw with a hexagonal head;

b) With a green, hexagonal, not readily removable terminal nut;

c) With the words, "Ground" or "Grounding" ;

d) With the letters, "G", "GR", "GRD", "GND" or "GRND" ;

e) With the symbol in Figure 54.1.

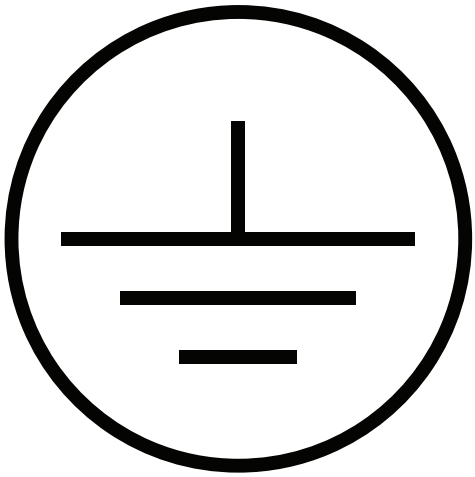
f) If the equipment grounding conductor terminal is within a housing (i.e., terminal block), identification shall be made by either or both of the following methods:

1) 54.5 (c), (d), or (e) on or adjacent to the housing near the terminal opening;

2) The terminal housing colored the bicolor combination green-and-yellow.

Figure 54.1

Grounding symbol (IEC Publication 417, Symbol 5019)



54.6 Field wiring terminals of a low-voltage limited energy circuit or of a low-voltage, less than 30 Vrms, isolated secondary circuit shall be marked "Class 1 control circuit," "Use Class 1 conductors," "For connection to a Class 1 remote control circuit," or the equivalent.

54.7 Field wiring terminals of a Class 2 circuit shall be marked "Class 2 control circuit," "Use Class 2 conductors," "For connection to a Class 2 remote control circuit," or the equivalent.

54.8 An industrial control panel that contains a Class 1 control circuit and/or a power circuit and also contains a Class 2 circuit and that is not provided with barriers shall have markings or instructions specifying how required separation of field wiring conductors shall be maintained.

54.9 A field wiring terminal for a control circuit conductor smaller than 14 AWG (2.1 mm^2) as specified in the Exception to 37.2.1 shall be marked with the wire size(s) to be used.

54.10 For an industrial control panel containing one or more grounding electrode conductor terminals required by 16.2, each grounding electrode conductor terminal shall be marked to identify the size of the field supplied grounding electrode conductor and the source of the separately derived system voltage.

Exception No. 1: The marking is not required when the grounding electrode conductor terminal is not required in accordance with the Exception No. 1 to 16.2.

Exception No. 2: When a single grounding electrode conductor terminal is supplied for multiple separately derived systems in accordance with Exception No. 2 to 16.2, the marking in 54.10 shall specify that a 3/0 AWG grounding electrode conductor is required to connect the grounded conductors of multiple separately derived systems to a grounding electrode.

54.11 All field-wiring terminals shall be marked with one of the following:

a) "Use Copper Conductors Only" for terminals intended for connection only to copper wire;

b) "Use Aluminum Conductors Only" for terminals evaluated only for connection to aluminum wire;

c) "Use Copper or Aluminum Conductors" or "Use Copper, Copper-Clad Aluminum, or Aluminum Conductors" for terminals evaluated for either copper or aluminum wire; or

d) "Use Copper or Copper-Clad Aluminum Conductors" for terminals evaluated for connection to either copper or copper-clad aluminum wire.

54.12 For an industrial control panel with a slash voltage rating as in 49.6(a), the input terminals shall be marked, “For use on a solidly grounded wye source only”, or the equivalent.

55 Hazard Markings

55.1 Hazard markings shall be located on a part that is not removable without impairing the operation or appearance of the equipment.

55.2 A hazard marking shall be prefixed with the word "CAUTION" or "WARNING," as applicable, in letters not less than 1/8 inch (3.2 mm) high. The remaining letters of such marking, unless otherwise specified, shall not be less than 1/16 inch (1.6 mm) high.

55.3 A hazard marking intended to instruct the operator shall be legible and visible to the operator during normal operation of the equipment. A marking that provides servicing instructions shall be legible and visible when such servicing is performed.

55.4 An industrial control panel intended to be provided with more than one supply source such that more than one disconnect switch is required to disconnect all power within the control panel shall be marked with the word "CAUTION" or "WARNING" and the following or equivalent: "Risk of Electric Shock – More than one disconnect switch may be required to de-energize the equipment before servicing." A risk assessment shall be performed to justify if the word "WARNING" or "CAUTION" shall be used.

Exception: This marking is not required for an isolated control circuit contact that is separately supplied.

55.5 The marking required for enclosures intended for field assembly of the bonding means in accordance with 24.1(b) shall be located where visible during installation, such as inside the cover, and consist of the word "CAUTION" and the following or equivalent, "Bonding between conduit connection is not automatic and must be provided as a part of the installation;" or the word "CAUTION" and the following or equivalent, "Nonmetallic enclosure does not provide grounding between conduit connections. Use grounding bushings and jumper wires."

55.6 An industrial control panel provided with an instantaneous trip circuit breaker used as branch circuit protection for a combination motor controller shall be marked:

a) With the word "WARNING" and the following or the equivalent: "To maintain overcurrent, short-circuit, and ground-fault protection, the manufacturer's instructions for selecting current elements and setting the instantaneous-trip circuit breaker must be followed."

b) With the word "WARNING" and the following or the equivalent: "Tripping of the instantaneous-trip circuit breaker is an indication that a fault current has been interrupted. Current-carrying components of the magnetic motor controller should be examined and replaced if damaged to reduce the risk of fire or electric shock. If burnout of the current element of an overload relay occurs, the complete overload relay must be replaced."

55.7 An industrial control panel provided with a self-protected combination motor controller shall be marked:

a) With the word "WARNING" and the following or the equivalent: "To maintain overcurrent, short-circuit, and ground-fault protection, the manufacturer's instructions for selection of overload and short circuit protection must be followed to reduce the risk of fire or electric shock."

b) With the word "WARNING" and the following or the equivalent: "If an overload or a fault current interruption occurs, circuits must be checked to determine the cause of the interruption. If a fault condition exists, the current-carrying components should be examined and replaced if damaged, and the integral current sensors must be replaced to reduce the risk of fire or electric shock."

55.8 An industrial control panel incorporating UPS equipment shall be marked with the word "Danger" or "Warning" and the following or equivalent: “Risk of Electric Shock – UPS equipment outputs remain live with main disconnect in off position.”

56 Fuseholder Markings

56.1 A branch circuit fuseholder that accepts a fuse having a rating larger than the maximum specified rating and all control circuit fuseholders shall be marked with the voltage and current rating of the replacement fuse.

57 Switch Markings

57.1 The operating handle of each disconnecting means shall be marked to indicate the open ("off") and closed ("on") positions.

57.2 A manual switch not intended to be operated under load as specified in 33.2.2 shall be marked "Do not operate under load."

57.3 An industrial control panel containing a disconnecting means that is back-fed shall be marked to identify the location or disconnecting means with the back-fed line side connection.

58 Overload Relay Heater Table Markings

58.1 An industrial control panel provided with an eutectic alloy or bimetal overload relay with replaceable current (heater) elements or units, as described in 34.2.1, shall have the overload relay current element selection chart (heater table) provided with the industrial control panel.

59 Receptacle Markings

59.1 A general use receptacle protected by branch circuit overcurrent protection rated less than the rating of the receptacle and intended for connection of only a control circuit load shall be marked with the ampere rating of the overcurrent protective device and the intended use for the receptacle.

59.2 Multiple pin type receptacles having a common pin configuration shall be marked to identify the intended load connection.

59.3 A general use receptacle provided within a control circuit and intended for connection of a control circuit load shall be marked with the ampere rating of the overcurrent protective device and the intended use for the receptacle.

59.4 A multi-pin receptacle or a general-use receptacle rated more than 20 amperes shall be marked "For disconnecting use only, not for current rupturing" or the equivalent.

60 Field Provided Components

60.1 An industrial control panel provided with a power circuit where the disconnecting means, branch circuit protection and/or motor overload protection is omitted shall be marked to indicate that these devices shall be provided by the installer. The marking for field installed branch circuit protection shall include the size and type of protection when required as a result of a component marking as indicated in 31.2.2.

Exception: Individual motor circuits intended to supply field-installed thermally, impedance, or electronically-protected motors and marked in accordance with 50.4 are not required to identify that motor overload protection shall be provided by the installer.

60.2 An industrial control panel provided with a separately supplied control circuit where the disconnecting means and/or branch circuit protection is omitted shall be marked to indicate that these devices shall be provided by the installer.

60.3 An industrial control panel schematic wiring diagram that includes devices that are not provided with the industrial control panel shall be marked to indicate that these devices shall be provided by the installer.

60.4 An industrial control panel with bus bars intended for field installation of pressure wire connectors, cable lugs or similar termination devices in accordance with the Exception to 28.1.1, shall be provided with a marking stating the number and type of pressure wire connectors, cable lugs or terminal kit that is acceptable for use with the anticipated field wiring identified in 54.2 and for mounting to the bus bar hole pattern.

61 Schematic Wiring Diagrams

61.1 An industrial control panel shall be provided with a complete electrical schematic wiring diagram including all components provided by the manufacturer. The diagram shall be an accurate representation of the electrical circuitry and components provided in the panel at the time of shipping. Field installed components shown on the schematic wiring diagram shall comply with 60.3.

61.2 A standardized schematic wiring diagram that includes optional components and circuits that are commonly supplied by a manufacturer shall be modified on a per unit basis to include only those components that are actually being supplied by the manufacturer.

PART 2 – SPECIFIC USE INDUSTRIAL CONTROL PANEL TYPES

ENCLOSURES

62 General

62.1 The requirements in Sections 63 and 64 cover Type 1 enclosures constructed of sheet or cast metal.

62.2 A Type 1 – 13 enclosure constructed of polymeric material enclosure shall be investigated to the construction requirements, performance requirements, and marking requirements applicable to the enclosure environmental Type(s) in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

62.3 A Type 2 – 13 enclosure constructed of sheet or cast metal shall comply with:

a) The construction requirements in Section 63, Construction, and Section 64, Markings, of this standard; and

b) The construction, performance, and marking requirements applicable to the enclosure environmental Type(s) in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

c) A Type 3RX, 3SX, and 3X enclosure shall additionally comply with the corrosion resistance test in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

62.4 In addition to complying with 62.2 and 62.3, a Type 4, 4X or 12 enclosure or compartment having ventilation openings shall be subjected to the indoor Circulating Dust or Atomized Water Test, and the Rod Entry Test, in accordance with the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E. When the enclosure or compartment is provided with a fan, it shall be subjected to all environmental tests required by UL 50E, both with the fan on and with the fan off. As a result of these tests, there shall be no entry of dust into the enclosure or compartment having a Type 4, 4X or 12 rating.

62.5 A polymeric Type 4X enclosure complying with the requirements for a Type 4X enclosure intended for indoor use only in the Standard for Industrial Control Equipment, UL 508, is able to be marked in accordance with 64.3. Enclosure openings shall comply with Section 19 for enclosures rated Type 4X.

63 Construction

63.1 Metal thickness

63.1.1 A cast-metal enclosure shall be made from iron, aluminum, brass, or copper and be at least 1/8 inch (3.2 mm) thick at every point, more than 1/8 inch thick at reinforcing points, and at least 1/4 inch (6.4 mm) thick at tapped holes for conduit.

63.1.2 The thickness of a sheet-metal enclosure shall not be less than that specified in Table 63.1 and Table 63.2, except that at points to which a wiring system is to be connected, steel shall be at least 0.032 inch (0.81 mm) thick, and nonferrous metal at least 0.045 inch (1.14 mm) thick.

Exception: An enclosure that complies with the Compression Test and Deflection Test of the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50, is not required to comply with this requirement at points other than where a wiring system is to be connected.

63.1.3 Table 63.1 and Table 63.2 are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

63.1.4 With reference to Table 63.1 and Table 63.2, a supporting frame is a structure of angle or channel or folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and that has torsional rigidity to resist the bending moments that are applied by the enclosure surface when it is deflected. Constructions without supporting frame include:

a) A single sheet with single formed flanges – formed edges;

b) A single sheet that is corrugated or ribbed;

c) An enclosure surface loosely attached to a frame, for example, with spring clips; and

d) An enclosure surface having an unsupported edge.

See Figure 63.1 for evaluation of supported and unsupported enclosure surfaces. This figure further defines the means of selecting the required metal thickness from either the "with supporting frame" or "without supporting frame" columns in Table 63.1 and Table 63.2.

Table 63.1
Thickness of sheet metal for enclosures – carbon or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcement[a]				Minimum required thickness, in	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]			
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inches	(mm)
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020	(0.51)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)		
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited		0.026	(0.66)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)		
8.0	(20.3)	Not limited		12.0	(30.5)	Not limited		0.032	(0.81)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)		
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited		0.042	(1.07)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)		
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited		0.053	(1.35)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)		
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited		0.060	(1.52)
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)	43.0	(109.2)		
25.0	(63.5)	Not limited		39.0	(99.1)	Not limited		0.067	(1.70)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)		
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited		0.080	(2.03)
38.0	(96.5)	47.0	(119.4)	54.0	(137.2)	66.0	(167.6)		
42.0	(106.7)	Not limited		64.0	(162.6)	Not limited		0.093	(2.36)
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)	84.0	(213.4)		
52.0	(132.1)	Not limited		80.0	(203.2)	Not limited		0.108	(2.74)
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)		
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123	(3.12)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)		

[a] See 63.1.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure other than the cover shall comply with 63.1.5 and 63.1.6 or be made of a single sheet.

[c] Not limited applies only when the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not routinely removed in use.

Table 63.2
Thickness of metal for electrical enclosures – aluminum, copper, or brass

Without supporting frame[a]				With supporting frame or equivalent reinforcement[a]				Minimum required thickness,	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]			
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inches	(mm)
3.0	(7.6)	Not limited		7.0	(17.8)	Not limited		0.023	(0.58)
3.5	(8.9)	4.0	(10.2)	8.5	(21.6)	9.5	(24.1)		
4.0	(10.2)	Not limited		10.0	(25.4)	Not limited		0.029	(0.74)
5.0	(12.7)	6.0	(15.2)	10.5	(26.7)	13.5	(34.3)		

Table 63.2 Continued on Next Page

Table 63.2 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcement[a]				Minimum required thickness,	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]			
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inches	(mm)
6.0	(15.2)	Not limited		14.0	(35.6)	Not limited		0.036	(0.91)
6.5	(16.5)	8.0	(20.3)	15.0	(38.1)	18.0	(45.7)		
8.0	(20.3)	Not limited		19.0	(48.3)	Not limited		0.045	(1.14)
9.5	(24.1)	11.5	(29.2)	21.0	(53.3)	25.0	(63.5)		
12.0	(30.5)	Not limited		28.0	(71.1)	Not limited		0.058	(1.47)
14.0	(35.6)	16.0	(40.6)	30.0	(76.2)	37.0	(94.0)		
18.0	(45.7)	Not limited		42.0	(106.7)	Not limited		0.075	(1.91)
20.0	(50.8)	25.0	(63.5)	45.0	(114.3)	55.0	(139.7)		
25.0	(63.5)	Not limited		60.0	(152.4)	Not limited		0.095	(2.41)
29.0	(73.7)	36.0	(91.4)	64.0	(162.6)	78.0	(198.1)		
37.0	(94.0)	Not limited		87.0	(221.0)	Not limited		0.122	(3.10)
42.0	(106.7)	53.0	(134.6)	93.0	(236.2)	114.0	(289.6)		
52.0	(132.1)	Not limited		123.0	(312.4)	Not limited		0.153	(3.89)
60.0	(152.4)	74.0	(188.0)	130.0	(330.2)	160.0	(406.4)		

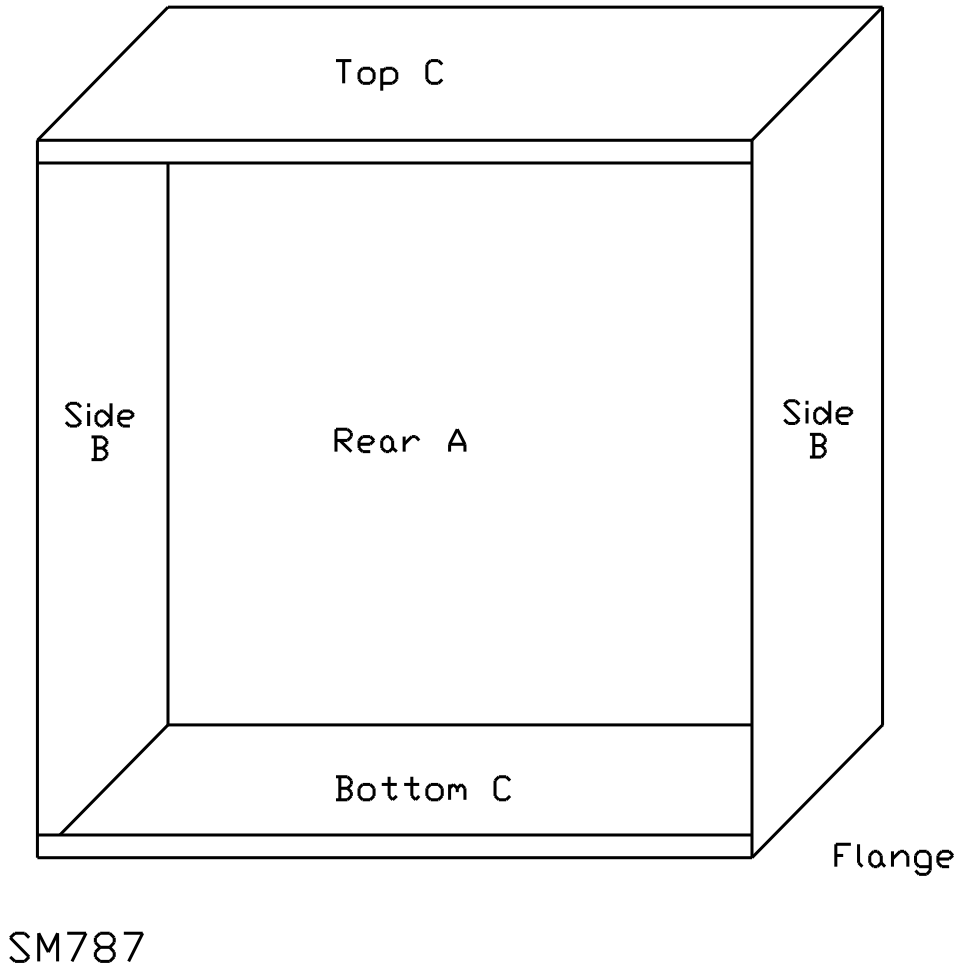
[a] See 63.1.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure other than the cover shall comply with 63.1.5 and 63.1.6 or be made of a single sheet.

[c] Not limited applies only when the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not routinely removed in use.

Figure 63.1

Supported and unsupported enclosure surfaces



NOTES:

Each enclosure surface is evaluated individually based on the length and width dimensions. For each set of surface dimensions, A, B or C, the width is the smaller dimension regardless of its orientation to other surfaces. In Table 63.1 and Table 63.2, there are two sets of dimensions that correspond to a single metal thickness requirement and the following describes the applicable procedure for determining the minimum metal thickness for each surface:

1. For a supported surface, all of the table dimensions, including the "not limited" lengths, are able to be applied. The rear surface "A", top and bottom surfaces "C", are supported either by adjacent surfaces of the enclosure or by a 1/2 inch (12.7 mm) wide flange. To determine required metal thickness for supported surfaces, the width is to be measured and compared with the table value in the maximum width column that is equal to or greater than the measured width. When the corresponding length in the maximum length column is "Not limited", the minimum thickness in the far right column is to be used. When the corresponding length in the maximum length column is a numerical value, and the measured length of the side does not exceed this value, the minimum thickness from the far right column is to be used. When the measured length of the side exceeds the numerical value, the next line in the table is to be used.

2. For an unsupported surface, only the table dimensions that include a specific length requirement are applied. The dimensions with a "not limited" length do not apply. The front edge of the left and right surfaces "B", are not supported by an adjacent surface or by a flange. An edge that is rabbeted , as shown in Figure 63.3, is also evaluated as an unsupported surface. To determine the required metal thickness for unsupported surfaces, the length is to be measured and compared with the table value in the maximum length column that is not less than the measured length, ignoring the "not limited" entries. When the corresponding width in the maximum width column is not less than the measured width, the minimum thickness from the far right column is to be used. When the measured width of the surface exceeds the value in the maximum width column, the next line in the table is to be used.

63.1.5 All seams, joints, or splices at corners or back edges of an enclosure shall be closed by:

a) Overlapping flanges formed of sheet metal from which the enclosure is made;

b) Metal surfaces overlapping adjacent surfaces or supporting frame;

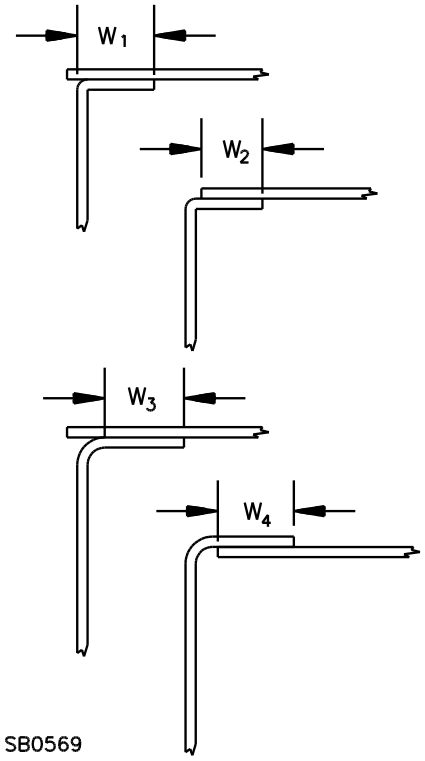
c) Separate overlapping flanges; or

d) Continuous welding that provides a construction equivalent to an integral-flanged construction.

63.1.6 With reference to the requirement in 63.1.5, the overlap shall be at least 1/2 inch (12.7 mm) and shall extend the full length of the seam. See Figure 63.2.

Figure 63.2

Overlap between flat cover and box flange and at corner or box seam



63.1.7 A piece of angle or channel having a thickness not less than the enclosure wall, and having a flange perpendicular to the enclosure wall at least 1/2 inch (12.7 mm) in height and extending the full length or width of an enclosure wall shall be evaluated as a supported side for the purpose of subdividing the overall area of an enclosure wall into two smaller areas to determine compliance with the metal thickness requirements of Table 63.1 and Table 63.2. The inclusion of a single support does not constitute a supporting frame with regard to Table 63.1 and Table 63.2.

63.1.8 When two or more covers or panels are provided to close a single opening, the thickness of each cover or panel shall be not less than a single sheet as specified in Table 63.1 or Table 63.2. The adjacent edges of such multiple panels or covers shall:

a) Be flanged at least 1/2 inch (12.7 mm);

b) Be supported against an inward force at 10 inches (254 mm) maximum intervals; or

c) Overlap each other at least 1/2 inch (12.7 mm) and be secured together at 10 inches (254 mm) maximum intervals.

63.2 Covers and doors

63.2.1 A cover or door shall be provided with means, such as latches, locks, or screws, of securing it in place. The means shall be so located or used in such quantity to hold the cover or door closed over its entire length.

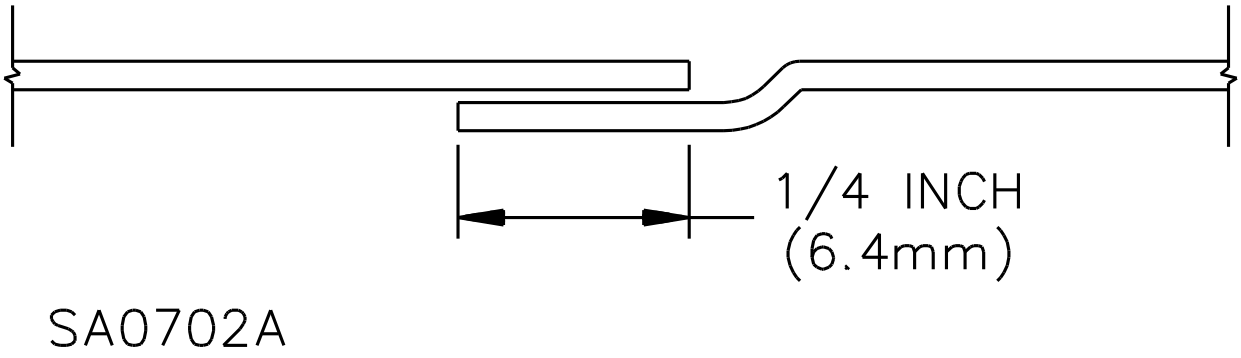
63.2.2 A door shall be provided with captive fasteners, such as snap latches, a multi-point latch, multi- or partial-turn fasteners, that remain attached to the enclosure when the door is open. A captive fastener shall be operable by hand or by a simple hand tool such as a screwdriver.

63.2.3 A door that is more than 48 inches (1.2 m) long on the hinged side shall be provided with one or more captive fasteners that hold the door closed at two or more points on the enclosure.

63.2.4 A door shall shut closely against a 1/4 inch (6.4 mm) rabbet as in Figure 63.3 for the entire length of all edges.

Figure 63.3

Rabbet



63.2.5 A flat cover shall overlap a flange on the enclosure at least 1/2 inch (12.7 mm) for the entire length of all edges. Where the radius of the flange bend in the enclosure is small, the flange width shall be determined as in W1 or W2 of Figure 63.2. Where the radius of the flange bend is excessive or where the flat cover is on the inside of the enclosure flange, the flange width shall be determined as in W3 or W4 of Figure 63.2.

63.2.6 A flanged cover or door shall have flanges for the full length of all edges. Flanges on a cover or door shall fit closely with the outside walls of the enclosure and shall comply with the dimensions of Table 63.3 based on the type of construction as illustrated in Figure 63.4.

Exception: An enclosure provided with a gasket having a thickness that fills:

a) The space between parts, dimension A of Table 63.3; or

b) The maximum gap, dimension B of Table 63.3 is not required to comply with the requirements for dimensions A or B of Table 63.3.

The gasket material shall be closed cell neoprene or one that complies with the requirements in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

63.2.7 Each door shall be able to be opened to a minimum of 90 degrees from the closed position.

Table 63.3
Dimensions for flanged cover or door constructions

Sketch from Figure 63.4	W		A		B		C		D	
	Minimum flange width[a,c]		Maximum space between parts		Maximum gap		Minimum overlap[d]		Minimum barrier extension	
	inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)
A	1/2	(12.7)	1/8	(3.2)	1/8	(3.2)	7/16	(11.1)	–	–
A	3/4	(19.1)	3/16	(4.8)	3/16	(4.8)	5/8	(15.9)	–	–
A	1	(25.4)	1/4	(6.4)	1/4	(6.4)	7/8	(22.2)	–	–
B	1/2	(12.7)	1/8	(3.2)	1/8	(3.2)	7/16	(11.1)	–	–
B	3/4	(19.1)	3/16	(4.8)	3/16	(4.8)	5/8	(15.9)	–	–
B	1	(25.4)	1/4	(6.4)	1/4	(6.4)	7/8	(22.2)	–	–
C	1/2	(12.7)	3/16	(4.8)	3/16	(4.8)	1/4	(6.4)	–	–
C	3/4	(19.1)	1/4	(6.4)	1/4	(6.4)	7/16	(11.1)	–	–
D	1/2	(12.7)	3/32	(2.4)	–	–	7/16	(11.1)	–	–
E	1/2	(12.7)	1/8	(3.2)	1/8	(3.2)	7/16	(11.1)	1/4	(6.4)
F	1/2	(12.7)	–	–	1/4	(6.4)	7/16	(11.1)	–	–
G[b]	1/2	(12.7)	–	–	1/8	(3.2)	–	–	1/2	(12.7)
H	1/4	(6.4)	1/8	(3.2)	–	–	3/16	(4.8)	–	–

[a] Tolerance: minus 1/16 inch (1.6 mm).

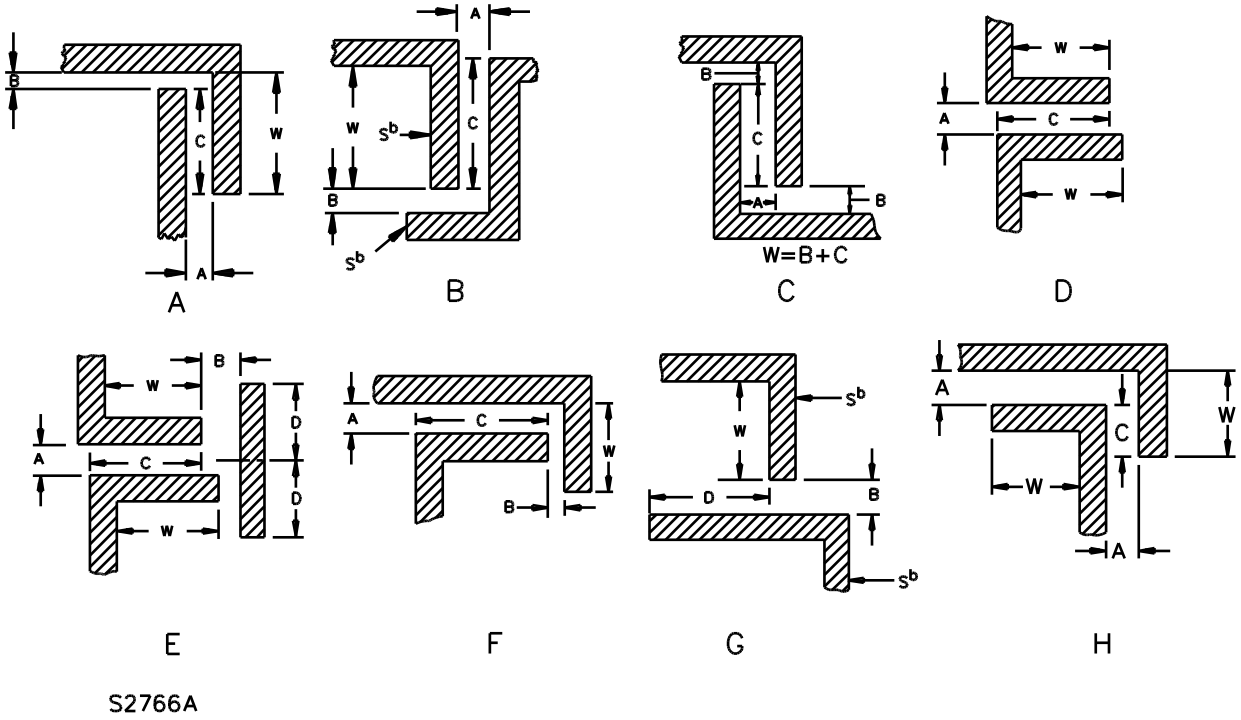
[b] Equipment within the enclosure shall be located on the side of the barrier extension D that is opposite the gap B.

[c] To determine whether a flanged cover complies with Dimension W, width of flange, the distance between the flat portion of the cover – clear of forming radii, beads, and draws – and a straight edge placed anywhere across any two flanges at any points is to be measured.

[d] To determine the overlap of a telescoping cover, the enclosure is to be placed on its back on a bench, with the cover in its closed position, and a mark is to be scribed on all walls of the box along the edge of the flange. The overlap is the measured distance between the scribe marks and the edges of the box walls, as in Figure 63.5. In scribing the marks, the cover is to be held in a fixed position without bending or distorting any portion of the box, cover, or other part of the enclosure, to prohibit displacement of the cover by the scribing tool.

Figure 63.4

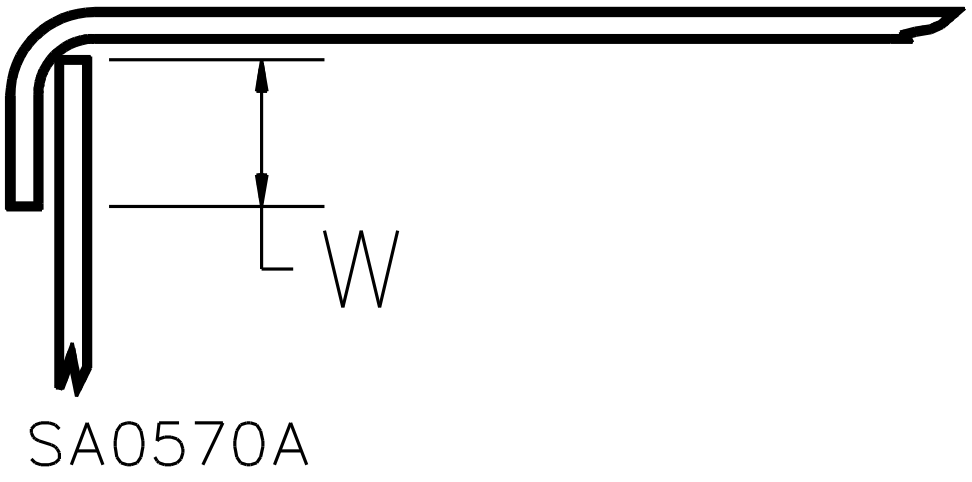
Flanged cover or door constructions[a]



[a] See Table 63.3 for dimensions for sketches A – H.
[b] The surfaces "S" are able to be in line with one another – not as shown.

Figure 63.5

Measurement of overlap



63.3 Corrosion protection

63.3.1 Both the inside and outside surfaces of an enclosure, including means for fastening, that are made of iron or steel shall be protected against corrosion by enameling, galvanizing, or plating.

Exception: The requirement does not apply to sliding surfaces of a hinge or to parts made of aluminum, brass, or stainless steel.

63.4 Enclosure openings

63.4.1 Openings in industrial control panel enclosures shall comply with Section 19.

63.5 Ventilation openings

63.5.1 Ventilation openings in an industrial control panel enclosure shall comply with Section 21.

63.6 Observation windows

63.6.1 Observation windows provided in an industrial control panel enclosure shall comply with Section 23.

64 Markings

64.1 An enclosure that complies with the requirements in Section 62, General, and Section 63, Construction, shall be marked with the manufacturer's name and "Type 1 Enclosure."

64.2 An enclosure that is not provided with a door shall be marked "Not suitable for housing renewable overload protective devices."

64.3 An enclosure that complies with the requirements in 62.5 is able to be marked “4X Indoor Use Only” in letters at least 5/32 inch (4.0 mm) high.

INDUSTRIAL MACHINERY

65 General

65.1 These requirements cover industrial control panels for industrial machinery (NFPA 79, Electrical Standard for Industrial Machinery). The following types of machines are identified as industrial machinery:

a) Metalworking machine tools, including machines that cut or form metal;

b) Plastics machinery, including injection molding, extrusion, blow molding, specialized processing, thermoset molding, and size reduction machines;

c) Wood machinery, including woodworking, laminating, and sawmill machines;

d) Assembly machines;

e) Material handling machines, including industrial robots and transfer machines; and

f) Inspection and testing machines, including coordinate measuring and in-process gauging machines.

65.2 Industrial control panels for industrial machinery shall comply with the requirements in Sections 4 – 61 and also with the requirements in Section 66, Construction, and Section 67, Markings, which supplement or modify the general-use industrial control panel requirements.

66 Construction

66.1 Enclosures

66.1.1 When swing out panels are provided, the construction shall permit the open position of the swing out panel to be not less than 110 degrees from the closed position. The movement of the swing out panel shall not be restricted by the internal wiring.

66.1.2 Opening of an enclosure (e.g. opening doors, lids, covers, and the like) containing live parts operating at or above 50 volts rms ac or 60 volts dc, shall be possible only under one or more of the following conditions:

a) The use of a key or tool is necessary for access. AII live parts mounted on the inside of doors or covers that are operating at or above 50 volts rms ac or 60 volts dc shall be protected from unintentional direct contact by the inherent design of components or by the application of barriers or obstacles such that a 50 mm (2 in.) sphere cannot contact any live parts. Cautionary marking shall be provided in accordance with 67.4.3.

b) The disconnecting means supplying the enclosure is interlocked (mechanically, electrically or both) with the enclosure door(s) in accordance with 66.1.3.

c) Opening without the use of a key or a tool and without disconnection of live parts shall be possible only when all live parts that are operating at or above 50 volts rms ac or 60 volts dc are separately enclosed or guarded such that there cannot be any contact with live parts.

Exception: An industrial control panel that is disconnected by an attachment plug is not required to be interlocked with the enclosure door when the construction complies with 66.1.2 (a) or (c). Cautionary marking shall be provided in accordance with 67.4.2.

66.1.3 If 66.1.2(b) is used to limit enclosure access, none of the interlocked enclosure door(s) shall open unless the power is disconnected and, upon closing the door(s), the interlock is automatically restored. Access shall be permitted without removing power if all of the following conditions are met:

a) It is possible at all times while the interlock is defeated to open the disconnecting means without the use of tools and lock the disconnecting means in the OFF (open) position.

b) Closing of the disconnecting means while the door of the enclosure containing the disconnecting means is open shall be prevented unless an interlock is operated by deliberate action.

c) All live parts mounted on the inside of the doors that are operating at or above 50 volts rms ac or 60 volts dc shall be protected from unintentional direct contact by the inherent design of components or the application of barriers of obstacles such that a 50 mm (2 in.) sphere cannot contact any live parts.

d) Relevant information about the procedures for the defeat of the interlock is provided with the instructions tor use of the electrical equipment.

66.1.3.1 *Deleted*

66.1.3.2 *Deleted*

66.1.4 A lighting circuit (for maintenance lighting within the control panel or machine work lights external to the control panel or both) shall not exceed 150V between conductors, provided with branch circuit protection rated not more than 15A and be derived from one of the following:

a) The secondary of an isolating transformer located on the load side of the disconnecting means.

b) The secondary of an isolating transformer located on the line side of the disconnecting means, for the supply of lighting circuits located within the control enclosure only.

c) The secondary of an isolating transformer located on the line side of the disconnecting means where the transformer is supplied with a separate disconnecting means provided on the control panel next to the main disconnecting means.

d) A grounded machine circuit.

e) An externally supplied lighting circuit for lighting located within the control enclosure and machine work lights.

66.1.5 All electrical components mounted to a subplate or subpanel that is fixed in place, not a swing out panel, shall be able to be individually removed without removal of other components, removal of the entire subplate, or requiring the use of special tools unless supplied with the industrial control panel, and shall be:

a) Attached to mounting rails which are fastened to the subplate by means of screws, rivets, or welds; or

b) Mounted by machine screws or self-tapping screws that thread into the subplate from the component side; and

1) Provides two complete threads of engagement into a steel subplate; or

2) Has 32 threads per inch (32 threads per 25.4 mm) and threads into a 0.053 inch (1.35 mm) thick steel subplate; or

3) Provides three complete threads of engagement into an aluminum subplate; or

c) Attached by plug-in connection to another component, such as a fuseholder or relay socket, which is secured to the subplate as in subitem a) or b) above.

66.2 Electrical assembly

66.2.1 All components connected to the supply circuit voltage shall be grouped or mounted separately from components connected only to the control circuit voltage.

66.2.2 All terminals for power circuits, control circuits and control circuits supplied from external voltage, shall be arranged such that the terminals of each circuit are grouped together and are readily identified from one another by means such as physical separation, barriers or color coding.

66.3 Grounding

66.3.1 A transformer that supplies control enclosure lighting or machine work lights shall be grounded as in Section 1616, Transformer Secondary Grounding.

66.3.2 The secondary winding of a control transformer or the secondary of a power supply is not required to be grounded, as specified in 16.1, when the secondary supplies only devices included as part of the controlled machine, not other machines or circuits, and is provided with a monitoring device that:

a) Provides an audible or visual indication when a ground fault occurs in any ungrounded conductor, such as a panel mounted indicator light or display, or one that interrupts the circuit in the event of a ground fault, such as a ground fault protective device; and

b) Is arranged with the control circuit so that the machine cannot restart with a detected ground fault.

Exception: A control circuit, as described in 66.3.2, supplied from a secondary of a Class 2 transformer or Class 2 power supply is not required to be supplied with a monitoring device or a ground fault protective device.

66.3.3 A transformer that supplies circuits that are not part of the controlled machinery shall comply with Section 16, Transformer Secondary Grounding.

66.3.4 An internal bonding conductor shall be provided between a metal cover or a door on which electrical components are mounted, and the enclosure or the equipment grounding terminal. The bonding conductor shall have an ampacity not less than the largest circuit conductor used to connect the cover or door-mounted components.

Exception: When all electrical components mounted to a metal cover or door are connected to a control circuit rated 30V rms or less the bonding conductor is not required.

66.4 Field wiring – power circuits

66.4.1 Field wiring terminals for supply connections shall be sized based upon the sum of:

a) 125 percent of all heater loads;

b) 125 percent of the largest motor load; and

c) The full-load current ratings of all other motors and other loads that are simultaneously operable.

66.4.2 Terminals provided for connection of loads intended for connection in the field shall comply with Section 28, Field Wiring. Terminals intended for connection by the manufacturer to the controlled machine shall be evaluated based on the requirements in Section 29, Internal Wiring, and are not required to comply with the marking requirements for field wiring terminals specified in Section 54, Field Wiring Terminal Markings.

66.4.3 Flexible cords shall comply with 28.5 and 37.7, except they are able to be used for connections to:

a) Pendant stations;

b) Stationary motors; or

c) Limit or proximity switches.

66.4.4 Receptacles shall comply with 28.6 and 37.6, except they are able to be used for interconnection with mating parts for connection of machine wiring. Class A ground fault circuit interrupter protection complying with the requirements in the Standard for Ground-Fault Circuit-Interrupters, UL 943, shall be provided for all 120-volt, single-phase, 15- or 20-ampere receptacles to be used for accessory equipment (for example hand-held power tools, test equipment).

66.4.5 Removable equipment is able to be connected to a grounding-type general use receptacle.

66.4.6 The cord shall be a hard-service or junior hard-service flexible cord that:

a) Complies with the Standard for Flexible Cords and Cables, UL 62; and

b) Terminates in an attachment plug that complies with the Standard for Attachment Plugs and Receptacles, UL 498, or the Standard for Plugs, Receptacles and Cable Connectors of the Pin and Sleeve Type, UL 1682, or the Outline of Investigation for Multi-Point Interconnection Power Cable

Assemblies for Industrial Machinery, UL 2237, or the Standard for Cable Assemblies and Fittings for Industrial Control and Signal Distribution, UL 2238 and is rated for the voltage involved.

66.5 Internal wiring – power circuits

66.5.1 In addition to types specified in 29.2.1, hard usage or junior hard usage flexible cord types as specified in 28.5.3 are able to be used and shall comply with the Standard for Flexible Cords and Cables, UL 62.

66.5.1.1 All current carrying conductors shall be identified at each termination by letter(s), or number(s), or color(s) or a combination thereof corresponding with the wiring diagrams provided with the industrial control panel. Where colors are used, a table identifying the color with the appropriate circuit or location shall be marked inside the door of the control panel or on the wiring diagram, unless the colors are as described in 66.5.2.

Exception: Wire jumpers installed such that both ends and the entire length of the conductor are clearly and continuously visible without removing components or covers need not be identified.

66.5.2 Unless other colors have been identified as in 66.5.1.1, the following color coding shall be used throughout the panel:

a) Black – ungrounded ac and dc power circuit conductors; and

b) White, gray or three continuous white stripes on other than green, blue, or orange – grounded ac and dc current-carrying power circuit conductor.

Exception: Insulated conductors sized 4 AWG (21.2 mm^2) or larger and having insulation colored other than as in 17.4 shall be identified at each termination point by a white marking, such as tape wrapped around the conductor.

66.5.3 Power circuit conductors shall not be smaller than 14 AWG (2.1 mm^2).

Exception: For power circuits that comply with the conditions in Table 66.2, 16 AWG or 18 AWG are able to be used.

66.5.4 Power circuit conductors that carry current for a motor or heater load shall be sized for an ampacity not less than 125 percent of the full-load current.

66.5.5 Power circuit conductors that carry current for one or more motors or heaters shall be sized for a ampacity not less than 125 percent of all heater loads plus 125 percent of the largest motor load plus the full-load current ratings of all remaining motors and other loads that are simultaneously operable.

Exception: Internal power circuit conductors that comply with the Temperature Test in the Standard for Industrial Control Equipment, UL 508, based upon the specific operating cycle of multiple motors, or multiple motors and heaters of an industrial machine.

66.5.6 Power circuit conductors to standard size motor controllers shall not exceed the wire sizes in Table 66.1. Conductors to other types of motor controllers shall comply with 66.5.3 and Table 28.1.

66.5.7 Conductors and cable shall be run without splices from terminal to terminal.

Table 66.1
Maximum conductor size for given standard motor controller size

Motor controller size	Maximum conductor size	
	AWG or kcmil	(mm^2)
00	14	(2.1)
0	10	(5.3)
1	8	(8.4)
2	4	(21.2)
3	1/0	(53.6)
4	3/0	(85.0)
5	500	(253)

NOTE – As specified in ANSI/NEMA ICS2-1993, Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated Not More Than 2000 Volts AC or 750 Volts DC.

Table 66.2
Ampacity and protection for power circuits with 16 AWG or 18 AWG conductors

Conductor		Load type	Max. ampere rating for branch circuit protection	Motor overload trip class
Size	Ampacity			
16 AWG	8	Non-motor	10[a]	–
	8	Motor	Per Table 31.1 [a]	Class 10
	5.5	Motor	Per Table 31.1 [a]	Class 20
18 AWG	5.6	Non-motor	7[b]	–
	5	Motor	Per Table 31.1 [b]	Class 10
	3.5	Motor	Per Table 31.1 [b]	Class 20

[a] Inverse time circuit breaker marked for use with 16 AWG or 18 AWG conductors, Class CC, CF, J or T fuse.

[b] Inverse time circuit breaker marked for use with 18 AWG conductors, Class CC, CF, J or T fuse.

66.6 Disconnecting means

66.6.1 A disconnecting means shall be provided for each incoming supply source. Other than terminals, no components shall be located on the line side of the disconnecting means.

Exception: The following equipment and circuits shall be permitted to be connected to the supply side of each disconnecting means:

a) Lighting circuits for lighting needed during maintenance or repair;

b) Attachment plugs and receptacles (plug and socket outlets) for the exclusive connection of repair maintenance tools and programming equipment. (e.g., hand drills, test equipment);

c) Circuits supplying equipment required to remain energized for satisfactory operation [e.g. temperature controlled measuring devices, product (work in progress) heaters, program storage devices];

d) Undervoltage protection circuits that are only used for automatic tripping in the event of the supply circuit failure;

e) Control circuits supplied by a power source located external to the industrial control panel;

f) Meters or meter sockets (inclusively meter transformers, current and/or voltage), or meter disconnect switches nominally rated not in excess of 1000 volts;

g) High-impedance shunts, and surge arresters, and Type 1 surge-protective devices;

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

i) Load management devices if overcurrent protection is provided;

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

k) 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

l) Connections for a fire pump controller.

66.6.2 A disconnecting means shall not incorporate a fuseholder that accepts a Class H fuse.

66.6.3 In addition to 30.4, an operating mechanism for the disconnecting means shall be:

a) Readily accessible when the enclosure doors are in the open or closed position;

b) Installed so that its operation is not restricted by the enclosure door while in the open position;

c) Be operable independent of the door position without the use of accessory tools or devices;

d) Able to be locked in the off position independent of the door position; and when locked, closing of the disconnect is not possible.

66.6.4 For such circuits all of the following requirements shall be met:

a) Permanent cautionary marking(s) as required by 55.4 shall be placed adjacent to the supply circuit disconnecting operating handle(s), indicating that it does not de-energize all exposed live parts when it is in the open (off) (isolated) position;

b) A permanent cautionary warning such as Figure 67.1 shall be placed on a non-removable part inside the control enclosure in proximity to each excepted circuit, or shall be identified by color as defined in 66.9.1.

66.7 Branch circuit protection

66.7.1 In lieu of 32.1.2, a branch circuit fuse shall be designated Class RK1, RK5, J, L, CF, T or CC and shall comply with the Standard for Low-Voltage Fuses – Part 12: Class R Fuses, UL 248-12, the Standard for Low-Voltage Fuses – Part 8: Class J Fuses, UL 248-8, the Standard for Low-Voltage Fuses – Part 10: Class L Fuses, UL 248-10, the Outline of Investigation for Low-Voltage Fuses – Part 17: Class CF Fuses, UL 248-17, the Standard for Low-Voltage Fuses – Part 15: Class T Fuses, UL 248-15, the Standard for Low-Voltage Fuses – Part 4: Class CC Fuses, UL 248-4. Class H, K, and G, fuses shall not be used.

66.7.2 A branch circuit fuseholder shall be provided with a rejection feature that prohibits a Class H fuse from being installed.

66.7.3 A single set of fuses or a circuit breaker shall be provided as the main overcurrent protection immediately following each disconnecting means.

Exception: An industrial control panel for industrial machinery intended for connection to the load side of a set of main overcurrent protective devices in the field shall be marked with the required size and type of overcurrent protection in accordance with 60.1.

66.7.4 The main overcurrent protection shall be sized based upon article 32.3.1

Exception No. 1: When branch circuit protection is not provided within the panel, the main overcurrent protection shall comply with Section 31, Branch Circuit Protection, for single motor or heater loads or for a group of loads.

Exception No. 2: Where internal conductors are sized based on the Exception to 66.5.5, the ampere rating of the main overcurrent protective devices shall not exceed the conductor ampacity in Table 28.1.

66.7.5 In lieu of the requirement in 31.4.1(c), two or more motors are able to be connected to a single set of overcurrent protective devices provided with a panel which does not exceed the smaller of (a) or (b) below:

a) The rating or setting of the branch circuit protection shall not exceed the value in Table 66.3 for any wire in the group.

b) The size of the branch circuit protection shall not exceed the ampere rating specified in the group installation marking of all power components and the type of branch circuit protective device shall be of the type specified in the group installation marking.

66.7.6 Branch circuit protection for a lighting circuit shall not exceed 15 amperes.

Table 66.3
Relationship between conductor size and overcurrent protection rating for power circuits

Conductor size		Maximum rating of fuse or inverse time circuit breaker, amperes
AWG	(mm^2)	
18	See footnote	See footnote
16	See footnote	See footnote
14	(2.1)	60
12	(3.3)	80
10	(5.3)	100
8	(8.4)	150
6	(13.3)	200
4	(21.2)	250
3	(26.7)	300
2	(33.6)	350
1	(42.4)	400
1/0	(53.6)	500
2/0	(67.4)	600
3/0	(85.0)	700
4/0	(107.2)	800

* Maximum ratings and type of branch short-circuit and ground-fault protective devices for 16 AWG and 18 AWG shall be determined in accordance with the exception to 66.5.3.

66.8 Motor controllers

66.8.1 Reversing motor controllers and wye-delta controllers shall comply with Section 33 except, in lieu of 33.4.1 and 33.5.2, they shall be provided with both mechanical and electrical interlocking means.

66.8.2 Standard size motor controllers used for plugging or jogging a motor shall control motors with horsepower ratings that do not exceed those given in Table 66.4 for the size of motor controller used. Other types of motor controllers shall be used within the manufacturer's specifications for plugging or jogging duty.

66.8.3 A robot controller shall comply with the requirements in the Standard for Robots and Robotic Equipment, UL 1740, when evaluated with the intended manipulator arm. The manufacturer name and model of the manipulator arm to be supplied in the field shall be marked as in 67.3.2.

Table 66.4
Horsepower and locked-rotor ampere ratings for 3-phase, single-speed, full-voltage magnetic controllers for plug-stop, plug-reverse, or jogging duty

Size of controller	200 volts		230 volts		460 volts		575 volts	
	hp	LRA	hp	LRA	hp	LRA	hp	LRA
0	1-1/2	46	1-1/2	40	2	25	2	20
1	3	74	3	70	5	52	5	42
2	7-1/2	175	10	175	15	127	15	102
3	15	335	20	335	30	250	30	200
4	25	500	30	600	50	500	60	400
5	60	1250	75	1250	150	1250	150	1000
6	125	2500	150	2500	300	2500	300	2000

NOTE – These horsepower ratings are based on locked-rotor current ratings given in this Table. For motors having higher locked-rotor currents, a larger controller shall be used so that its locked-rotor current rating is not exceeded. This Table does not cover horsepower ratings of single-phase, reduced voltage, or multi-speed motor controller applications.

66.9 Internal wiring of control circuit

66.9.1 Unless other colors have been identified as in 66.9.1.1, the following color coding shall be employed for ungrounded control circuit conductors throughout the panel:

a) Red – ungrounded ac control circuits.

b) Blue – ungrounded dc control circuits.

Exception: Leads on assembled components, multiconductor cable, leads used to connect electronic devices, and conductor sizes 20 – 30 AWG (0.52 – 0.05 mm^2) are not required to comply with this requirement.

66.9.1.1 All current carrying control circuit conductors shall be identified at each termination by letter(s), or number(s), or color(s) or a combination thereof corresponding with the wiring diagrams provided with the industrial control panel. Where colors are used, a table identifying the color with the appropriate circuit or location shall be marked inside the door of the control panel or on the wiring diagram, unless the colors are as described in 66.9.1, 66.9.1.2 and 66.9.1.3.

66.9.1.2 Unless other colors have been identified as in 66.9.1.1, the following color coding shall be employed for grounded current carrying control circuit conductors throughout the panel:

a) White or gray or three white stripes on other than green, blue, or orange – grounded ac current-carrying control circuit conductor regardless of voltage.

b) White with blue stripe – grounded dc current-carrying control circuit conductor.

c) White with orange stripe – grounded ac or dc current-carrying conductor of an excepted circuit described in the Exception to 66.6.1 that remains energized when main disconnect switch is in the "off" position.

66.9.1.3 The color ORANGE shall only be used for ungrounded ac or dc excepted circuits, described in the Exception to 66.6.1, that remain energized when the main disconnect is in the "off" position.

Exception: Conductors not available in orange can be permanently re-identified by means of colored marker at each connection point.

66.9.2 Control circuit conductors shall not be smaller than 22 AWG (0.32 mm^2).

Exception: Control circuit conductors sized 24 – 30 AWG (0.20 – 0.05 mm^2) stranded are permitted in multiconductor cables, or as individual solid conductors where installed within control enclosures and not subject to flexing.

66.10 Overcurrent protection of common control circuit

66.10.1 Conductors of a control circuit tapped from the load side of a branch circuit protective device shall be protected by overcurrent devices rated not more than as specified in Table 66.5.

Table 66.5
Overcurrent device ratings for control circuit conductors tapped from load side of branch circuit protective device

Conductor size		Control circuit overcurrent device, amperes	Branch circuit overcurrent device, amperes	
AWG	(mm^2)		Control in wire panel	Remote control
larger than 14	(larger than 2.1)	equal to wire ampacity	400 percent of wire ampacity	300 percent of wire ampacity
14	(2.1)	20	80	60
16	(1.3)	20	40	20
18	(0.82)	20	25	20

66.11 Operator controls

66.11.1 Start operators shall be located above or to the left of the associated stop buttons.

Exception: Start buttons in series, such as for two-handed control, are not required to comply with this requirement.

66.11.2 An industrial control panel provided with operator controls, such as pushbuttons and selector switches, shall also be provided with an emergency stop button.

66.11.3 Both the emergency stop button or actuator and the associated contact blocks shall comply with the requirements in the Standard for Low-voltage Switchgear and Controlgear – Part 5-5: Control Circuit Devices and Switching Elements – Electrical Emergency Stop Device with Mechanical Latching Function, UL 60947-5-5.

67 Markings

67.1 Nameplate markings

67.1.1 In addition to the information in 52.1, the nameplate shall include "industrial control panel for industrial machinery", and the current rating of the largest heater load.

67.1.2 *Deleted*

67.1.3 When the main overcurrent protection in the panel is intended to provide protection for the supply conductors and the machine, the panel shall be marked “Supply conductor and machine overcurrent protection provided at main supply terminals.”

67.2 Operator controls

67.2.1 Each control device shall be identified as to its function by a legend plate placed next to the device.

Exception: When the requirements of 67.2.3 are met, emergency stop actuators do not require a legend plate.

67.2.2 The color red shall only be used for operators for stop, off, or emergency stop operations.

67.2.3 The actuator of an emergency stop button shall be red and the base of the emergency stop actuator shall be yellow.

67.3 Components

67.3.1 All components shall be identified with a designation that corresponds to its designation on the schematic wiring diagram.

67.3.2 The output connections for a robot manipulator arm shall be marked to identify the manufacturer name and model number of the manipulator arm that complies with 66.8.3.

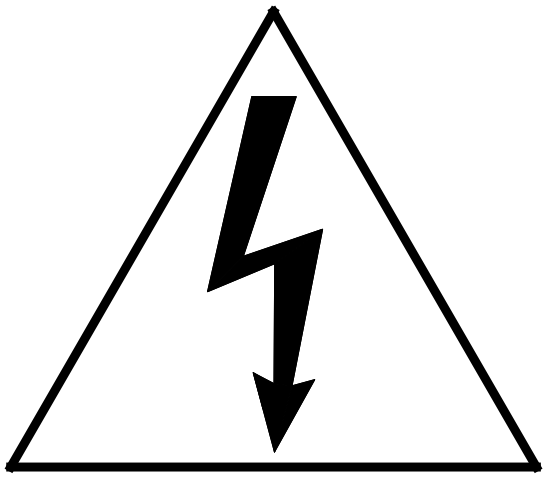
67.4 Cautionary marking

67.4.1 An enclosure that does not clearly contain electrical parts shall be marked, “CAUTION – High Voltage – ___V”, or with a black lightning flash on a yellow background within a black triangle as in Figure 67.1, or an equivalent marking.

Exception: Equipment provided with external electrical devices such as disconnect handles and operator controls are not required to comply with this requirement.

Figure 67.1

Warning symbol (IEC 417, symbol 5036)



67.4.2 An industrial control panel that is disconnected by an attachment plug and constructed as in the exception to 66.1.2 shall be marked on the outside of the door or cover with “CAUTION – Disconnect power before opening enclosure”, or the equivalent.

67.4.3 An industrial control panel that is disconnected by a remote disconnecting means and constructed as in 66.1.2 (a) shall be marked on the outside of the door or cover with “CAUTION – Disconnect power before opening enclosure. Close the enclosure before restoring power”, or the equivalent.

CRANE CONTROL

68 General

68.1 These requirements cover industrial control panels specifically designed for use with cranes or hoists.

68.2 Industrial control panels for crane control shall comply with the requirements in Sections 4 – 61 and also with the requirements in Section 69, Glossary, and Section 70, Construction, which supplement or modify the general-use industrial control panel requirements.

69 Glossary

69.1 For the purpose of the requirements in Sections 70 – 72, the following definition applies.

69.2 SHORT TIME DUTY MOTOR – A motor that is used for a short time period, usually 15, 30, or 60 minutes, due to the physical construction of a crane or a hoist.

70 Construction

70.1 Field wiring terminals of power circuits

70.1.1 Field wiring terminals for connection to a single motor intended for short time duty shall be capable of retaining a field wiring conductor sized in accordance with the ampacities of Table 70.1 using 100 percent of the motor full-load current rating.

70.1.2 Field wiring terminals for connections to multiple motors intended for short time duty shall be capable of retaining a field wiring conductor sized in accordance with the ampacities of Table 70.1 for the longest time motor of the group using the sum of:

a) 100 percent of the largest motor or group of motors controlling a single motion of the crane; and

b) 50 percent of the second largest motor or group of motors controlling a single motion of the crane.

70.1.3 Field wiring terminals for connection of secondary resistors of a short time duty motor shall be capable of retaining a field wiring conductor sized in accordance with the ampacities of Table 70.1 using the secondary current rating multiplied by the derating percentage from Table 36.1.

Table 70.1
Ampacities of field wiring conductors for use with short time rated motors

Wire size		75°C (167°F) conductor ampacity		
AWG or kcmil	(mm^2)	60 minutes	30 minutes	15 minutes
16	(1.3)	10	12	13
14	(2.1)	25	26	29
12	(3.3)	30	33	37
10	(5.3)	40	43	48
8	(8.4)	55	60	67
6	(13.3)	76	86	96
5	(16.8)	85	95	106
4	(21.2)	100	117	131
3	(26.7)	120	141	158
2	(33.6)	137	160	180
1	(42.4)	143	175	196
1/0	(53.6)	190	233	261
2/0	(67.4)	222	267	299
3/0	(85.0)	280	341	382
4/0	(107)	300	369	413
250	(127)	364	420	470
300	(152)	455	582	652
350	(177)	486	646	724
400	(203)	538	688	771
450	(228)	600	765	857
500	(253)	660	847	949

70.2 Internal wiring

70.2.1 Internal wiring to a short time duty motor shall be sized based on the full-load current carried by the conductor in accordance with Table 70.2.

Table 70.2
Ampacities of insulated internal wiring conductors for use with short time rated crane and hoist motors

Size of conductors		90°C (194°F) conductor ampacity		
AWG or kcmil	(mm^2)	60 minutes	30 minutes	15 minutes
14	(2.1)	31	32	36
12	(3.3)	36	40	45
10	(5.3)	49	52	58
8	(8.4)	63	69	77
6	(13.3)	83	94	105
5	(16.8)	95	106	119
4	(21.2)	111	130	146
3	(26.7)	131	153	171
2	(33.6)	148	173	194
1	(42.4)	158	192	215
0	(53.6)	211	259	290
2/0	(67.4)	245	294	329
3/0	(85.0)	305	372	417
4/0	(107)	319	399	447
250	(127)	400	461	516
300	(152)	497	636	712
350	(177)	542	716	802
400	(203)	593	760	851
450	(228)	660	836	936
500	(253)	726	914	1024

70.3 Disconnecting means

70.3.1 A disconnecting means, other than a circuit breaker, for a circuit supplying short time duty motors shall have a horsepower rating with an equivalent full-load current of not less than either of the following:

a) The full-load current(s) of all motors required for any single crane motion; or

b) The full-load current(s) of all motors and other loads that are able to be energized simultaneously.

Exception: For motor circuits supplied by power conversion equipment, the full-load current shall be the input current of the power conversion equipment.

70.3.2 A circuit breaker used as the disconnecting means for a circuit supplying short time duty motors shall be rated not less than 125 percent of either 70.3.1 (a) or (b).

70.4 Branch circuit protection

70.4.1 Two or more motors that operate a single motion of a crane or hoist are able to be evaluated as a single motor and protected by a single set of branch circuit protective devices sized in accordance with the requirements for single motor branch protection in Section 31, Branch Circuit Protection.

70.5 Motor overload protection

70.5.1 Two or more motors that operate a single motion of a crane or hoist and are controlled from a single motor controller are able to be evaluated as a single motor and protected by a single overload relay with a trip rating equal to the sum of the full-load currents.

70.5.2 Manually-operated hoist motors rated not more than 7-1/2 horsepower (5.6 kW) and that are not part of an overhead crane are not required to have overload protection.

70.6 Field wiring of control circuits

70.6.1 The minimum size of field wiring to a control circuit shall be 20 AWG (0.52 mm^2).

70.7 Overcurrent protection of control circuit

70.7.1 Control circuit conductors shall have overcurrent protection rated not more than 300 percent of the conductor capacity.

70.7.2 The primary and secondary conductors of a control transformer are protected by overcurrent protective devices located in the secondary circuit and rated not more than 200 percent of the ampacity of the secondary conductors.

71 Ratings

71.1 The nameplate rating of an industrial control panel for crane control shall include the longest short time duty rating of all short time duty motors controlled.

71.2 The load ratings of a short time duty motor shall include the short time duty rating.

72 Markings

72.1 The nameplate shall include "Crane Control Panel" or "Hoist Control Panel."

72.2 The field wiring terminals of a power circuit including a short time duty motor shall be marked to use 75°C (167°F) conductors only.

SERVICE EQUIPMENT USE

73 General

73.1 These requirements cover industrial control panels for service equipment use. These requirements also apply to other special-use industrial control panels that are intended for use as service equipment.

73.2 Industrial control panels for service equipment use shall comply with the requirements in Sections 4 – 61 and also with the requirements in Sections 74 – 79, which supplement or modify the general-use industrial control panel requirements.

74 Glossary

74.1 For the purpose of the requirements in Sections 75 – 79, the following definitions apply.

74.2 EQUIPMENT GROUNDING CONDUCTOR – A conductor that bonds an accessible metal part, such as an electrical enclosure, of load side equipment to the ground or neutral bus.

74.3 GROUND BUS – A bus bar that is bonded to the enclosure and typically connects grounding electrode conductor, main bonding jumper, and equipment grounding terminals together.

74.4 GROUND FAULT PROTECTION – Protection required for services rated 1000 amperes or more and derived form a 3-phase, 4-wire, solidly grounded wye with a rated voltage in excess of 150 volts to ground.

74.5 GROUNDED SERVICE CONDUCTOR – Service conductor intended to be connected to the grounding electrode conductor. See 74.6.

74.6 GROUNDING ELECTRODE CONDUCTOR – Conductor that connects the grounded service conductor to earth ground and is connected to either the ground or neutral bus.

74.7 MAIN BONDING JUMPER – Conductor that connects the neutral bus to the industrial control panel enclosure or ground bus.

74.8 NEUTRAL BUS – Bus bar that is insulated from the enclosure and typically connects grounded service conductor, main bonding jumper, and neutral conductor(s) together. When a ground bus is not provided, additionally connects grounding electrode conductor and equipment grounding terminals.

74.9 NEUTRAL CONDUCTOR – Current-carrying conductor connected to the ground or neutral bus on the load side of the connections for the grounded service conductor, grounding electrode conductor, and main bonding jumper.

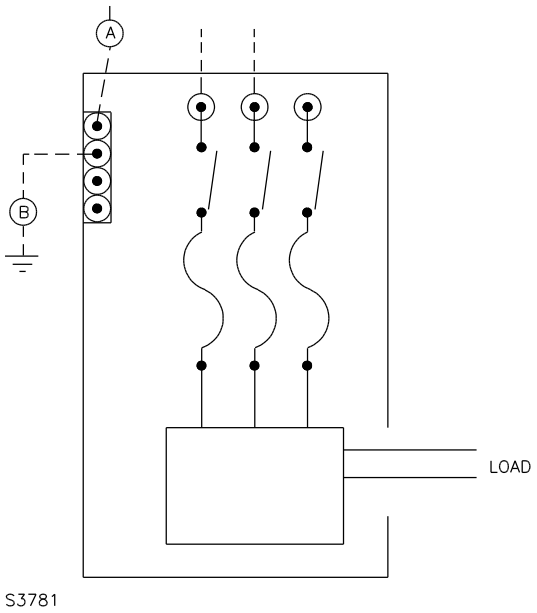
75 Construction

75.1 Grounding and bonding

75.1.1 A grounded service conductor terminal and a grounding electrode conductor terminal shall be provided for all industrial control panels for service equipment use. A main bonding jumper shall be provided when the grounded service conductor terminal and the grounding electrode conductor terminal are insulated from the enclosure. See Figure 75.1 – Figure 75.10 for application of requirements for grounding and bonding conductors and terminals.

Figure 75.1

Single-phase, 3-wire (factory bonded neutral)

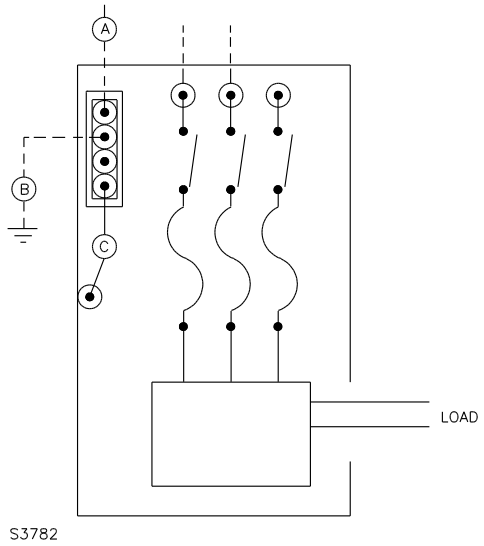


A – Grounded service conductor

B – Grounding electrode conductor

Figure 75.2

Single-phase, 3-wire (insulated neutral)



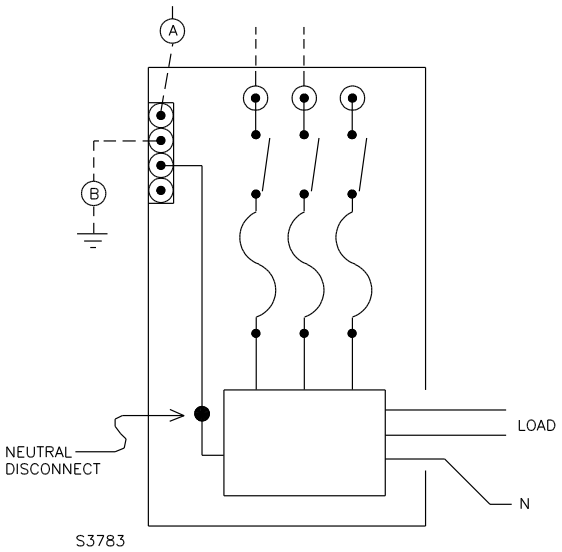
A – Grounded service conductor

B – Grounding electrode conductor

C – Main bonding jumper

Figure 75.3

Single-phase 3-wire with load neutral connection (factory bonded neutral)



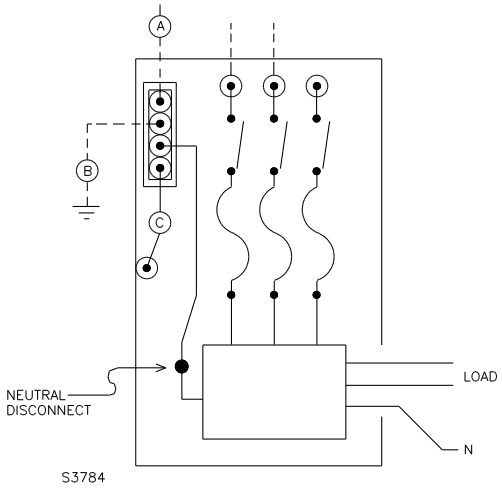
A – Grounded service conductor

B – Grounding electrode conductor

N – Neutral load conductor

Figure 75.4

Single-phase, 3-wire with load neutral connection (insulated neutral)



A – Grounded service conductor

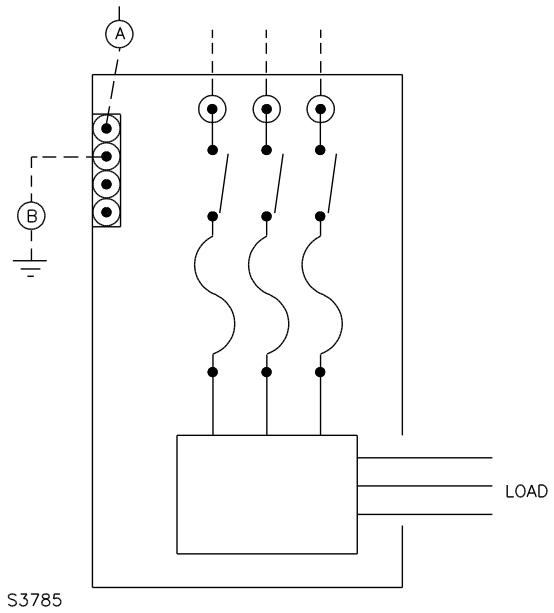
B – Grounding electrode conductor

C – Main bonding jumper

N – Neutral load conductor

Figure 75.5

Three-phase, 4-wire (factory bonded neutral)

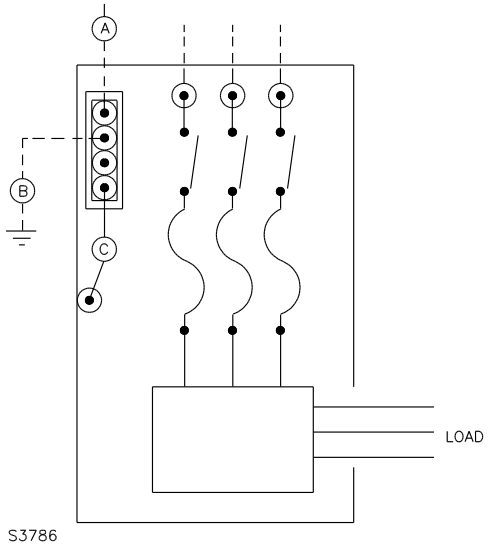


A – Grounded service conductor

B – Grounding electrode conductor

Figure 75.6

Three-phase, 4-wire (insulated neutral)



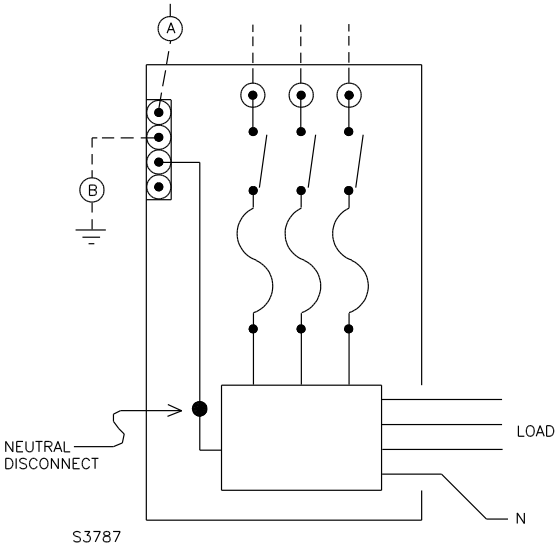
A – Grounded service conductor

B – Grounding electrode conductor

C – Main bonding jumper

Figure 75.7

Three-phase, 4-wire with load neutral connection (factory bonded neutral)



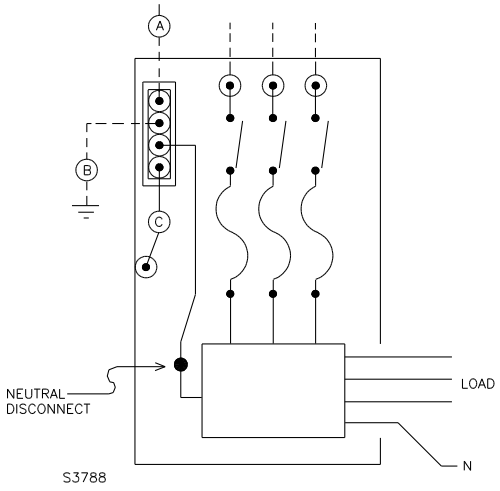
A – Grounded service conductor

B – Grounding electrode conductor

N – Neutral load conductor

Figure 75.8

Three-phase, 4-wire with load neutral connection (insulated neutral)



A – Grounded service conductor

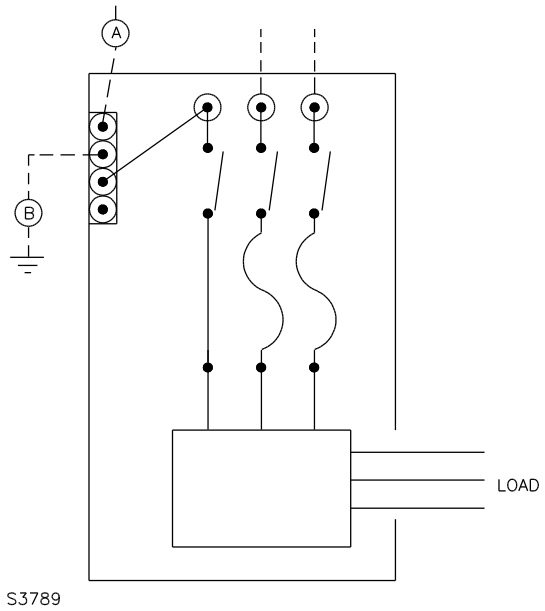
B – Grounding electrode conductor

C – Main bonding jumper

N – Neutral load conductor

Figure 75.9

Three-phase, delta end-grounded (factory bonded neutral)

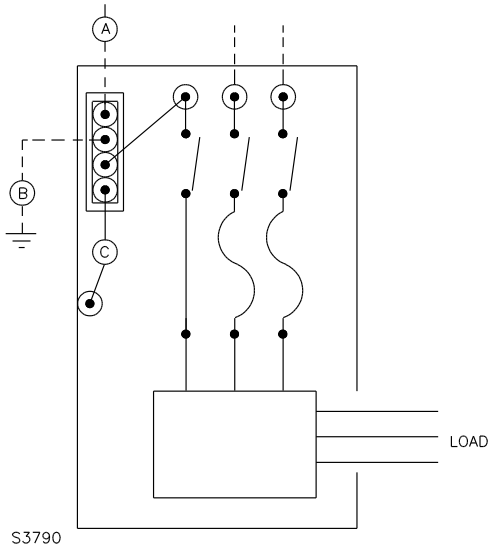


A – Grounded service conductor

B – Grounding electrode conductor

Figure 75.10

Three-phase, delta end-grounded (insulated neutral)



A – Grounded service conductor

B – Grounding electrode conductor

C – Main bonding jumper

75.1.2 For other than a three-phase three-wire delta, the grounded service conductor terminal shall accommodate a wire sized not smaller than the grounding electrode conductor specified in 75.1.3. The grounded service conductor terminal for a three-phase three-wire delta service shall accommodate a wire sized not smaller than the largest ungrounded service conductor. The grounded service conductor terminal shall accommodate a wire sized not smaller than the main bonding jumper specified in 75.1.4.

Exception: The grounded service conductor terminal is not required to accommodate a wire larger than the terminals for connection of the largest ungrounded service conductor.

75.1.3 The grounding electrode conductor terminal shall accommodate a wire sized not smaller than as specified in Table 75.1.

75.1.4 The main bonding jumper, when provided, shall be sized in accordance with Table 75.1. The terminals provided to retain the main bonding jumper shall accommodate the wire size involved.

75.1.5 The ground bus and neutral bus, when provided, shall have cross-sectional area not smaller than that specified in Table 75.1 for the main bonding jumper.

75.1.6 Terminals for equipment grounding conductors, when provided for load side equipment, shall be sized in accordance with Section 14, Grounding – General.

Table 75.1
Size of grounding electrode conductor and main or system bonding jumper

Service or system ampere rating not exceeding	Size of main bonding jumper or system bonding jumper (minimum)[b]				Equivalent cross section of main bonding jumper or system bonding jumper (minimum)				Size of grounding electrode conductor (minimum)[b]			
	Copper		Aluminum		Copper		Aluminum		Copper		Aluminum	
	AWG or kcmil	(mm^2)	AWG or kcmil	(mm^2)	$inches^2$	(mm^2)	$inches^2$	(mm^2)	AWG	(mm^2)	AWG or kcmil	(mm^2)
90	8	(8.4)	6	(13.3)	0.013[c]	(8.39)	0.021[c]	(13.55)	8	(8.4)	6	(13.3)
125	6	(13.3)	4	(21.2)	0.021[c]	(13.55)	0.033[c]	(21.29)	6	(13.3)	4	(21.2)
150	6	(13.3)	4	(21.2)	0.021[d]	(13.55)	0.033[d]	(21.29)	6	(13.3)	4	(21.2)
200	4	(21.2)	2	(33.6)	0.033[d]	(21.29)	0.052[d]	(33.55)	4	(21.2)	2	(33.6)
225	2	(33.6)	1/0	(53.5)	0.052[e,f]	(33.55)	0.083[e,f]	(53.55)	2	(33.6)	1/0	(53.5)
400	1/0[g]	(53.5)	3/0[g]	(85.0)	0.083[f,g]	(53.55)	0.132[f,g]	(85.16)	1/0[g]	(53.5)	3/0[g]	(85.0)
500	1/0	(53.5)	3/0	(85.0)	0.083	(53.55)	0.132	(85.16)	1/0	(53.5)	3/0	(85.0)
800	2/0	(67.4)	4/0	(107.2)	0.105	(67.74)	0.166	(107.10)	2/0	(67.4)	4/0	(107.2)
1000	3/0	(85.0)	250	(127)	0.132	(85.16)	0.196	(126.45)	3/0	(85.0)	250	(127)
1200	250[a]	(127)	250	(127)	0.196[a]	(126.45)	0.196	(126.45)	3/0	(85.0)	250	(127)
1600	300[a]	(152)	400[a]	(203)	0.236[a]	(152.26)	0.314[a]	(202.58)	3/0	(85.0)	250	(127)
2000	400[a]	(203)	500[a]	(253)	0.314[a]	(202.58)	0.393[a]	(253.55)	3/0	(85.0)	250	(127)
2500	500[a]	(253)	700[a]	(355)	0.393[a]	(253.55)	0.550[a]	(354.84)	3/0	(85.0)	250	(127)
3000	600[a]	(304)	750[a]	(380)	0.471[a]	(304.0)	0.589[a]	(380.00)	3/0	(85.0)	250	(127)
4000	750[a]	(380)	1000[a]	(506)	0.589[a]	(380.00)	0.785[a]	(506.45)	3/0	(85.0)	250	(127)
5000	900	(456)	1250	(633)	0.707	(456.0)	0.982	(633.0)	3/0	(85.0)	250	(127)
6000	1250	(633)	1500	(760)	0.982	(633.0)	1.178	(760.0)	3/0	(85.0)	250	(127)

Table 75.1 Continued on Next Page

Table 75.1 Continued

Service or system ampere rating not exceeding	Size of main bonding jumper or system bonding jumper (minimum)[b]		Equivalent cross section of main bonding jumper or system bonding jumper (minimum)		Size of grounding electrode conductor (minimum)[b]	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
	AWG or kcmil (mm^2)	AWG or kcmil (mm^2)	inches^2 (mm^2)	inches^2 (mm^2)	AWG (mm^2)	AWG or kcmil (mm^2)

[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 service equipment rated 1200 amperes and above. This applies when the cross section of the service conductor is limited by the wire terminal connectors provided.

[b] These are also sizes for the grounded service conductor of 75.1.2.

[c] A No. 8 (4.2 mm diameter) or larger brass or No. 10 (4.8 mm diameter) or larger steel screw, the head of which has a green finish that is visible after installation, may be used.

[d] A No. 10 (4.8 mm diameter) or larger brass or steel screw, the head of which has a green finish that is visible after installation, may be used.

[e] A No. 10 (4.8 mm diameter) or larger brass screw, the head of which has a green finish that is visible after installation, may be used.

[f] A 1/4 inch (6.4 mm) diameter or larger brass or steel screw, the head of which has a green finish that is visible after installation, may be used.

[g] When the ampere rating is 400 amperes and the wire terminal connectors for the main service conductors are rated for two 3/0 AWG (85 mm^2) copper or two 250 kcmil (127 mm^2) aluminum conductors but will not accept a 600 kcmil (304 mm^2) conductor, these values may be reduced to 2 AWG [0.052 square inch, (33.55 mm^2)] copper or 1/0 AWG [0.083 square inch, (53.55 mm^2)] aluminum.

75.2 Spacings

75.2.1 The spacings on the supply side of the main overcurrent protection between uninsulated current-carrying parts of adjacent components and grounded dead-metal parts and at field wiring terminals shall comply with the spacing requirements specified in Table 10.2 regardless of their location in the circuit (such as the feeder, branch, or control circuit).

75.3 Field wiring terminals

75.3.1 The field wiring terminals for the ungrounded service conductors shall accommodate the connection of a conductor sized in accordance with Section 28, Field Wiring.

75.4 Disconnecting means

75.4.1 A disconnect switch shall comply with 30.1.1 – 30.1.4. A manual motor controller shall not be used as the service disconnecting means.

75.4.2 A main disconnecting means which simultaneously opens all ungrounded conductors of each service entrance to the panel shall be provided as a part of the industrial control panel.

75.4.3 No more than six disconnecting means shall be required to completely disconnect the service to the industrial control panel. A service for connection of lighting or appliances shall not require more than two disconnecting means to completely disconnect the service.

75.4.4 A disconnecting means for SPDs, ground fault equipment, and the control circuit for power operated disconnecting means shall not be counted towards the number of disconnecting means allowed by 75.4.3.

75.5 Neutral disconnecting means

75.5.1 The neutral conductor shall be provided with a disconnecting means. The disconnecting means shall consist of:

a) Another pole of the main disconnecting means; or

b) A removable link that complies with 75.5.2.

75.5.2 The disconnecting means required in 75.5.1 is able to be any of the following:

a) A link, screw, or similar conducting piece that connects two terminals.

b) Wire connectors or a terminal plate or bus provided with wire-binding screws and upturned lugs or the equivalent for clamping a 10 AWG (5.3 mm^2) or smaller wires.

c) A stud provided with wire connectors or lugs or with nuts and cupped washers for clamping 10 AWG (5.3 mm^2) or smaller wires.

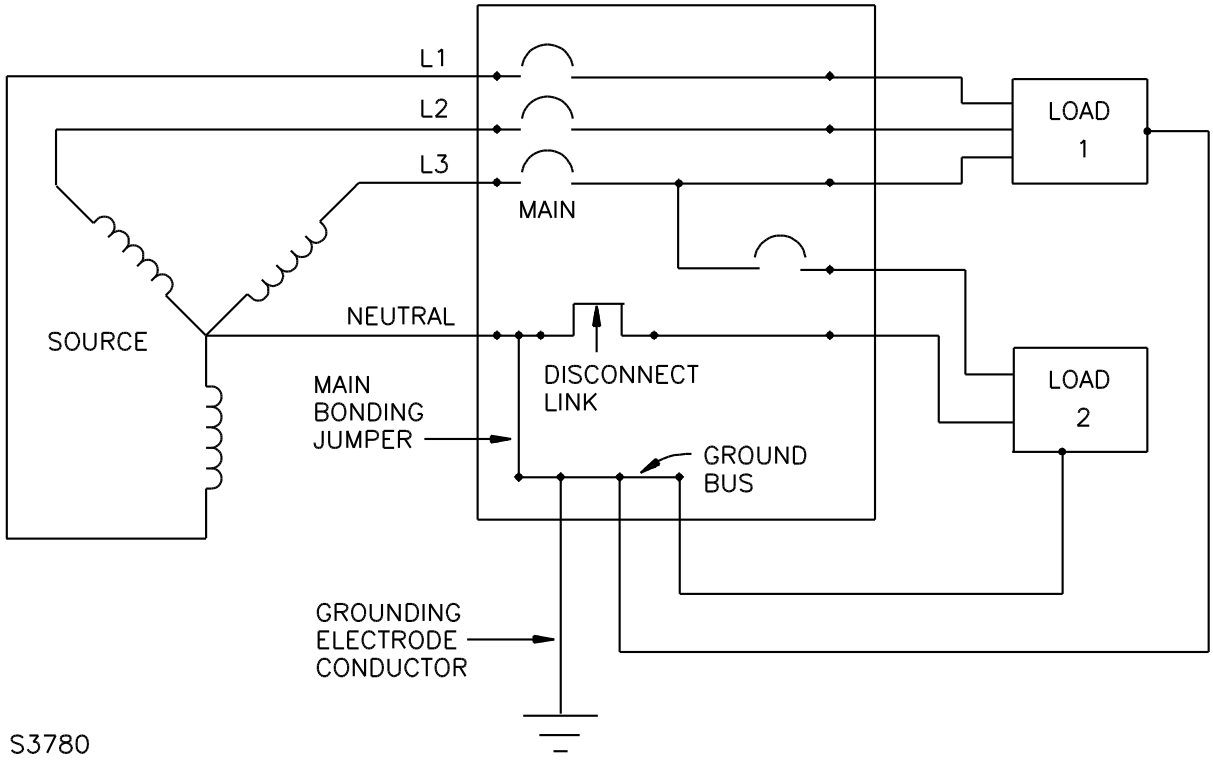
d) A multiwire connector.

75.5.3 With respect to 75.5.2 (b), (c), and (d), the disconnecting means is the joint between the load conductor and the load conductor connector.

75.5.4 The disconnect link shall be located on the load side of the grounding electrode conductor terminal and the main bonding jumper terminal, as shown in Figure 75.11. The link shall be located so that unintentional contact with any uninsulated ungrounded part on the line side of the disconnecting means does not occur while the link is being removed or replaced. The disconnecting link shall be accessible for removal without the need for loosening any screws or bolts that secure parts other than the disconnect link.

Figure 75.11

Neutral disconnecting means location



75.6 Ground-fault protection

75.6.1 A device provided for ground fault protection for equipment as required in 75.6.2 shall comply with the requirements in the Standard for Ground-Fault Sensing and Relaying Equipment, UL 1053. Circuit breakers that have been investigated to the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489 and include ground-fault protection for equipment comply with this requirement.

75.6.2 Equipment intended for 3-phase, 4-wire, solidly grounded wye-connected services rated in excess of 150 volts to ground, and 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 protection 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: Ground-fault protection is not required to be provided for equipment marked in accordance with 77.5.4.

75.6.3 Compliance with the requirements specified in 75.6.1 and 79.1 anticipates that each service disconnect device to which the requirement applies is provided with automatic tripping means for actuating by ground-fault sensing and relaying equipment that is able to be a part of the service disconnect device or a separate device.

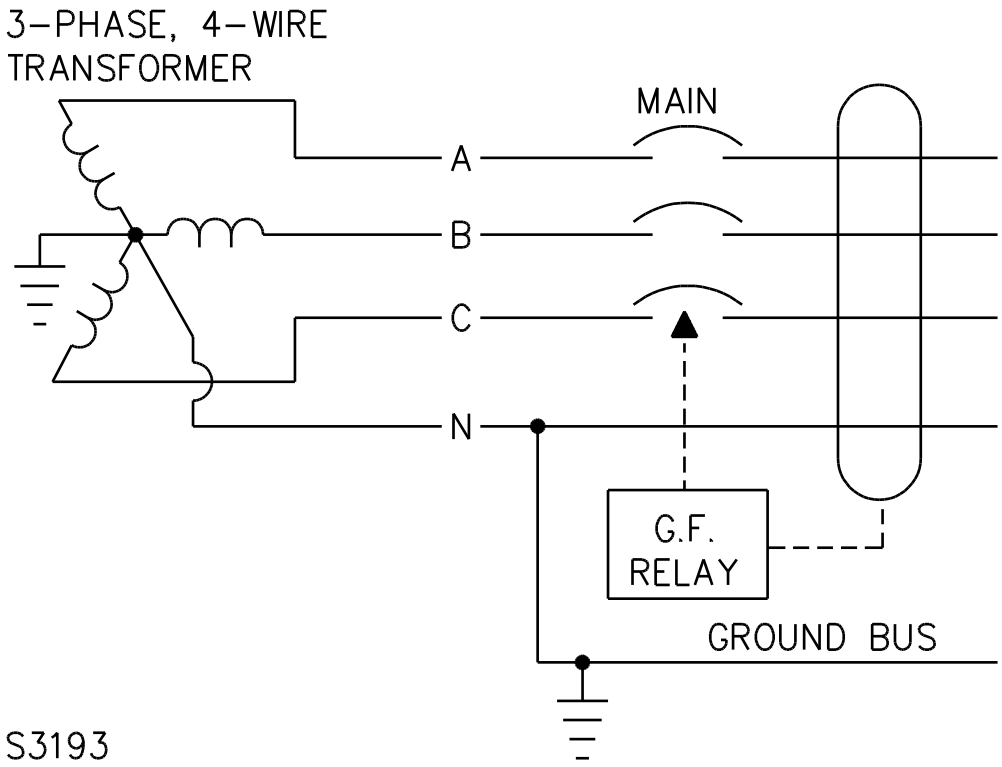
75.6.4 Ground-fault sensing and relaying equipment that is not a part of the disconnect device shall be mounted in the equipment enclosure and connected to the disconnect device and power source. The

rating of the disconnect device control circuit shall be compatible with that of the sensing and relaying components.

75.6.5 A ground fault protection system that employs a sensing element that encircles the grounded service conductor, when provided, and all ungrounded conductors of the protected circuit (commonly referred to as a zero-sequence type system) shall be connected in such a manner that the sensing element is located on the load side of any grounding or bonding connection to the grounded service conductor. It is able to be on the line or load side of the disconnecting device for the protected circuit. A typical zero-sequence type system is shown in Figure 75.12.

Figure 75.12

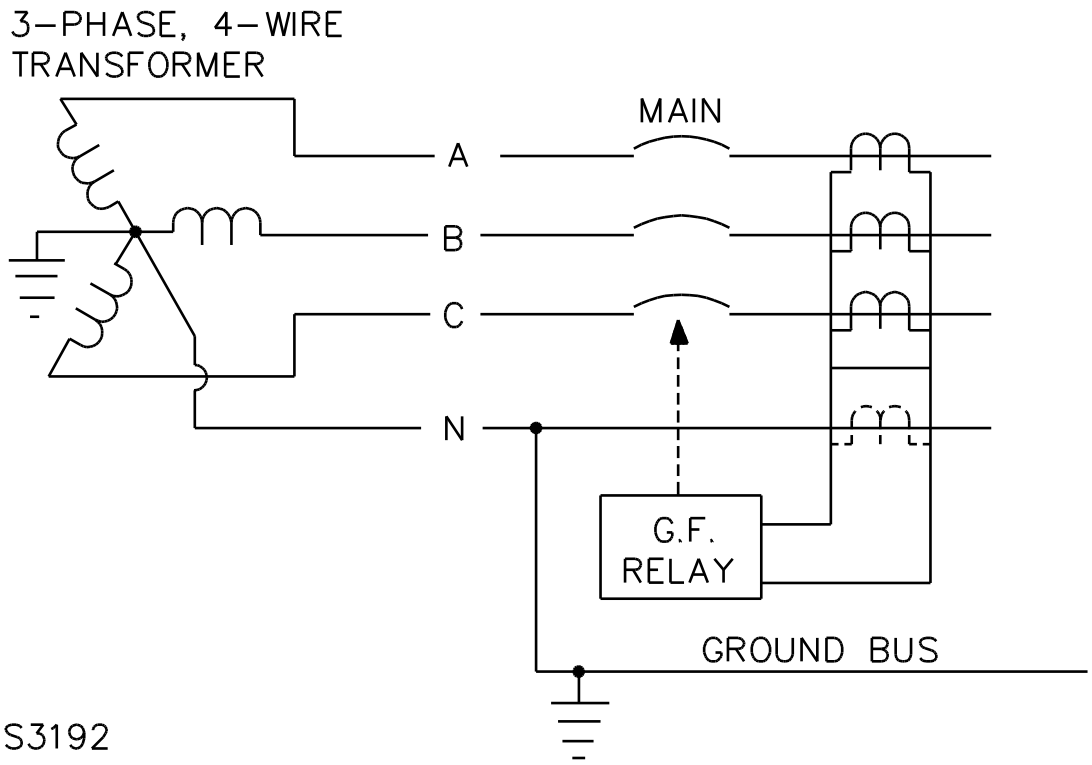
Zero-sequence system



75.6.6 A ground fault protection system that combines the outputs of separate sensing elements for the grounded service conductor, if any, and each ungrounded conductor (commonly referred to as a residual type system) 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 grounded service conductor. The ungrounded conductor sensors are able to be within or on the line or load side of the disconnecting device for the protected circuits. A typical residual type system is shown in Figure 75.13.

Figure 75.13

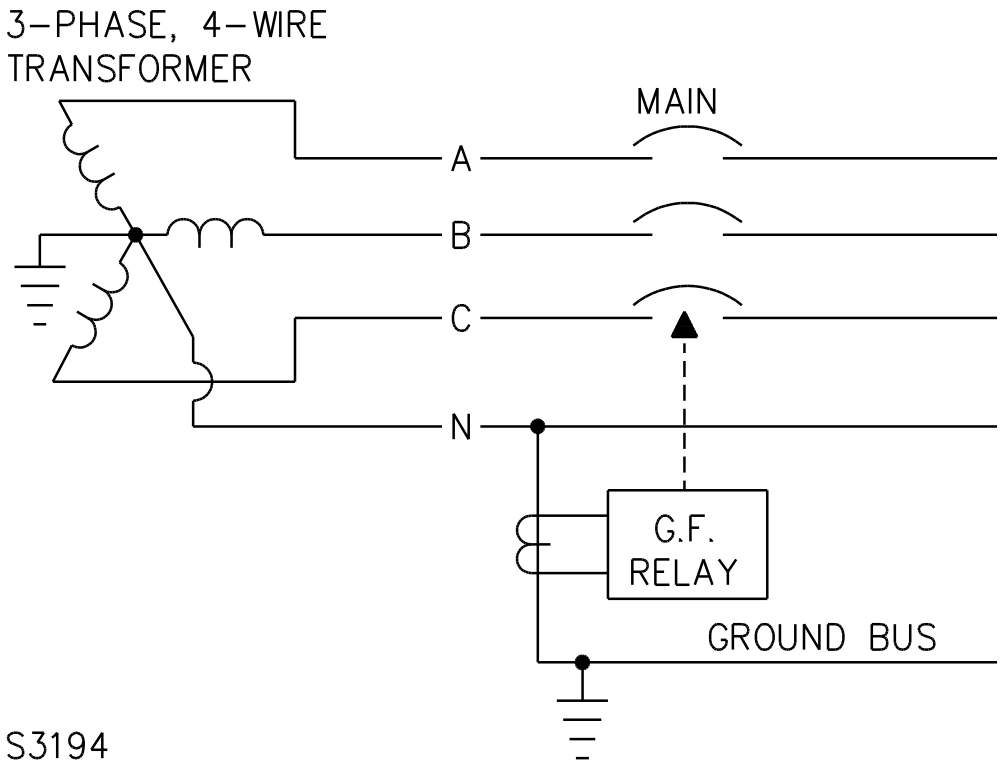
Residual system



75.6.7 A ground fault protection system that employs a single sensing element to detect the actual fault current (commonly referred to as a ground return system) 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 connection within the equipment that is able to be made to the grounded service conductor. This will require that, other than for the connections mentioned, the grounded service conductor be insulated from the noncurrent-carrying metal. A typical ground return system is shown in Figure 75.14.

Figure 75.14

Ground return system



75.6.8 When the construction 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 construction shall prohibit the 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.

75.6.9 The primary of a ground-fault protection control circuit transformer is able to 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 a phase conductor and the grounded service conductor). When connected to the line side of the main, a fused disconnect switch or circuit breaker that is intended for service equipment and that provides overcurrent protection shall be installed on the line side of the transformer or control circuit or both, and the service equipment shall be marked as specified in 77.5.2. 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.

75.6.10 The secondary circuit of a control power transformer for the ground fault protection system shall be grounded when the circuit extends or is able to extend beyond the equipment in which the transformer is mounted and when the secondary voltage:

a) Is less than 50 volts and the transformer supply is greater than 150 volts to ground or the transformer supply at any voltage is ungrounded; or

b) Is 50 volts or greater and the secondary circuit is capable of being grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts.

75.6.11 When a transformer secondary is required to be grounded in accordance with 75.6.10 a main bonding jumper shall be factory connected to the transformer secondary and to the ground bus (or the

terminal for the grounding electrode conductor when there is no ground bus). The size of the main bonding jumper shall be as specified in Table 75.1 based on the transformer secondary current rating.

75.6.12 In equipment incorporating ground-fault protection of the ground return type as described in 75.6.7, the main bonding jumper shall be factory connected to the neutral bus and to the enclosure or the ground bus, and the equipment shall be marked as specified in 77.1.1.

75.7 Overcurrent protection

75.7.1 Overcurrent protective devices shall comply with 31.1 or 32.1, as applicable.

75.7.2 The equipment is able to be provided with overcurrent protection consisting of:

a) A single main overcurrent protective device (fuse or circuit breaker pole) in series with each ungrounded service conductor; or

b) For other than control of a lighting and appliance circuit, not more than six overcurrent protective devices for each ungrounded service conductor (or set of parallel conductors of the same polarity).

Overcurrent protective devices of the same polarity are able to be connected together on the line side, and fuseholders shall not be arranged for accommodation of fuses in parallel (both line and load sides, respectively). When two overcurrent devices per pole are used for a lighting and appliance circuit, the sum of their current ratings shall equal that of the full-load current.

75.7.3 No overcurrent protective device shall be placed in any permanently grounded conductor unless it simultaneously opens all conductors of the circuit.

75.8 Components on the supply side of the disconnecting means

75.8.1 Other than as specified in 75.8.2 – 75.8.4, components shall not be located on the line side of the service disconnecting means.

75.8.2 A meter socket shall comply with the Standard for Meter Sockets, UL 414 and is able to be located on the line side of the service disconnecting means.

75.8.3 Control circuits for power operable service disconnecting means, or for ground fault protection covered by 75.6, are able to be connected to the line side of the service disconnecting means when provided with disconnecting means and overcurrent protection.

75.8.4 A Type 1 SPD shall comply with the requirements in the Standard for Surge Protective Devices, UL 1449.

76 Ratings

76.1 An industrial control panel intended 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 a suitable combination voltage rating as indicated in 76.2.

76.2 The requirement in 76.1 is in regard to the combination rating of an industrial control panel that is intended for use only on circuits such as:

a) 120/240 volt, single phase, 3-wire, ac, with grounded neutral;

b) 125/250 volts, 3-wire, dc, with grounded neutral;

c) 208Y/120 volt, 3-wire, ac (from 3-phase, 4-wire network);

d) 480Y/277 volt, 3-wire, ac (from 3-phase, 4-wire network);

e) 208Y/120 volt, 3-phase, 4-wire;

f) 240/120 volt, 3-phase, 4-wire, delta; or

g) 480Y/277 volt, 3-phase, 4-wire.

76.3 An industrial control panel for service equipment use shall be provided with a short circuit current rating for each input that complies with the requirements in Supplement SB.

77 Markings

77.1 Bonded neutral

77.1.1 Equipment having a neutral that is factory bonded to the enclosure and that is capable of accommodating not more than six main disconnecting means shall be marked "Suitable only for use as service equipment."

77.1.2 Equipment that has the neutral bonded at the factory by a removable bonding means shall be marked "Bonded neutral, remove bonding means for test purposes only."

77.2 Insulated neutral

77.2.1 Equipment having a neutral insulated from the enclosure, intended for use as service equipment, and that accommodates not more than six main disconnecting means shall be marked "Suitable for use as service equipment."

77.3 Marking location

77.3.1 The markings specified in 77.1 and 77.2 shall be an integral part of the manufacturer's nameplate marking containing the manufacturer's name or trademark as specified in 52.1.

77.4 Disconnects

77.4.1 Each service disconnecting means for ungrounded conductors shall be marked "Service disconnect" as specified in 77.4.2 and 77.4.3.

Exception No. 1: Several adjacent service disconnects are able to be identified by the single marking "Service disconnects" together with an indication as to which switch or circuit breaker handles are the service disconnects.

Exception No. 2: A disconnect means provided for the control circuit of a ground-fault protection system is not required to be so marked.

77.4.2 For equipment marked as "Suitable only for use as service equipment," the marking or indication identifying a service disconnecting switch or circuit breaker required in 77.4.1 is to appear on or adjacent to the switch or circuit breaker handles where visible without removing a trim or dead front.

77.4.3 When the equipment is marked "Suitable for use as service equipment," the marking "Service disconnect" shall be provided in the form of pressure sensitive labels in an envelope, or on a card, with instructions to apply near the disconnect handles when the equipment is used as service equipment.

77.5 Ground-fault protection

77.5.1 When ground-fault protection is provided, a marking shall be provided to indicate the circuit (main, feeder, or branch) that is so protected. The marking shall be on the ground-fault sensing or relaying equipment and shall be visible from the front of the equipment with a cover removed, or a separate marking visible from the front of the equipment with a cover removed (such as on a wiring diagram) shall be provided.

77.5.2 When a transformer providing control voltage for ground-fault protection is connected to the line side of the main disconnect, this disconnect is able to be identified as the "main" and the service equipment shall be marked adjacent to the main disconnect "DANGER – This main does not disconnect control and instrument circuits."

77.5.3 In equipment with ground-fault protection, the part of the neutral bus for load termination shall be marked "WARNING – Do not connect grounding conductors to these or any other neutral terminals; to do so will defeat ground-fault protection."The marking shall be located on or adjacent to the portion of the grounded service conductor for load terminals.

77.5.4 Equipment that is not provided with ground-fault protection as specified in the Exception to 75.6.2 shall be marked for its intended use as follows:

a) For equipment rated 3-phase, 4-wire, "Suitable only for use as service equipment when supplying a continuous industrial process"; or

b) For equipment rated 3-phase, 3-wire, "Suitable only for use as service equipment when supplying a continuous industrial process or for systems where the neutral is not solidly grounded."

78 Installation Instructions

78.1 To provide for system performance testing, each ground-fault relay or apparatus incorporating a ground fault relay or its functions intended for protection of a solidly grounded wye service rated more than 150 volts to ground and not exceeding 1000 volts phase-to-phase shall be provided with information sheets describing system testing instructions, and with a test form. The form shall include a space for the date the test was performed and the results, and shall state that the form should be retained by those in charge of the building's electrical installation in order to be available to the authority having jurisdiction. The instructions shall include the following items and shall basically prescribe only that information necessary to perform the tests. The instructions shall be separate and apart from any more elaborate test detail that the manufacturer wishes to provide. The instructions shall specify that:

a) The interconnected system shall be investigated in accordance with the panel manufacturer's detailed instructions, and that this investigation is to be undertaken by qualified personnel.

b) The location of the sensors around the bus of the circuit to be protected shall be determined. This can be done visually with knowledge of which bus is involved.

c) The grounding points of the system shall be verified to determine that ground paths do not exist that would bypass the sensors. The use of high-voltage testers and resistance bridges is able to be suggested.

d) The installed system is to be tested for correct response by the application of full scale current into the equipment to duplicate a ground-fault condition, or by equivalent means such as by a simulated fault current generated by:

1) A coil around the sensors; or

2) A separate test winding in the sensors.

e) The results of the test shall be recorded on the test form provided with the instructions.

79 Tests By The Manufacturer – Ground-Fault Protection Test

79.1 With a simulated fault current flowing as described in 79.2, a factory test shall be conducted for each switchboard section or interior incorporating ground-fault protection equipment to determine that the ground-fault sensing and protective equipment functions. The primary of the control transformer, when provided, is to be energized at not more than 57 percent of its voltage rating. The relay is able to be set for any convenient pickup 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. When the switch or breaker stays closed, the simulated ground-fault current is to be reapplied and the ground-fault protection system shall function.

Exception No. 1: The factory test is not required for a residual type ground-fault protector when:

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.

Exception No. 2: The applied voltage may approximately be rated voltage when the particular combination of transformer, ground-fault sensing and relaying equipment, and disconnecting means has been previously tested at not more than 57 percent of rated voltage.

79.2 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 pickup setting of the relay divided by the number of turns is passed through the wire to simulate the ground-fault current. Other methods of simulating a ground-fault current are able to be used when agreed upon by all concerned.

ELEVATOR CONTROL

80 General

Section 80 deleted

FLAME CONTROL

81 General

81.1 These requirements cover industrial control panels intended for control of fossil fuel-burning equipment such as incinerators, kilns, and drying ovens. A flame control panel shall contain one or more primary safety controls and/or ignition transformers.

81.2 For the purpose of these requirements, a primary safety control is a device that controls and monitors the operation of the burner.

81.3 For the purpose of these requirements, an ignition transformer is an isolating transformer with a high-voltage secondary winding that is used to create a spark to light a pilot flame.

81.4 A flame control panel shall comply with the requirements in Sections 4 – 61 of this standard and shall also comply with Section 82, Construction.

82 Construction

82.1 Component requirements

82.1.1 A primary safety control shall comply with the Standard for Automatic Electrical Controls for Household and Similar Use – Part 2: Particular Requirements for Burner Ignition Systems and Components, UL 372.

82.1.2 An ignition transformer shall comply with the requirements in the Standard for Specialty Transformers, UL 506.

82.1.3 A high-voltage ignition cable shall comply with the Standard for Gas-Tube-Sign Cable, UL 814.

82.2 Spacings

82.2.1 Uninsulated live parts of the high-voltage secondary of the ignition transformer that are ungrounded shall have spacings in accordance with Table 82.1 between parts of opposite polarity and to grounded dead-metal parts including the enclosure.

Exception: These spacings are not required to be maintained between a grounded secondary part and a grounded dead-metal part.

Table 82.1
Minimum spacings involving live secondary parts

Transformer secondary voltage rating, volts	Through air		Over surface	
	inches	(mm)	inches	(mm)
0 – 5,000	1/2	(12.7)	3/4	(19.1)
5,001 – 10,000	7/8	(22.2)	1-1/4	(31.8)
10,001 – 12,000	1-1/8	(28.6)	1-1/2	(38.1)
12,001 – 15,000	1-1/2	(38.1)	2	(50.8)

82.3 Internal wiring

82.3.1 Internal wiring to an ungrounded part of the ignition transformer shall comply with 82.1.3 and have a voltage rating not less than the rated secondary voltage of the ignition transformer.

82.4 Location

82.4.1 The output from a primary safety control to the main gas valve shall not have interposing components that are able to switch or isolate the control voltage.

82.5 Separation of circuits

82.5.1 Internal wiring and field wiring terminals to the high-voltage secondary of the ignition transformer shall be segregated or separated by barriers from uninsulated live parts, internal wiring, and field wiring of all other circuits.

82.6 Overcurrent protection

82.6.1 The primary winding of an ignition transformer shall have overcurrent protection in accordance with Section 42, Overcurrent Protection – Control Circuits (Isolated Secondary).

83 Marking

83.1 The nameplate required in 52.1 shall additionally include the words "Flame Control Panel."

MARINE USE

84 General

84.1 These requirements cover industrial control panels intended for use aboard vessels over 65 feet (19.9 m) in length [USCG Electrical Engineering Regulations Subchapter J (46 CFR, Part 110)]. These requirements supplement the applicable requirements in Sections 4 – 61 of this standard.

85 Construction

85.1 Enclosures

85.1.1 An enclosure shall comply with the requirements in Sections 18 – 27 except as modified by this section.

85.1.2 An enclosure shall be one of the following types:

a) Nonwatertight and in compliance with the requirements for Type 1 enclosures;

b) Dripproof and in compliance with the requirements for Type 2, 3, 3R, 3S, 5, 12, or 13 enclosures; or

c) Watertight and in compliance with the requirements for Type 4, 4X, 6, or 6P enclosures.

85.1.3 Cable entrance plates, when provided, for watertight enclosures and at the top of dripproof enclosures shall be at least 1/8 inch (3.2 mm) thick and shall be fitted with gaskets. Watertight enclosures shall be provided with external feet or external lugs for mounting.

85.1.4 A controller having doors that are either more than 45 inches (1.14 m) high or more than 24 inches (610 mm) wide shall be provided with door positioners and stops.

85.1.5 Equipment mounted on a door shall be constructed or shielded so that no live parts of the equipment mounted on the door will be exposed to unintentional contact when the door is open and the circuit is energized.

85.2 Autotransformer starters

85.2.1 An autotransformer starter with a case for oil shall not leak when tilted to an angle of 30 degrees and shall be constructed to prohibit the oil from splashing out of the case as a result of motion of the vessel.

85.3 Insulating materials

85.3.1 Porcelain shall not be used for lampholders, switches, receptacles, fuse blocks, or similar parts, where the material is rigidly fastened by machine screws or equivalent means.

85.4 Branch circuit overcurrent devices

85.4.1 Plug fuses of Edison-screw and renewable-link cartridge type fuses shall not be used.

86 Ratings

86.1 An ambient temperature rating of 40°C (104°F) shall be assigned to all control panels.

87 Markings

87.1 The nameplate required in 52.1 shall additionally include the ambient temperature rating and the following: "Industrial Control Panel for Marine Use."

87.2 A heat-resistant, durable wiring diagram shall be permanently attached to the inside of the controller door. An adhesive-backed label used for this marking shall comply with the Standard for Marking and Labeling Systems, UL 969, for the surface and environment involved.

87.3 A dripproof or watertight enclosure that complies with 85.1.2 shall be marked "Dripproof" or "Watertight ," as appropriate.

AIR CONDITIONING AND REFRIGERATION EQUIPMENT

88 General

88.1 These requirements cover industrial control panels intended for control of electric motor driven air conditioning and refrigeration equipment, including hermetic refrigerant motor compressors.

88.2 A panel for use with air conditioning and refrigeration equipment shall comply with the requirements in Sections 4 – 61 of this standard and also with the requirements in Sections 89 – 92, which supplement or modify the general-use requirements.

89 Glossary

89.1 For the purpose of applying the requirements in Sections 90 – 92, the following definition applies.

89.2 BRANCH CIRCUIT SELECTION CURRENT – Maximum continuous current allowed by running overload protective, such as a thermal protector, provided as part of the motor. The branch circuit selection current is equal to or greater than the rated load current and is included on the motor nameplate.

90 Construction

90.1 Field wiring sizing – power circuit

90.1.1 For hermetic refrigerant compressor motors, the anticipated field wiring shall have an ampacity of 125 percent of the full-load current rating of the load involved.

Exception: For a hermetic refrigerant compressor motor with a designated branch circuit selection current, the field wiring terminal shall be sized per 28.3.1, based on the branch circuit selection current.

90.2 Disconnecting switches – power circuits

90.2.1 A disconnecting means for control of a hermetic refrigerant compressor motor shall be sized in accordance with 30.2.2, using the larger of:

a) The motor full-load current; or

b) The branch circuit selection current and the motor locked rotor current.

90.3 Branch circuit protection sizing – power circuits

90.3.1 The size of branch circuit protection for a hermetic refrigerant motor compressor shall be:

a) Based on the full-load motor current calculated from Table 50.1 or Table 50.2, or the branch circuit selection current, whichever is higher; and

b) Determined using the maximum ratings for dual element (time-delay) fuses of Table 31.1, regardless of the type of branch circuit protective device employed.

90.4 Load controllers – power circuits

90.4.1 An electro-magnetic load controller for control of a hermetic refrigerant motor compressor shall comply with the requirements for a definite-purpose motor controller specified in the Standard for Industrial Control Equipment, UL 508.

90.4.2 A solid-state motor controller or a variable speed drive for control of a hermetic refrigerant motor compressor shall comply with the requirements specified in the Standard for Industrial Control Equipment, UL 508, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1.

90.4.3 A definite-purpose controller for a hermetic refrigerant motor compressor shall:

a) Have a voltage rating not less than the rated voltage of the circuit;

b) Have a current rating not less than the full-load current of the motor or the branch circuit selection current, whichever is higher; and

c) Have an LRA (locked rotor ampere) rating not less than the LRA rating of the motor.

90.4.4 A solid state motor controller or a variable speed drive shall comply with 90.4.3 (a) or (b).

91 Ratings

91.1 The output terminals for connection to a hermetic refrigeration motor compressor shall be rated in:

a) FLA of motor or branch circuit selection current, whichever is used for sizing of components in Section 90, Construction;

b) LRA; and

c) Volts.

92 Marking

92.1 The nameplate required in 52.1 shall additionally include "Industrial Control Panel for Refrigeration Equipment" or "Industrial Control Panel for Air Conditioning Equipment."

FOUNTAIN CONTROL PANELS

93 General

93.1 These requirements cover fountain control panels intended for control of permanently installed fountains or floating fountains intended for aeration or aesthetic value.

93.2 A fountain control panel shall comply with the requirements in Sections 4 – 61 of this standard and also with the requirements in Sections 94 – 96, which supplement or modify the general-use requirements.

94 Construction

94.1 Grounding

94.1.1 The equipment grounding terminal(s) for the controller's supply circuit and for controller output circuits that are intended for supplying any of the following types of equipment shall accommodate the larger of a 12 AWG conductor and the conductor size required by Table 15.1 based upon the size of overcurrent protection for the circuit.

a) Pump motor,

b) Underwater luminaire supplied directly or through a field-provided, external-to-controller, transformer, junction box, GFCI, or other device.

94.1.2 Controllers intended for direct conduit connection to wet-niche or no-niche underwater luminaires shall comply with the Standard for Electric Spas, Equipment Assemblies, and Associated Equipment, UL 1563, Supplement SA – Supplemental Requirements for Enclosures of Products Constructed For Direct Conduit Connection To A Wet-Niche or No-Niche Luminaire except those portions relating to 8 AWG Supplemental Bonding conductors.

94.2 Ground – fault protection

94.2.1 A controller with output circuits intended for connection to any of the following types of equipment shall include ground-fault circuit interrupter protection for the circuit. The GFCI shall comply with the requirements for a Class A ground-fault circuit interrupter in the Standard for Ground-Fault Circuit-Interrupters, UL 943.

a) Submersible pumps

b) Underwater luminaires (pool or fountain)

c) Other submersible equipment

Exception No. 1: Ground-fault circuit-interrupter protection is not required for output circuits for the equipment of items (b) and (c) provided the output circuit operates at:

a) 15 volts AC, or less, and is supplied by an isolating transformer that is integral with the controller and that complies with the requirements specified in the Standard for Power Units for Fountain, Swimming Pool, and Spa Luminaires, UL 379, or

b) 30 volts DC, or less, and is supplied by an isolating power supply that is integral with the controller and that complies with the requirements specified in the UL 379.

Exception No. 2: Controllers marked with the following or equivalent: "This controller is not provided with integral GFCI protection for the [] circuit. When this controller is used to supply this type of equipment, suitable GFCI protection (or a swimming pool type transformer or power supply) shall be provided in the field". The blank shall be filled in with the type of equipment for which the circuits are intended. The terms in parenthesis are optional.

94.3 Equipotential bonding

94.3.1 A pressure wire connector, sized to accommodate an 8 AWG (8.4 mm^2) solid copper conductor, shall be provided to bond the unit, if needed, to the local bonding grid during installation. The wire connector shall be conductively connected to the equipment grounding means.

94.4 Cord strain relief

94.4.1 Units intended to terminate the cords from remote submersible luminaires or floating fountains shall be provided with integral strain relief or cord grip fittings suitable for the size of cords involved that comply with the Standard for Conduit, Tubing and Cable Fittings, UL 514B.

95 Ratings

95.1 The maximum voltage between conductors on the load side of the panel for connection to luminaires (lighting fixtures) shall not be more than 150 Volts where lighting load is connected between one of line leads and neutral.

95.2 The maximum voltage between conductors on the load side of the panel for connection to a submersible pump and other submersible equipment shall not be more than 300 Volts.

96 Marking

96.1 The nameplate required in 52.1 shall additionally include “Industrial Control Panel for Floating Fountain” or “Industrial Control Panel for Permanently Installed Fountain” or “Fountain Control Panel”.

96.2 For panels intended to control a non-submersible, single phase, 120 or 240 volt motor, the motor output terminals on the panel or installation drawing shall be additionally marked “Not For Control of Submersible Motor” or the equivalent.

96.3 The installation instructions for controllers intended for connection to floating fountains shall specify mounting a minimum of 300 mm (12 in.) above the electrical datum plane.

INDUSTRIAL CONTROL PANELS FOR IRRIGATION EQUIPMENT

97 General

97.1 These requirements cover industrial control panels intended for control of electrically operated irrigation equipment.

97.2 An industrial control panel for irrigation equipment shall comply with the requirements in Sections 4 – 61 of this standard and also with the requirements in Sections 97 – 99, which supplement or modify the general-use requirements.

98 Construction

98.1 Sizing of motor controller

98.1.1 For an industrial control panel is intended for intermittent duty only, a motor controller is able to be sized in accordance with 98.1.2 or 98.1.3.

98.1.2 For marked for intermittent duty only, the full load current rating, or equivalent FLC based on the motor HP from Table 50.1, shall be not less than 125 percent of the largest motor plus 100 percent of all remaining motor loads and also have a locked rotor current rating based on the motor horsepower from Table 50.3 for three phase motors, or six times the equivalent FLC from the motor HP – Table 50.1 for single phase motors, shall be not less than the locked rotor current of the two largest motors plus the FLC of all remaining motors.

98.1.3 For an industrial control panel marked for use with a center pivot irrigation machine, the full load current rating shall be not less than 125 percent of the largest motor plus 60 percent of the full load current ratings of all remaining motors and also shall have a locked rotor current rating of 200 percent of the locked rotor current of the largest motor plus 80 percent of the FLA's of all remaining motors.

98.2 Disconnecting means

98.2.1 The disconnecting means shall be sized not less than 98.1.

98.3 Branch circuit protection

98.3.1 Several motors may be protected by a 30 A, 1000 V or smaller branch circuit protective device when all of the following are met:

a) All motors are rated 2 hp or less;

b) The full load current of each motor is not more than 6 A; and

c) Each motor is provided with individual motor overload protection and the branch circuit protection does not exceed the ratings on the overload relay heater table.

98.4 Internal conductors

98.4.1 Internal conductors that carry the current of multiple motor loads shall be sized to the full load current as determined in 98.1.

99 Marking

99.1 The industrial control panel nameplate shall include the following information:

a) The rating of the main disconnecting means and branch circuit protection if not provided in the industrial control panel;

b) "Industrial Control Panel for Electric Irrigation Equipment" or "Industrial control panel for center pivot irrigation equipment", as appropriate; and

c) The output ratings for motors shall be marked, "intermittent duty only", when the provisions of 98.1.2 have been applied for sizing the motor controller and disconnecting means.

CONTROL PANELS FOR AQUATIC PLAYGROUNDS

100 General

100.1 These requirements cover control panels intended for control of permanently installed electrical equipment for aquatic playgrounds.

An Aquatic Playground is a recreational area designed specifically for interactive water play. Unlike swimming and wading pools, aquatic playgrounds have no standing water. Occupants are exposed to water by various types of spraying devices.

100.2 These requirements do not cover control panels intended for control of permanently installed electrical equipment for recreational areas having standing water or water in common with swimming, wading or paddling pools. For panels in these applications reference Section 105 as well as the Standard for Electric Spas, Equipment Assemblies, and Associated Equipment, UL 1563.

100.3 An aquatic playground control panel shall comply with the requirements in Sections 4 – 61 of this standard and also with the requirements in Sections 101 – 104, which supplement or modify the general-use requirements.

101 Glossary

101.1 AQUATIC PLAYGROUND – A recreational area designed specifically for interactive water play and having no standing water or water in common with swimming, wading or paddling pools.

101.2 LOW VOLTAGE CONTACT LIMIT – A voltage not exceeding the following values:

a) 15 volts (RMS) for sinusoidal ac;

b) 21.2 volts peak for nonsinusoidal ac;

c) 30 volts for continuous dc; and

d) 12.4 volts peak for dc that is interrupted at a rate of 10 to 200 Hz.

102 Construction

102.1 Grounding

102.1.1 The equipment grounding terminal(s) for the controller's supply circuit and for controller outputs shall accommodate the conductor size required by Table 15.1 based upon the size of overcurrent protection for the circuit, but not smaller than 12 AWG.

Exception: Outputs marked for use with low-voltage luminaires not requiring grounding.

102.2 Ground-fault protection

102.2.1 A controller with output circuits intended for connection to any of the following types of equipment shall include ground-fault circuit interrupter (GFCI) protection for the circuit. The GFCI shall comply with the requirements for a Class A GFCI in the Standard for Ground-Fault Circuit-Interrupters, UL 943.

a) Submersible pumps;

b) Underwater luminaires;

c) Other submersible equipment; or

d) Other electrical equipment installed outdoors.

Exception No. 1: Outputs intended for luminaires, submersible pumps and other submersible equipment operating at the Low Voltage Contact Limit or less and supplied by a transformer or power supply that complies with 102.3.

Exception No. 2: Output circuits for (a) – (c) when the controllers are marked with the following or equivalent: "This controller is not provided with integral GFCI protection for the [ ] circuit. When this controller is used to supply this type of equipment, suitable GFCI protection shall be provided in the field". The blank shall be filled in with the type of equipment for which the circuits are intended.

102.3 Transformers and power supplies

102.3.1 An integral power source shall comply with:

a) The Standard for Power Units for Fountain, Swimming Pool, and Spa Luminaires, UL 379; or

b) The Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

103 Ratings

103.1 The maximum voltage between conductors on the load side of the panel for connection to luminaires shall not be more than 150 Volts where lighting load is connected between one of line leads and neutral.

104 Marking

104.1 The nameplate required in 52.1 shall include the phrase "Industrial Control Panel for Aquatic Playground" or "Aquatic Playground Control Panel".

104.2 The nameplate required in 52.1 shall include the phrase “Not for use with installations with water in common to a pool or spa".

CONTROL PANELS FOR SWIMMING POOLS AND IN-GROUND SPAS

105 General

105.1 These requirements cover control panels intended for control of permanently installed electrical equipment associated with commercial and large residential swimming pools and in-ground spas.

These panels typically control electrical equipment outside the 5 ft. (1.5 m) limit from the inside walls of the pool or spa. These panels do not have sensors in contact with the pool water or remote controls within the 5 ft. (1.5 m) limit.

105.2 These requirements do not cover control equipment for factory produced self-contained spas, nor panels with sensors in contact with the pool water or user controls intended to be mounted within 5 ft. (1.5 m) of the inside walls of the pool or spa. Reference the Standard for Electric Spas, Equipment Assemblies, and Associated Equipment, UL 1563.

105.3 A swimming pool and spa control panel shall comply with the requirements in Sections 4 – 61 of this standard and also with the requirements in Sections 105 – 109, which supplement or modify the general-use requirements.

106 Glossary

106.1 LOW VOLTAGE CONTACT LIMIT – A voltage not exceeding the following values:

a) 15 volts (RMS) for sinusoidal ac;

b) 21.2 volts peak for nonsinusoidal ac;

c) 30 volts for continuous dc; and

d) 12.4 volts peak for dc that is interrupted at a rate of 10 to 200 Hz.

107 Construction

107.1 General

107.1.1 Control panels for use with swimming pools and in-ground spas shall have no sensors or other circuits in direct contact with the pool or spa water. This includes sensors for pool sanitation chemicals as well as chlorine or bromine cells. They are not prohibited from powering external loads that have such circuits.

107.1.2 Control panels for use with swimming pools and in-ground spas shall have no user controls intended to be mounted within 5 ft. (1.5 m) of the inside walls of the pool or spa.

107.1.3 Control panels for use with swimming pools and in-ground spas shall have no integral ozone generators.

107.2 Grounding

107.2.1 The equipment grounding terminal(s) for the controller's supply circuit and for controller outputs shall accommodate the conductor size required by 15.1 based upon the size of overcurrent protection for the circuit, but not smaller than 12 AWG.

Exception: Outputs marked for use with low-voltage luminaires not requiring grounding.

107.2.2 Controllers intended for direct conduit connection to wet-niche or no-niche underwater luminaires shall comply with the Standard for Electric Spas, Equipment Assemblies, and Associated Equipment, UL 1563, Supplement SA – Supplemental Requirements for Enclosures of Products Constructed for Direct Conduit Connection to a Wet-Niche or No-Niche Luminaire.

107.3 Ground-fault protection

107.3.1 A controller with output circuits intended for connection to any of the following types of equipment shall include ground-fault circuit interrupter (GFCI) protection for the circuit. The GFCI shall comply with the requirements for a Class A GFCI in the Standard for Ground-Fault Circuit-Interrupters, UL 943.

a) Pump motors connected to single-phase 120-volt through 240-volt branch circuits;

b) Underwater luminaires.

Exception No. 1: Luminaires operating at the Low Voltage Contact Limit or less and supplied by a transformer or power supply that complies with 107.4.

Exception No. 2: Output circuits for (a) – (b) when the controllers are marked with the following or equivalent: "This controller is not provided with integral GFCI protection for the [ ] circuit. When this controller is used to supply this type of equipment, suitable GFCI protection shall be provided in the field". The blank shall be filled in with the type of equipment for which the circuits are intended.

107.4 Luminaire transformers and power supplies

107.4.1 An integral power source shall comply with:

a) The Standard for Power Units for Fountain, Swimming Pool, and Spa Luminaires, UL 379; or

b) The Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

107.5 Cord strain relief

107.5.1 Units intended to terminate the cords of submersible luminaires shall be provided with integral strain relief or cord grip fittings suitable for the size of cords involved that comply with the Standard for Conduit, Tubing and Cable Fittings, UL 514B.

108 Ratings

108.1 The maximum voltage between conductors on the load side of the panel for connection to luminaires shall not be more than 150 Volts where the lighting load is connected between one of line leads and neutral.

109 Markings

109.1 The nameplate required in 52.1 shall include the phrase: "Industrial Control Panel for Swimming Pool and Spa" or "Swimming Pool and Spa Control Panel".

CONTROL PANELS FOR WATER PARK RIDES AND SIMILAR INSTALLATIONS

110 General

110.1 These requirements cover control panels intended for control of permanently installed electrical equipment associated with commercial water park rides, wave pools and similar installations.

These panels control electrical equipment associated with amusement park rides where occupants may become wet, but are not exposed to standing water or bodies of water. These panels also control electrical equipment associated with wave pools where occupants do not have access or exposure to the equipment being controlled.

110.2 Installations of water park rides assume users may be wet but are not immersed in bodies of water. Users of wave pool installations may be near to, but do not have access to electrical equipment.

110.3 These requirements cover equipment that may have sensors or switches necessary for the function of the product that are mounted within 5 ft. (1.5 m) of user access.

110.4 These control panels shall comply with the requirements in Sections4– 61 of this standard and also with the requirements in Sections 110– 114, which supplement or modify the general-use requirements.

111 Glossary

111.1 LOW VOLTAGE CONTACT LIMIT – A voltage not exceeding the following values:

a) 15 volts (RMS) for sinusoidal ac;

b) 21.2 volts peak for nonsinusoidal ac;

c) 30 volts for continuous dc; and

d) 12.4 volts peak for dc that is interrupted at a rate of 10 to 200 Hz.

112 Construction

112.1 General

112.1.1 Control panels for use with water park rides, wave pools and the like shall have no sensors or other circuits with live parts in direct contact with the water. This includes sensors for sanitation chemicals as well as chlorine or bromine cells. They are permitted to provide power to external loads that have such circuits.

112.1.2 Control panels for use with wave pools and the like shall have no user controls intended to be mounted within 5 ft. (1.5 m) of the inside walls of a pool.

112.1.3 Control panels for use with water park rides, wave pools and the like shall have no integral ozone generators.

112.2 Grounding of wave pools

112.2.1 The equipment grounding terminal(s) for the controller's supply circuit and for controller outputs shall accommodate the conductor size required by Table 15.1 based upon the size of overcurrent protection for the circuit, but not smaller than 12 AWG.

Exception: Outputs marked for use with low-voltage luminaires not requiring grounding.

112.2.2 Controllers intended for direct conduit connection to wet-niche or no-niche underwater luminaires shall comply with the Standard for Electric Spas, Equipment Assemblies, and Associated Equipment, UL 1563, Supplement SA – Supplemental Requirements for Enclosures of Products Constructed for Direct Conduit Connection to a Wet-Niche or No-Niche Luminaire.

112.3 Sensors

112.3.1 Sensor circuits within 5 ft. (1.5 m) of user access shall operate at a voltage not exceeding the Low-Voltage Contact Limit and be powered by a transformer or power supply complying with the requirements for Luminaire Transformers and Power Supplies, Section 112.4.

112.3.2 Sensor circuits outside 5 ft. (1.5 m) of swimmer access shall be suitable for the location. See Ground-Fault Protection, 112.4.

112.4 Ground– fault protection

112.4.1 A controller with output circuits intended for connection to any of the following types of equipment shall include ground-fault circuit interrupter (GFCI) protection for the circuit. The GFCI shall

comply with the requirements for a Class A GFCI in the Standard for Ground-Fault Circuit-Interrupters, UL 943.

a) Pump motors connected to single-phase 120-volt through 240-volt branch circuits;

b) Underwater luminaires; or

c) Sensor circuits.

Exception No. 1: Luminaires and sensor circuits operating at the Low Voltage Contact Limit or less and supplied by a transformer or power supply that complies with 112.5.

Exception No. 2: Output circuits for (a) – (b) when the controllers are marked with the following or equivalent: "This controller is not provided with integral GFCI protection for the [ ] circuit. When this controller is used to supply this type of equipment, suitable GFCI protection shall be provided in the field". The blank shall be filled in with the type of equipment for which the circuits are intended.

112.5 Luminaire transformers and power supplies

112.5.1 An integral power source shall comply with:

a) The Standard for Power Units for Fountain, Swimming Pool, and Spa Luminaires, UL 379; or

b) The Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

113 Ratings

113.1 The maximum voltage between conductors on the load side of the panel for connection to luminaires shall not be more than 150 Volts where the lighting load is connected between one of line leads and neutral.

114 Marking

114.1 The nameplate required in 52.1 shall include the phrase: "Industrial Control Panel for Water Park Ride" or "Industrial Control Panel for Wave Pool".

SUPPLEMENT SA – *Deleted*

On July 28, 2017, and March 19, 2018, a proposal to remove Supplement SA from UL 508A and relocate the information therein to a UL LLC website achieved and maintained consensus. In accordance with this decision by STP 508A, the information in Supplement SA may now be found by clicking the link below. This website will be maintained by UL LLC, any changes or questions about this website should be directed to the UL Principal Engineer for UL 508A.

www.ul.com/UL508A-SupplementSA

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SUPPLEMENT SB – SHORT CIRCUIT CURRENT RATINGS FOR INDUSTRIAL CONTROL PANELS

SB1 Scope

SB1.1 These requirements cover industrial control panels provided with a short-circuit current rating. These requirements supplement and in some cases modify the requirements contained elsewhere in this standard.

SB2 Glossary

SB2.1 For the purpose of applying the requirements in this supplement, the following definitions apply.

SB2.2 HIGH FAULT SHORT CIRCUIT CURRENT RATING – Marked short circuit current rating of a component that is greater than the standard fault short circuit current rating.

SB2.3 STANDARD FAULT SHORT CIRCUIT CURRENT RATING – Short circuit current rating of a component as specified in Table SB4.1.

SB3 Construction

SB3.1 Internal wiring connections

SB3.1.1 All terminals of power circuit wiring connectors, wiring ferrules, and components shall be torqued to the manufacturer's specified value or crimped-on according to the manufacturer's instructions.

SB3.2 Overcurrent protection of control circuit

SB3.2.1 For control circuits tapped from the feeder circuit, the overcurrent protection for the common control circuit or for the primary of a control transformer or power supply shall be provided with branch circuit protective devices having an interrupting rating not less than the overall panel short circuit current rating, see SB4.4.2. For control circuits tapped from the load-side of a motor branch circuit protective device, the overcurrent protection for the common control circuit or for the primary of a control transformer or power supply, the interrupting rating of the overcurrent protection shall be included in the determination of the branch circuit short circuit current rating in SB4.4.1 and SB4.4.2(a).

Exception: Secondary circuits operating at 24 vdc maximum and supplied from a source with a maximum output power of 100 VA, shall be considered control circuits for the purpose of applying SB3.2.1.

SB4 Ratings

SB4.1 Short circuit current rating

SB4.1.1 The short circuit current rating of the overall industrial control panel shall be determined based upon:

a) First, establishing the short circuit current ratings of individual power circuit components as specified in SB4.2;

b) Second, modifying the available short circuit current within a portion of a circuit in the panel due to the presence of current limiting components as specified in SB4.3, when applicable; and

c) Third, determining the overall panel short circuit current rating as specified in SB4.4.

SB4.2 Short circuit current ratings of individual power circuit components

SB4.2.1 All power circuit components, including disconnect switches, branch circuit protective devices, branch circuit fuseholders, load controllers, motor overload relays, terminal blocks, bus bars, and line

filters, such as electromagnetic interference (EMI), or radio frequency interference (RFI) filters, or active or passive harmonic filters shall have a short circuit current rating or interrupting rating expressed in amperes or kiloamperes and voltage.

Exception No. 1: Power transformers, reactors, current transformers, dry-type capacitors, resistors, one-port SPDs, power monitoring devices (devices that monitor incoming power and power quality parameters such as voltage, current, frequency, power, etc.), and voltmeters are not required to have a short circuit current rating.

Exception No. 2: The "S" contactor of a wye-delta motor controller is not required to have a short circuit current rating.

Exception No. 3: Enclosure air conditioners that are cord-and-attachment-plug connected are not required to have a short circuit current rating.

Exception No. 4: Wiring ferrules are not required to have a short circuit current rating, provided that the requirements of 29.3.6 are met.

Exception No. 5: Components installed on the load side of a variable-speed drive where the variable-speed drive has built-in electronic short circuit protection, are not required to have a short circuit current rating.

SB4.2.2 The short circuit current rating of a feeder or branch circuit component shall be established by one of the following methods:

a) The short circuit current rating marked on the component or on instructions provided with the component;

b) The short circuit current rating determined by the voltage rating of the component and the assumed short circuit current from Table SB4.1; or

c) The short circuit current rating for a component that has been investigated in accordance with the performance requirements, including short circuit test requirements for standard fault currents or high fault currents specified in the associated product standard, and described in the manufacturer's Procedure.

Table SB4.1
Assumed maximum short circuit current rating for unmarked components

Component	Short circuit current rating or interrupting rating[e], kA
Bus bars	10
Circuit breaker (including GFCI type)	5[e]
Current meters	a
Connectors for Use in Data, Signal, Control and Power Applications	10
Current shunt	10
Fuse	10[e]
Fuse, miniature or miscellaneous	10[b, e]
Fuseholder	10
Industrial control equipment:	
a. Auxiliary devices (overload relay)	5
b. Switches (other than mercury tube type)	5

Table SB4.1 Continued on Next Page

Table SB4.1 Continued

Component		Short circuit current rating or interrupting rating[e], kA
c. Mercury tube switches		
Rated over 60 amperes or over 250 volts		5
Rated 250 volts or less, 60 amperes or less, and over 2 kVA		3.5
Rated 250 volts or less and 2 kVA or less		1
Motor controller, (including combination motor controllers, float and pressure operated motor controllers, power conversion equipment and solid state motor controllers), and active and passive harmonic filters rated in horsepower (kW)[d]		
Controller Rated 0-600V	**Controller Rated 601-1000V**	
a. 0 – 50 (0 – 37.3)	0 – 50 A	5[c]
b. 51 – 200 (38 – 149)	51 – 200 A	10[c]
c. 201 – 400 (150 – 298)	201 – 400 A	18[c]
d. 401 – 600 (299 – 447)	401 – 600 A	30[c]
e. 601 – 900 (448 – 671)	601 – 900 A	42[c]
f. 901 – 1600 (672 – 1193)	901 – 1600 A	85[c]
Meter socket base		10
Receptacle (GFCI type)		2
Receptacle (other than GFCI type)		10
Supplementary protector		0.2
Switch unit		5
Terminal block or power distribution block		10
Multi-point interconnection power cable assembly		10
Cable Assemblies and Fittings for Industrial Control and Signal Distribution		10
Multiwire (power distribution) lug		10
Electromagnetic interference (EMI) or radio frequency interference (RFI) filters rated:		
a. 100 amperes or less		5
b. More than 100 amperes		10

[a] A short circuit current rating is not required when connected via a current transformer or current shunt. A directly connected current meter shall have a marked short circuit current rating.

[b] The use of a miniature fuse is limited to 125-volt circuits.

[c] Standard fault current rating for motor controller rated within specified horsepower range.

[d] Highest rated horsepower of motor controller. For devices rated in amperes instead of horsepower or kW, use Table 50.1 to convert to horsepower.

[e] Interrupting rating for overcurrent protection devices.

SB4.2.3 A high fault short circuit current rating for a feeder or branch circuit component, as specified in SB4.2.2 (a) or (c), shall only be used as the short circuit current rating of the component when the specified feeder or branch circuit protective device is provided.

Exception No. 1: When the specified branch circuit protection related to the high fault short circuit current rating is a Class CC, G, J, L, RK1, RK5, or T fuse, a fuse of a different class is able to be used at the same high fault rating where the peak let-through current and I^2t of the new fuse is not greater than that of the specified fuse. See Table SB4.2 for maximum let-through currents and I^2t.

Exception No. 2: The specified branch circuit protection is able to be provided in the field when the panel is marked in accordance with SB5.1.2. The specified feeder circuit protection is able to be provided in the field when the panel is marked in accordance with SB5.1.3.

Exception No. 3: When the specified branch circuit protection related to the high fault short circuit current rating is a listed circuit breaker marked "current limiting", a different current-limiting circuit breaker is able to be used at the same high fault rating where the peak let-through current and I^2t of the new current-limiting circuit breaker is not greater than that of the specified circuit breaker. See published let-through values for current-limiting circuit breakers provided by the manufacturer. Figure SB4.1 is provided to assist in determining the peak let-through current and I^2t from the manufacturers data sheets.

Exception No. 4: When the specified branch circuit protection related to the high fault short-circuit current rating is a non-current limiting overcurrent device, a current-limiting fuse according to Table SB4.2 is able to be used at the same high fault rating where the interrupting rating of the current-limiting fuse is equal to or greater than the specified overcurrent device , and where the rated current of the fuse is equal to or less than the specified overcurrent device .

Table SB4.2
Fuse Peak let through currents, I_p, and clearing, I^2t, based on available short circuit current levels

Fuse types	Fuse rating amperes	Between threshold and 50 kA		100 kA		200 kA	
		$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$
Class CC	15	2	3	2	3	3	4
	20	2	3	3	4	3	5
	30	7	6	7	7.5	7	12
Class G	15	–	–	3.8	4	–	–
	20	–	–	5	5	–	–
	30	–	–	7	7	–	–
	60	–	–	25	10.5	–	–
300 volt Class T[b]	1	–	–	0.4	0.8	–	–
	3	–	–	0.6	1.3	–	–
	6	–	–	1	2	–	–
	10	–	–	1.5	3	–	–
	15	–	–	2	4	–	–
	20	–	–	2.5	4.5	–	–
	25	–	–	2.7	5.5	–	–
	30	3.5	5	3.5	7	3.5	9
	35	–	–	6	7	–	–
	40	–	–	8.5	7.2	–	–
	45	–	–	9	7.6	–	–
	50	–	–	11	8	–	–
	60	15	7	15	9	15	12
	70	–	–	25	10	–	–
	80	–	–	30	10.7	–	–
	90	–	–	38	11.6	–	–
	100	40	9	40	12	40	12
	110	–	–	50	12	–	–
	125	–	–	75	13	–	–
	150	–	–	88	14	–	–
	175	–	–	115	15	–	–
	200	150	13	150	16	150	20
	225	–	–	175	21	–	–
	250	–	–	225	22	–	–
	300	–	–	300	24	–	–

Table SB4.2 Continued on Next Page

Table SB4.2 Continued

Fuse types	Fuse rating amperes	Between threshold and 50 kA		100 kA		200 kA	
		$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$
	350	–	–	400	27	–	–
	400	500	22	550	28	550	35
	450	–	–	600	32	–	–
	500	–	–	800	37	–	–
	600	1000	29	1000	37	1000	46
	700	–	–	1250	45	–	–
	800	1500	37	1500	50	1500	65
	1000	–	–	3500	65	–	–
	1200	3500	50	3500	65	4000	80
Class CF (up to 400 A), Class J and 600 volt Class T[b]	1	–	–	0.8	1	–	–
	3	–	–	1.2	1.5	–	–
	6	–	–	2	2.3	–	–
	10	–	–	3	3.3	–	–
	15	–	–	4	4	–	–
	20	–	–	5	5	–	–
	25	–	–	5.5	6	–	–
	30	7	6	7	7.5	7	12
	35	–	–	12	7.5	–	–
	40	–	–	17	8	–	–
	45	–	–	18	8.5	–	–
	50	–	–	22	9	–	–
	60	30	8	30	10	30	16
	70	–	–	50	11.5	–	–
	80	–	–	60	12.5	–	–
	90	–	–	75	13.5	–	–
	100	60	12	80	14	80	20
	110	–	–	100	14.5	–	–
	125	–	–	150	15.5	–	–
	150	–	–	175	17	–	–
	175	–	–	225	18.5	–	–
	200	200	16	300	20	300	30
	225	350[c]	19[c]	350	22.5	350[c]	33[c]
	250	–	–	450	24	–	–
	300	–	–	600	26	–	–
	350	–	–	800	29	–	–
	400	1000	25	1100	30	1100	45
	450	–	–	1500	36	–	–
	500	–	–	2000	42	–	–
	600	2500	35	2500	45	2500	70
	700[a]	–	–	3500	50	–	–
	800[a]	4000	50	4000	55	4000	75
	1000	–	–	8000	65	–	–
	1200	10000	55	10000	70	10000	88
Class L	800	10000	80	10000	80	10000	80
	1200	12000	80	12000	80	15000	120
	1600	22000	100	22000	100	30000	150

Table SB4.2 Continued on Next Page

Table SB4.2 Continued

Fuse types	Fuse rating amperes	Between threshold and 50 kA				100 kA				200 kA			
		$I^2t \times 10^3$		$I_p \times 10^3$		$I^2t \times 10^3$		$I_p \times 10^3$		$I^2t \times 10^3$		$I_p \times 10^3$	
	2000	35000		110		35000		120		40000		165	
	2500	–		–		75000		165		75000		180	
	3000	–		–		100000		175		100000		200	
	4000	–		–		150000		220		150000		250	
	5000	–		–		350000		–		350000		300	
	6000	–		–		350000		–		500000		350	
Class R		RK1	RK5	RK1	RK5	RK1	RK5	RK1	RK5	RK1	RK5	RK1	RK5
	30	10	50	6	11	10	50	8.7	11	11	50	12	14
	60	40	200	10	20	40	200	12	21	50	200	16	26
	100	100	500	14	22	100	500	16	25	100	500	20	32
	200	400	1600	18	32	400	1600	22	40	400	2000	30	50
	400	1200	5000	33	50	1200	5000	35	60	1600	6000	50	75
	600	3000	10000	45	65	3000	10000	50	80	4000	12000	70	100

[a] Value applies to Class T fuses.

[b] When values at 50 kA and 200 kA are needed, the standard case size shall be used.

[c] Value applies to Class CF fuses.

SB4.2.4 A high fault short circuit current rating of a bus bar can additionally be determined by one of the following methods:

a) Use of a bus bar system, that complies with the Standard for Industrial Control Equipment, UL 508, with the short circuit current rating marked on the component or on instructions provided with the component and installed according to the installation instructions provided by the product; or

b) Use of a bus bar system constructed with electrical ratings and short circuit current rating in accordance with Appendix D.

SB4.3 Feeder components that limit the short circuit current available

SB4.3.1 For feeder and branch circuit components and overcurrent protective devices supplied by a power transformer with an isolated secondary winding, the short circuit current rating on the line side of the transformer shall be one of the following:

a) For a power transformer with a marked or known impedance, where the secondary short circuit current (I_{sc}) is calculated using the formulas below, and where the short circuit current rating of all components and interrupting rating of all overcurrent protective devices supplied by the transformer are not less than the calculated secondary short circuit current (I_{sc}), the interrupting rating of the primary overcurrent protective device is able to be assigned to the short circuit current rating on the line side of the power transformer circuit.

Single Phase Transformers:

Transformer Full-Load Current (I_{FL}) = (Transformer kVA × 1000) / Voltage*

Short Circuit Current (I_{SC} line-to-line) = ((Transformer Full Load Current (I_{FL})) / Transformer Impedance (Z)

*Line-to-line secondary voltage

Three Phase Transformers:

Transformer Full-Load Current (I_{FL}) = (Transformer kVA × 1000) / (Voltage** × 1.732)

Short Circuit Current (I_{SC} line-to-line-to-line) = ((Transformer Full Load Current (I_{FL})) / Transformer Impedance (Z)

**Line-to-line-to-line secondary voltage

Note: These formulas and Table SB4.3 and Table SB4.4 provide the worse case value for I_{SC} (assumes infinite available short circuit current).

b) For a power transformer with an unmarked impedance, or with a marked or known impedance not less than 2.1%, the impedance shall be permitted to be assumed to be 2.1%. The short circuit rating shall be determined by either the formula method in SB4.3.1(a) or by using Table SB4.3 or Table SB4.4 as follows:

For a power transformer with a rated kVA not exceeding that in Column 1 of Table SB4.3 (single phase) or Table SB4.4 (three phase) and a specified secondary voltage not less than one of the values listed in Column 2, where the short circuit current rating of all components and interrupting rating of all overcurrent protective devices supplied by the transformer are not less than the corresponding available short-circuit current short-circuit shown for the specified secondary voltage in Column 2 of the table, the interrupting rating of the primary overcurrent protective device is able to be assigned to the short circuit current rating on the line side of the power transformer circuit.

c) For components that do not comply with SB4.3.1(a) or SB4.3.1(b), the lowest short circuit current rating of the components or the lowest interrupting rating of the overcurrent protective devices supplied by the transformer, whichever is lower, is assigned to the line side of the power transformer circuit.

Table SB4.3
Single phase transformer secondary available short circuit currents (Amps)[a]

Column 1	Column 2							
Transformer	Minimum Transformer Secondary Voltage (V)							
Max kVA	120	120/240[b]	208	240	277	347	480	600
1	400 A	300 A	230 A	200 A	180 A	140 A	100 A	80 A
3	1,200 A	900 A	690 A	600 A	520 A	420 A	300 A	240 A
5	1,990 A	1,490 A	1,150 A	1,000 A	860 A	690 A	500 A	400 A
10	3,970 A	2,980 A	2,290 A	1,990 A	1,720 A	1,380 A	1,000 A	800 A
15	5,960 A	4,470 A	3,440 A	2,980 A	2,580 A	2,060 A	1,490 A	1,200 A
25	9,930 A	7,450 A	5,730 A	4,970 A	4,300 A	3,440 A	2,490 A	1,990 A
37.5	14,890 A	11,170 A	8,590 A	7,450 A	6,450 A	5,150 A	3,730 A	2,980 A
50	19,850 A	14,890 A	11,450 A	9,930 A	8,600 A	6,870 A	4,970 A	3,970 A
75	29,770 A	22,330 A	17,180 A	14,890 A	12,900 A	10,300 A	7,450 A	5,960 A

[a] Z assumed to be 2.1%. All values are rounded up.

[b] Short-circuit current shown is line-to-neutral. (1.5 times line-to-line)

Table SB4.4
Three phase transformer secondary available short circuit currents (Amps)[a]

Column 1	Column 2						
Transformer	Minimum Transformer Secondary Voltage (V)						
Max kVA	208Y/120[b]	208	240	480Y/277[b]	480	600Y/347[b]	600
5	830 A	670 A	580 A	360 A	290 A	290 A	230 A
10	1,660 A	1,330 A	1,150 A	720 A	580 A	580 A	460 A
15	2,480 A	1,990 A	1,720 A	1,080 A	860 A	860 A	690 A

Table SB4.4 Continued on Next Page

Table SB4.4 Continued

Column 1	Column 2						
Transformer	Minimum Transformer Secondary Voltage (V)						
Max kVA	208Y/120[b]	208	240	480Y/277[b]	480	600Y/347[b]	600
20	3,310 A	2,650 A	2,300 A	1,440 A	1,150 A	1,150 A	920 A
25	4,140 A	3,310 A	2,870 A	1,800 A	1,440 A	1,440 A	1,150 A
30	4,960 A	3,970 A	3,440 A	2,150 A	1,720 A	1,720 A	1,380 A
45	7,440 A	5,950 A	5,160 A	3,230 A	2,580 A	2,580 A	2,070 A
75	12,400 A	9,920 A	8,600 A	5,370 A	4,300 A	4,300 A	3,440 A
100	16,530 A	13,220 A	11,460 A	7,160 A	5,730 A	5,730 A	4,590 A

[a] Z assumed to be 2.1%. All values are rounded up.

[b] Short-circuit current shown is line-to-neutral. (1.25 times line-to-line)

SB4.3.2 For branch circuits supplied by a Listed circuit breaker marked "current limiting" in the feeder circuit, the short circuit current rating on the line side of the circuit breaker shall be one of the following:

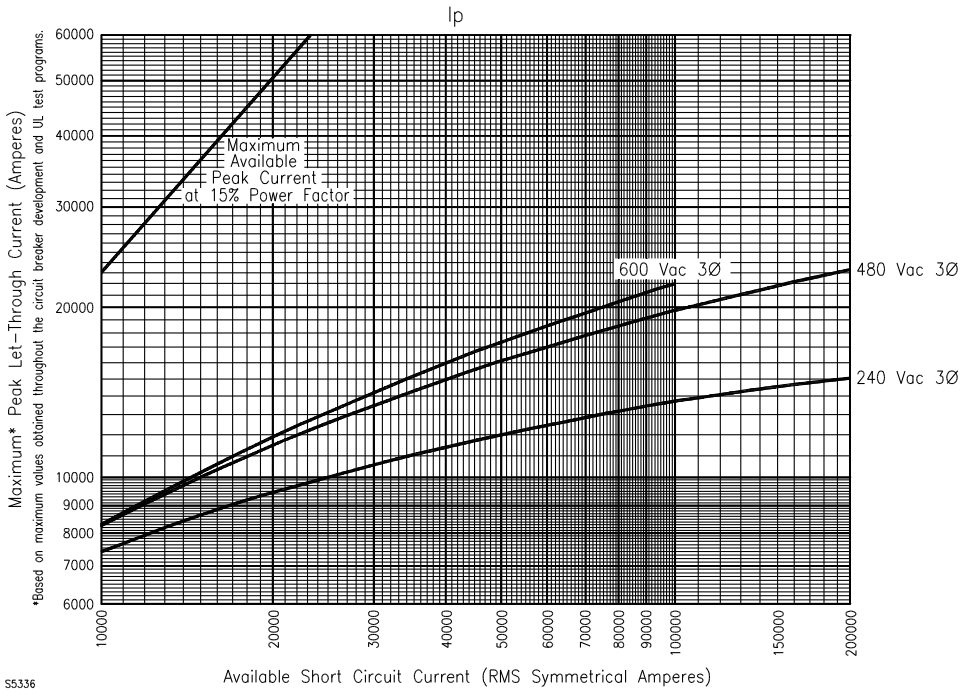
a) The available short circuit current selected for the feeder circuit breaker, any value up to the interrupting rating, when all of the individual components in the branch circuit have a short circuit current rating not less than the published peak let-through current corresponding to the specific circuit breaker, ampacity, voltage and selected available short-circuit current, see Figure SB4.1, and the interrupting rating of all branch circuit protective devices or the short circuit current rating of any combination motor controller on the load side are not less than the available short circuit current selected for the feeder circuit breaker. For branch circuit protective devices not marked with an interrupting rating, or combination motor controllers not marked with a short circuit current rating, the values in Table SB4.1 shall be used.

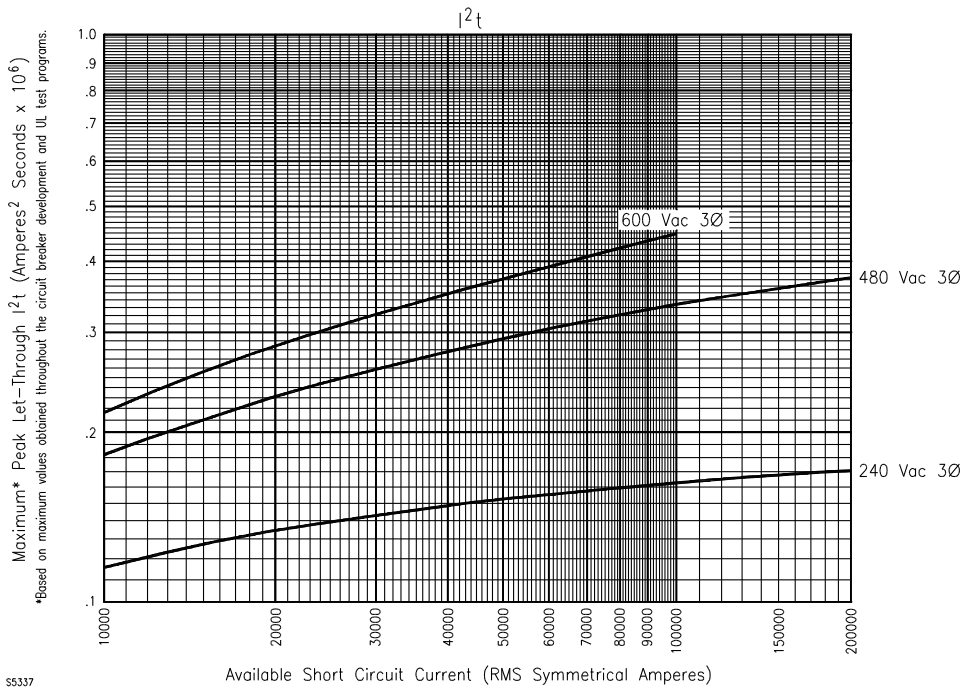
b) The smallest interrupting rating of any branch circuit protective device or the short circuit current rating of any combination motor controller on the load side of the feeder circuit breaker, when the conditions of SB4.3.2(a) exist except the interrupting rating of the branch circuit protective devices or the short circuit current rating of any combination motor controller on the load side are less than the available short circuit current selected for the feeder circuit breaker, any value up to the interrupting rating. For branch circuit overcurrent protective devices not marked with an interrupting rating, or for combination motor controllers not marked with a short circuit current rating, the values in Table SB4.1 shall be used.

c) The smallest short circuit current rating of any branch circuit on the load side of the feeder circuit breaker, when the conditions of SB4.3.2(a) or SB4.3.2(b) are not met.

Figure SB4.1

Sample plots of current limiting circuit breakers let-through values





To determine peak let-through current and I^2t value:

a) Obtain plots of the maximum let-through values for the specific current limiting circuit breaker from the manufacturer;

b) Select the available short circuit current along the horizontal axis at the bottom of the chart that is equal to the short circuit current rating of the industrial control panel;

c) Move vertically to the intersection with the curve corresponding to the rated voltage of the circuit breaker that is not less than the rated voltage of the industrial control panel.

d) Move horizontally left to intersection with the vertical axis to determine the peak let-through current or I^2t value.

SB4.3.3 For branch circuits supplied by a Class CC, G, CF, J, L, RK1, RK5, or T fuse in the feeder circuit, the short circuit current rating on the line side of the fuse shall be one of the following:

a) The available short circuit current selected for the feeder fuse, any value up to the interrupting rating, when all of the individual components in the branch circuit have a short circuit current rating not less than the peak let-through current corresponding to the specific fuse class, ampacity and selected available short-circuit current employed from Table SB4.2, and the interrupting rating of all branch circuit protective devices or the short-circuit current ratings of any combination motor controller on the load side are not less than available short circuit current selected for the feeder fuse. For branch circuit protective devices not marked with an interrupting rating, or for combination motor controllers not marked with a short-circuit current rating, the values in Table SB4.1 shall be used;

b) The smallest interrupting rating of any branch circuit protective device or the short circuit current rating of any combination motor controller on the load side of the feeder fuse, when the conditions of SB4.3.3(a) exist except the interrupting rating of the branch circuit protective devices or the short circuit current rating of any combination motor controller on the load side are less than the available short circuit current selected for the feeder fuse, any value up to the interrupting rating. For branch circuit overcurrent protective devices not marked with an interrupting rating, or for combination motor controllers not marked with a short-circuit current rating, the values in Table SB4.1 shall be used;

c) The smallest short circuit current rating of any branch circuit on the load side of the feeder fuse, when the conditions of SB4.3.3(a) or SB4.3.3(b) are not met.

SB4.3.4 The specified circuit breaker marked “current limiting” or current-limiting Class of fuse supplied in the feeder circuit that limits the peak let-through current available in accordance with SB4.3.2 and SB4.3.3 is able to be provided in the field when the panel is marked in accordance with SB5.1.3.

SB4.4 Determination of the overall short circuit current rating of the panel

SB4.4.1 For each branch circuit provided with branch circuit protection within the industrial control panel, the smallest short circuit current rating of all power circuit components on the load side of a branch circuit protective device and the control circuit overcurrent protection in SB3.2.1 shall be determined and compared with the interrupting rating of the branch circuit protective device. The smaller of the two ratings shall be assigned to the line side of the branch circuit protective device.

SB4.4.2 The overall short circuit current rating of the panel shall be one of the following:

a) For an industrial control panel consisting of a single branch circuit without branch circuit protection within the panel, the lowest short circuit current rating for any power circuit component or the interrupting rating of the control circuit overcurrent protection in SB3.2.1;

b) For an industrial control panel consisting of a single branch circuit including branch circuit protective devices and power circuit components within the panel, the short circuit current rating is in accordance with SB4.4.1;

c) For an industrial control panel consisting of multiple branch circuits, and feeder components within the panel, such as disconnecting switches, bus bars, terminal blocks, and feeder overcurrent protective devices, the short circuit current rating shall be the lowest of the following:

1) The lowest short circuit current rating of any branch circuit in accordance with SB4.4.1 that has not been modified by SB4.3.1 – SB4.3.3;

2) The lowest interrupting rating of feeder overcurrent protective devices or short circuit current rating of any feeder component and the interrupting rating of any control circuit overcurrent protection connected to the feeder as in SB3.2.1; or

3) The modified short circuit current rating determined from SB4.3.1 – SB4.3.3 for each branch circuit supplied by the associated feeder component.

SB5 Markings

SB5.1 General

SB5.1.1 The nameplate rating of an industrial control panel shall include: "Short circuit current rating: ___kA rms symmetrical, ___V maximum" or the equivalent. If the short circuit current rating is dependent upon a specific overcurrent protective device, the manufacturer name, model number, type and ampere rating of the overcurrent protection device required to be installed in the field shall be marked.

SB5.1.2 An industrial control panel marked with a high fault short circuit current rating and is not provided with the required branch circuit protective device as specified in the Exception to SB4.2.3 shall be marked with the type and size of branch circuit protection required to be installed in the field. This marking shall be included as part of the marking in SB5.1.1.

SB5.1.3 An industrial control panel marked with a high fault short circuit current rating and is not provided with the required feeder circuit protective device as specified in Exception No. 2 to SB4.2.3, or SB4.3.4, shall be marked with the type and size of feeder circuit protection required to be installed in the field. This marking shall be included as part of the marking in SB5.1.1.

SB5.2 Cautionary markings

SB5.2.1 An industrial control panel with a short circuit current rating based on the high fault short circuit current ratings of one or more components as specified in SB4.2.3 shall be marked with the word "WARNING" and the following statement: "Risk of Fire or Electric Shock – The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. All current-carrying parts and other components protected by this device should be examined and replaced if damaged. If burnout of a current element of an overload relay occurs, the complete overload relay must be replaced."

Exception: An instantaneous trip circuit breaker used as branch circuit protection for a combination motor controller shall be marked as specified in 55.6 and a self-protected combination motor controller shall be marked as specified in 55.7.

APPENDIX A

Standards for Components

Standards under which components of the products covered by this standard are evaluated include the following:

Title of Standard − UL Standard Designation

Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy – UL 61800-5-1
Attachment Plugs and Receptacles – UL 498
Audible Signaling Devices for Fire Alarm and Signaling Systems, Including Accessories – UL 464
Automatic Electrical Controls for Household and Similar Use – Part 2: Particular Requirements for Burner Ignition Systems and Components – UL 372
Batteries, Lithium – UL 1642
Batteries, Standby – UL 1989
Cables, Communications – UL 444
Cables, Power-Limited Circuit – UL 13
Capacitors – UL 810
Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains – UL 60384-14
Circuit Breakers, Molded-Case, Molded-Case Switches, and Circuit-Breaker Enclosures – UL 489
Class 2 Power Units – UL 1310
Coated Electrical Sleeving – UL 1441
Controllers, Programmable – Part 2: Equipment Requirements and Tests – UL 61131-2
Controls – Part 1: General Requirements, Automatic Electrical – UL 60730-1 and/or the applicable Part 2 standard from the UL 60730 series
Dry-Type General Purpose and Power Transformers – UL 1561
Electric Fans – UL 507
Electric Heating Appliances – UL 499
Electrical Machines, Rotating – General Requirements – UL 1004-1
Electrically Isolated Semiconductor Devices – UL 1557
Electrically Operated Valves – UL 429
Electromagnetic Interference Filters – UL 1283
Enclosures for Electrical Equipment, Environmental Considerations – UL 50E
Enclosures for Electrical Equipment, Non-Environmental Considerations – UL 50
Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors – UL 486E
Extruded Insulating Tubing – UL 224
Fittings, Conduit, Tubing, and Cable – UL 514B
Flexible Cords and Cables – UL 62
Gas-Tube-Sign Cable – UL 814
Ground-Fault Circuit-Interrupters – UL 943
Grounding and Bonding Equipment – UL 467
Industrial Control Equipment – UL 508
Information Technology Equipment – Safety – Part 1: General Requirements – UL 60950-1
Insulating Tape, Polyvinyl Chloride, Polyethylene, and Rubber – UL 510
Lampholders – UL 496
Low-Voltage Fuses – Part 1: General Requirements – UL 248-1
Low-Voltage Fuses – Part 2: Class C Fuses – UL 248-2
Low-Voltage Fuses – Part 3: Class CA and CB Fuses – UL 248-3
Low-Voltage Fuses – Part 4: Class CC Fuses – UL 248-4
Low-Voltage Fuses – Part 5: Class G Fuses – UL 248-5
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 8: Class J Fuses – UL 248-8
Low-Voltage Fuses – Part 9: Class K Fuses – UL 248-9
Low-Voltage Fuses – Part 10: Class L Fuses – UL 248-10
Low-Voltage Fuses – Part 11: Plug Fuses – UL 248-11

Low-Voltage Fuses – Part 12: Class R Fuses – UL 248-12
Low-Voltage Fuses – Part 13: Semiconductor Fuses – UL 248-13
Low-Voltage Fuses – Part 14: Supplemental Fuses – UL 248-14
Low-Voltage Fuses – Part 15: Class T Fuses – UL 248-15
Low-Voltage Fuses – Part 16: Test Limiters – UL 248-16
Low-Voltage Fuses – Part 17: Class CF Fuses – UL 248-17
Luminaires – UL 1598
Motor Control Centers – UL 845
Overheating Protection for Motors – UL 2111
Panelboards – UL 67
Plastic Materials for Parts in Devices and Appliances, Tests for Flammability of – UL 94
Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C
Power Units Other Than Class 2 – UL 1012
Protectors, Supplementary, for Use in Electrical Equipment – UL 1077
Room Air Conditioners – UL 484
Sealed Wire Connector Systems – UL 486D
Splicing Wire Connectors – UL 486C
Surge Protective Devices – UL 1449
Switches, Clock-Operated – UL 917
Switches, Enclosed and Dead-Front – UL 98
Switches for Appliances – Part 1: General Requirements – UL 61058-1
Switchgear and Controlgear, Low-Voltage – Part 1: General Rules – UL 60947-1
Switchgear and Controlgear, Low-Voltage – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters – UL 60947-4-1
Switchgear and Controlgear, Low-Voltage – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches – UL 60947-5-2
Temperature-Indicating and -Regulating Equiment – UL 873[1)]
Terminal Blocks – UL 1059
Time-Indicating and -Recording Appliances – UL 863
Transformers, Low Voltage – Part 1: General Requirements – UL 5085-1
Transformers, Low Voltage – Part 2: General Purpose Transformers – UL 5085-2
Transformers, Low Voltage – Part 3: Class 2 and Class 3 Transformers – UL 5085-3
Transformers, Specialty – UL 506
Uninterruptible Power Systems – UL 1778
Wire Connectors – UL 486A-486B
Wires and Cables, Machine-Tool – UL 1063
Wires and Cables, Thermoset-Insulated – UL 44
Wireways, Auxiliary Gutters, and Associated Fittings – UL 870

1) Note: Compliance with the UL 60730-1, and/or the applicable Part 2 standard from the UL 60730 series fulfills these requirements.

APPENDIX B – (informative) – USE OF COMPONENTS NOT UL LISTED OR RECOGNIZED IN INDUSTRIAL CONTROL PANELS

The information contained in Appendix B is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. As such, Appendix B may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary to fulfill the objectives of the standard.

B.1 Scope

B.1.1 These requirements cover the use of components in an industrial control panel that have not been previously investigated by UL. The panels in which these components are used shall otherwise comply with the requirements in this standard.

B.1.2 The requirements in this supplement are not applicable to a component:

a) That functions to cause the opening of a circuit in the case of overcurrent (including a running motor overload), short circuit, or a ground fault;

b) Where additional safety concerns are present, such as a risk of implosion of a cathode ray tube (CRT), use of components with flammable liquids or gases (such as oxygen), or high pressures [greater than 300 psi (2.08 MPa)];

c) That has been previously evaluated and is being used for a purpose or at electrical ratings other than those for which it has been evaluated, or that preclude the requirements in this standard pertaining to the component;

d) That has any electrical connection to a power circuit; or

e) Located entirely within a circuit that is isolated from the control circuit voltage, where the ground fault circuit interrupter is installed.

B.1.3 Components able to be covered under the requirements of this supplement include a switching device, relay, meter, recording device, or similar component that controls loads or other devices within the control circuit of an industrial control panel and do not include connections to external devices other than as specified in B.2.4.

B.1.4 A component that is not included in the scope of this supplement or does not comply with the conditions of use requirements of this supplement shall be investigated to the requirements in the Standard for Industrial Control Equipment, UL 508, or other applicable component standard and included in the manufacturer's Procedure.

B.2 Conditions of Use

B.2.1 Enclosures

B.2.1.1 The component shall be completely enclosed in the industrial control panel.

Exception No. 1: The component is able to extend through an opening in the industrial control panel enclosure when the component housing material is fabricated from:

a) A polymeric material, the area of which does not exceed 30 square inches (194 cm^2); or

b) Metal and glass, where the area of the exposed glass does not exceed 100 square inches (645 cm^2).

Exception No. 2: A component of an open type industrial control panel with:

a) A sub-enclosure that completely encloses the component; or

b) Barrier(s) complying with the requirements for ventilation openings where a ventilation opening is able to be located at any point in the front or to the sides of the unevaluated components.

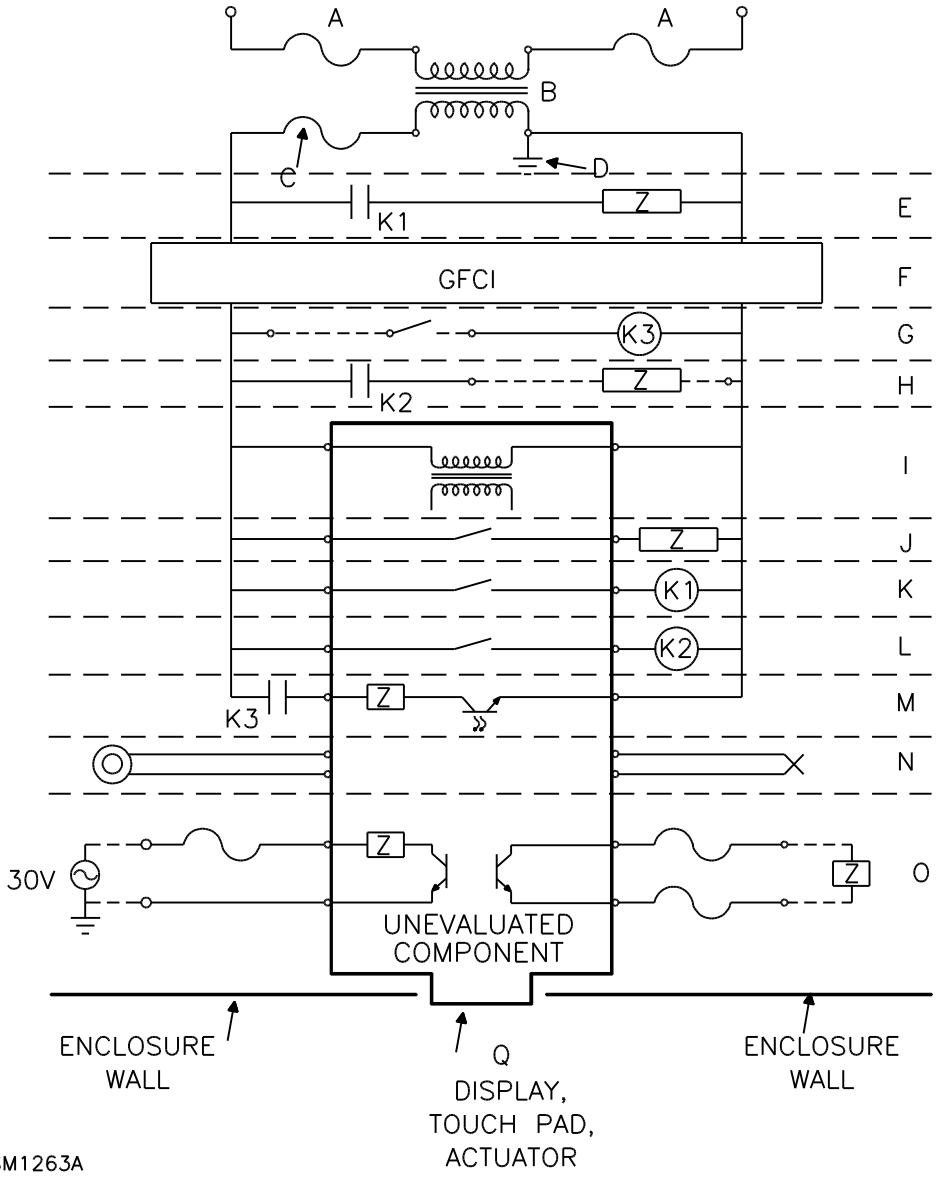
B.2.1.2 With respect to the requirements for ventilation openings in Section 21, Ventilation Openings, the component is an arcing part.

B.2.1.3 The component shall be connected within the control circuit of the industrial control panel.

B.2.1.4 All inputs to or outputs from the unevaluated component shall be connected to control circuit components that comply with the component requirements of this standard (See www.ul.com/UL508A-SupplementSA), as shown in Figure B.2.1 and described in B.2.2 – B.2.4.

Figure B.2.1

Required connections to a component evaluated to the requirements of Appendix B



A – Primary overcurrent protection for isolation transformer

B – Isolation transformer

C – Secondary overcurrent protection for isolation transformer

D – Secondary ground connection

E – Control of load inside control panel and not protected by GFCI. Also see K.

F – Ground-fault circuit interrupter (GFCI)

G – Coil of isolating relay input from switching device operating at over 30 Vrms. Also see M.

H – Control of load outside control panel from isolating relay contacts. Also see L.

I – Power supply input to component under evaluation

J – Control of control circuit load inside control panel and on load side of GFCI

K – Control of internal load on line side of GFCI via isolating relay

L – Control of external load operating at over 30 Vrms via isolating relay

M – Input from external switching device operating at over 30 Vrms

N – Low-voltage connections without fusing

O – Low-voltage connections with fusing

Q – Accessible part of component under evaluation

B.2.1.5 The industrial control panel shall have the following markings:

a) "WARNING – Use of the following components is dependent upon the additional protection afforded by the ground fault circuit interrupter and the overcurrent protective device provided. Do not remove or defeat these protective devices." This marking shall be followed by a tabulation of the component(s) that require the use of the ground fault circuit interrupter including schematic reference, type of device, manufacturer's name, and manufacturer's part number.

Example:	Component	Identification
	Relay, K1	Acme, p/n 508

b) "The ground fault circuit interrupter should be checked periodically for proper operation."

B.2.1.6 Records shall be maintained for the components evaluated to the requirements in this supplement as specified in .

B.2.1.7 Unless otherwise noted in this supplement, the components and construction required by this supplement shall be provided as a part of the panel containing the component under evaluation.

B.2.2 Power supplies

B.2.2.1 The power supply to the component shall be a transformer that complies with 40.1.1, with isolated secondary rated 115 – 120 volts or 230 – 240 volts nominal, supplying a load not in excess of its rating.

Exception: An isolation transformer is not required to be supplied in the immediate control panel when specific instructions are provided for the control circuit power to be tapped from a control transformer housed in an adjacent cabinet.

B.2.2.2 One side of the secondary circuit shall be grounded.

B.2.2.3 The secondary circuit shall be protected by a Class A (6 mA trip) circuit breaker and ground-fault circuit-interrupter (CBGFCI), or a Class A receptacle-type ground-fault circuit-interrupter (GFCI) complying with the Standard for Ground-Fault Circuit-Interrupters, UL 943, and used within its ratings. For a receptacle-type GFCI, the following additional requirements apply:

a) The component shall be connected directly to the terminals (not plugged into the receptacle);

b) A marking on or adjacent to the receptacle shall indicate the receptacle is not to be used for external connections; and

c) The receptacle shall be mounted so that it is not accessible from outside the enclosure.

A component provided with a power supply cord that includes an attachment plug shall have the attachment plug removed so that the leads of the cord are connected directly to the terminals of the GFCI.

B.2.3 Inputs

B.2.3.1 All inputs to the component, other than the power supply, shall comply with B.2.3.2 – B.2.3.5.

B.2.3.2 For input voltages greater than 30 Vrms (42.4 V peak or dc), the component shall be connected to a device, such as a relay, that complies with the component requirements of this standard (See www.ul.com/UL508A-SupplementSA), and is provided as part of the industrial control panel. The source voltage shall be supplied from the load side of the ground-fault circuit-interrupter.

B.2.3.3 For input voltages of 30 Vrms (42.4 V peak or dc) or less from a low-voltage limited energy source or Class 2 transformer provided as part of the industrial control panel, no additional protection is required.

B.2.3.4 For input voltages 30 Vrms (42.4 V peak or dc) or less from a source located outside the industrial control panel, each ungrounded conductor to the component shall be protected by a fuse rated 0.5 A located within the industrial control panel. A marking shall be provided near the fuse with the signal word "CAUTION" and the following or equivalent wording: "To reduce the risk of fire, replace only with same type and rating of fuse." An additional marking shall be placed next to the field wiring terminals with the word "CAUTION" and the following or equivalent wording: "To reduce the risk of electric shock, connections to these terminals shall not involve a potential of greater than 30 Vrms or 42.4 V peak between live parts of opposite polarity and between a live part and ground."

B.2.3.5 For input voltages from a sensing device that is isolated from line voltage circuits and located either inside or outside the industrial control panel, such as a transducer, tachometer, thermocouple, or similar feedback device, no additional protection is required.

B.2.4 Outputs

B.2.4.1 For output voltages greater than 30 Vrms (42.4 V peak or dc), the component shall be connected to a device, such as a relay, that has complies with the component requirements of this standard (See www.ul.com/UL508A-SupplementSA), and is provided as part of the industrial control panel. The source voltage shall be supplied from the load side of the ground-fault circuit-interrupter.

B.2.4.2 For output voltages of 30 Vrms (42.4 V peak or dc) or less from a low-voltage limited energy source or Class 2 transformer provided as part of the industrial control panel, no additional protection is required.

B.2.4.3 For output voltages 30 Vrms (42.4 V peak or dc) or less from a source located outside the industrial control panel, each ungrounded conductor to the component shall be protected by a fuse rated 0.5 A located within the industrial control panel. A marking shall be provided near the fuse with the signal word "CAUTION" and the following or equivalent wording: "To reduce the risk of fire, replace only with same type and rating of fuse."

B.3 Responsibility of the Manufacturer

B.3.1 The manufacturer shall conduct the test in B.3.2 to determine that the ground-fault circuit-interrupter protects against all ground faults.

B.3.2 With the control circuit energized, a resistance is to be connected between live parts of the component and ground. The value of the resistance shall be such that the current through it is greater than 6 mA and less than the rating of the secondary overcurrent protective device. The ground fault circuit interrupter shall open the circuit. Alternatively, the manufacturer shall test the correct bonding of the component: using an impedance measuring device, the measured impedance shall be 0.1 ohm or less. The measurement is between grounded parts adjacent to the component and the neutral side of the isolation transformer in B.2.2 that is supplying the component.

B.3.3 The manufacturer shall maintain records of the use of components evaluated to the requirements of this supplement for periodic review by a UL representative. The records shall be maintained in a form similar to the one in Table B.3.1.

B.3.4 Records of all components evaluated to the requirements of this supplement shall be retained for at least six months.

Table B.3.1
Information for unevaluated components

Component Designation	Component Manufacturer's Name	Catalog Designation	Number Used	Panel Identification	Ground Fault Date Testing

Appendix C – *Reserved for Future Use*

Appendix D – Maximum 100 000 Ampere Short-Circuit Current Rating Without Short-Circuit Test (normative)

D1 Scope

D1.1 These requirements cover stand alone busbar assemblies having an rms symmetrical short-circuit current rating for which short-circuit tests may be waived. These requirements do not otherwise amend the requirements in this standard.

D2 Glossary

D2.1 For the purposes of this Appendix, the following definitions apply.

D2.2 Brace – a mechanical assembly that is secured to bus bars to restrict relative motion between the bus bars

D2.3 Support – a mechanical assembly that is secured to bus bars and that is further secured to a rigid structural member such as the enclosure or a separate member secured to the framework.

D3 Construction

D3.1 General

D3.1.1 A maximum rms symmetrical short-circuit current rating as shown in Table D3.1 may be assigned to a stand-alone bus bar assembly rated as specified in Table D3.1 without conducting short-circuit tests if all the following conditions are met:

a) The construction complies with the requirements in D3.1.2 – D3.3.5.

b) The performance complies with requirements in D4.1.1 – D4.3.1.

c) The industrial control panel is marked in accordance with D5.1.

D3.1.2 For a maximum assigned rms symmetrical short-circuit current rating of 100 000 A, the industrial control panel shall contain a single integral main molded-case circuit breaker, low voltage AC power circuit breaker, or fused switch having a short-circuit rating not less than that of the industrial control panel, or shall be marked for use with a remote device of one of these types as covered in D5.2 having a short-circuit current rating not less than that of the industrial control panel. If provided, supply bus bars ahead of the main overcurrent protective device shall be located in the same industrial control panel.

D3.1.3 Copper or aluminum bus bars shall be nominally 1/4-in (6.4-mm) thick and have a width as described in Table D3.1; holes in bus bars shall not be larger than 0.438 by 0.813 in (11.1 by 20.7 mm) with the larger dimension limited to use along the axis of the bus bar.

Exception: Larger holes may be provided as specified in D3.1.4 for provision of current transformers.

D3.1.4 With regard to Figure D3.1, copper or aluminum bus bars shall be minimum 1/4-in (6.4-mm) thick and 2- to 4-in (50.8- to 102-mm) wide; holes in bus bars at supports shall not be larger than 0.406 by 0.750 in (10.3 by 19.1 mm) and holes for bus bar type current transformers shall not be larger than 9/16 by 1-13/32 in (14.3 by 35.7 mm). A bus bar shall be prevented from rotating by means other than the mounting bolt specified in D3.3.3.

Table D3.1
Bus Bar Assembly ratings and characteristics

Max. RMS sym. short-circuit current	Min. ampere rating	Max. ampere rating	Max. voltage rating (single- or three-phase)	Min. bus bar width		Max. bus bar width[a]		Bus bars FF or EE[b]	No. of phases	Minimum distance between opposite polarity bus bars[c]				Maximum distance between supports or fraction thereof[d]		Ref. Figures
										Closest point		Center to center				
amps	amps	amps	volts	in.	(mm)	in.	(mm)			in.	(mm)	in.	(mm)	in.	(mm)	
100 000[e]	800	4 000[f]	480[f]	4	(102)	7	(178)	EE	3	1	(25.4)	5	(127)	21	(533)	Figure D3.2 – Figure D3.6
100 000[e]	800	4 000[f]	480[f]	4	(102)	7	(178)	EE	1	2[g]	(50.8)	6[g]	(152)	21	(533)	
100 000[e]	800	4 000[f]	480[f]	4	(102)	7	(178)	FF	3	4	(102)	6	(152)	13[h]	(330)	Figure D3.7
100 000[e]	800	4 000[f]	480[f]	4	(102)	7	(178)	FF	1	5	(127)	7	(178)	13[h]	(330)	Figure D3.7
65 000	800	4 000[f]	480[f]	4	(102)	7	(178)	EE	3	1	(25.4)	5	(127)	21[g]	(533)	Figure D3.2 – Figure D3.6
65 000	800	4 000[f]	480[f]	4	(102)	7	(178)	EE	1	2[g]	(50.8)	6[g]	(152)	21[g]	(533)	
65 000	800	4 000[f]	480[f]	4	(102)	7	(178)	FF	3	4	(102)	6	(152)	21[i]	(533)	Figure D3.7
65 000	800	4 000[f]	480[f]	4	(102)	7	(178)	FF	1	5	(127)	7	(178)	21[i]	(533)	Figure D3.7
50 000	800	4 000[f]	480[f]	2	(50.8)	4	(102)	EE[j]	3	1-1/2	(38.1)	3-1/2	(88.9)	14	(356)	Figure D3.2 – Figure D3.6
50 000	800	4 000[f]	480[f]	2	(50.8)	4	(102)	EE[j]	1	2	(50.8)	6	(152)	14	(356)	
50 000	800	4 000[f]	480[f]	2	(50.8)	4	(102)	FF	3	4	(102)	6	(152)	21[i]	(533)	Figure D3.7
50 000	800	4 000[f]	480[f]	2	(50.8)	4	(102)	FF	v	5	(127)	7	(178)	21[i]	(533)	Figure D3.7
42 000	200	1500	480	2	(50.8)	4	(102)	EE[j]	1,3	5	(127)	9	(229)	21	(533)	D3.1

[a] Bus bars nominally 1/4-in (6.4-mm)thick aluminum or copper, one to four per phase. Refer to D3.1.3 and D3.1.4 for mounting and support hole size.

[b] Refer to D3.1.7 (EE – bus bars arranged edge to edge; FF – bus bars arranged face to face).

[c] Refer to D3.2.2 – D3.2.5 and Figure D3.8 and Figure D3.9. Spacing between bus bars crossing at right angles may be as covered in D3.2.3.

[d] Refer to D3.1.4 – D3.3.5 and Figure D3.1 – Figure D3.7, Figure D4.1, and Figure D4.2.

[e] Integral or remote main circuit breaker or fused switch required as described in D3.1.2. Ratings are not applicable to a tap.

[f] The maximum voltage rating may be 600 volts if the current rating does not exceed 2 000 amperes.

[g] The minimum distance may be 1 in (25.4 mm) for the closest point and 5 in (127 mm) center to center if the distance between supports is no more than 17 in (432 mm).

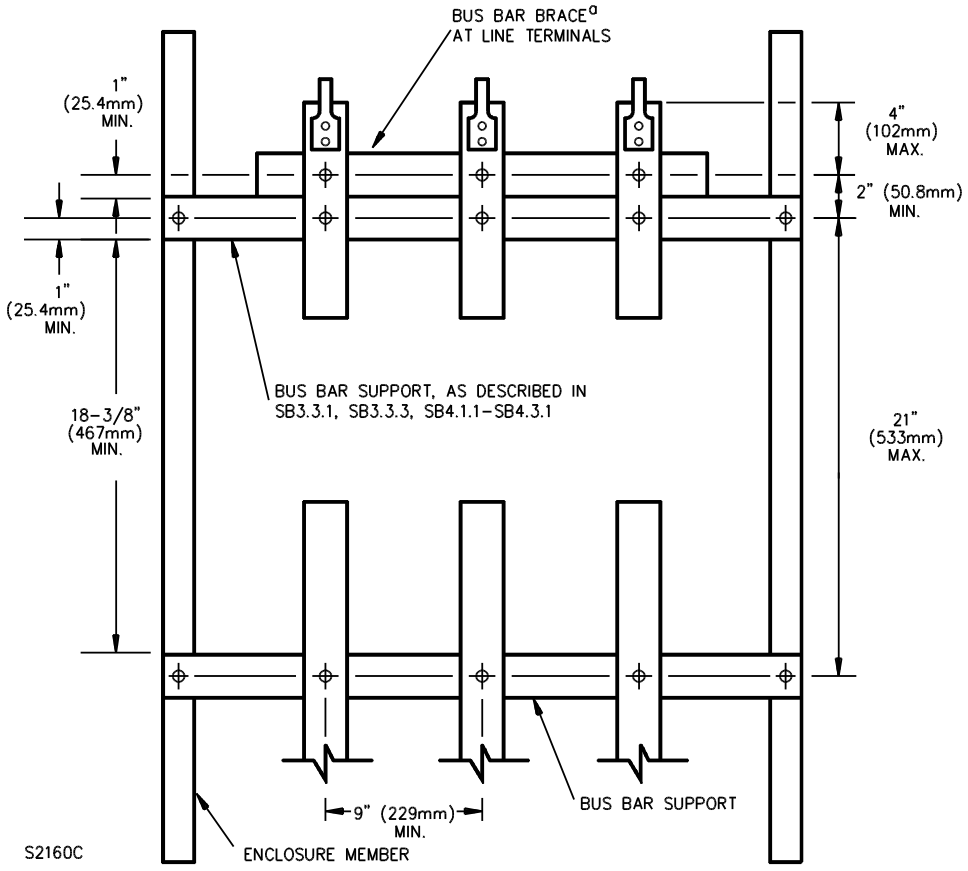
[h] Supports may be located maximum 48 in (1.2 mm) apart if braces are located maximum 13 in (330 mm) apart. See Figure D3.7.

[i] Supports may be located maximum 48 in apart if braces are located maximum 21 in (533 mm) apart. See Figure Figure D3.7.

[j] Bus bars greater than 2 in (50.8 mm) in width may be L-shaped as covered in the Exception to D3.1.5.

Figure D3.1

Current transformer (CT) compartment

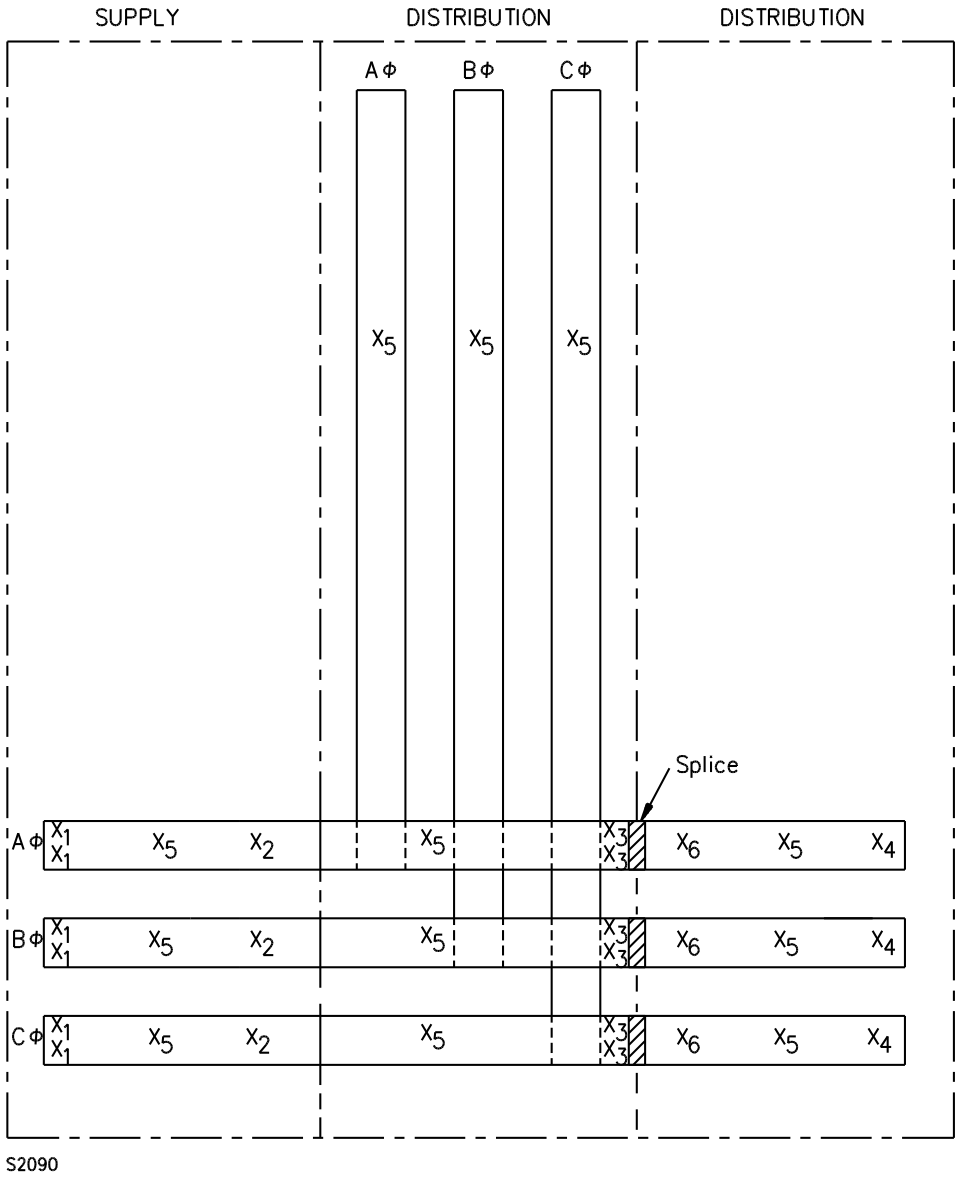


NOTE – Constructions shown in Figure D3.2 – Figure D3.6 may also be used at connection to current transformers.

[a] See D3.3.5.

Figure D3.2

Location of supports for edge-to-edge connection of bus bars for a switchboard marked for use without a main or for use with a remote main



In which:

X – Bus supports (bolts to nonmetallic channel, standoff insulator, or steel channel) as shown in Figure D3.10 – Figure D3.12.

X_1X_1 – Two at end of bus in supply section except that one support may be used with a single bus bar 2 – 3-in (50.8 – 76.2-mm) wide with a short-circuit current rating of 50 000 A or less.

X_2 – At end of section. One support when horizontal bus is continuous.

X_3X_3 – When splice plate is used, two supports for copper bus, one support for aluminum bus, except that one support may be used for a single copper bus bar 2 – 3-in (50.8 – 76.2-mm) wide with a short-circuit current rating of 50 000 A or less.

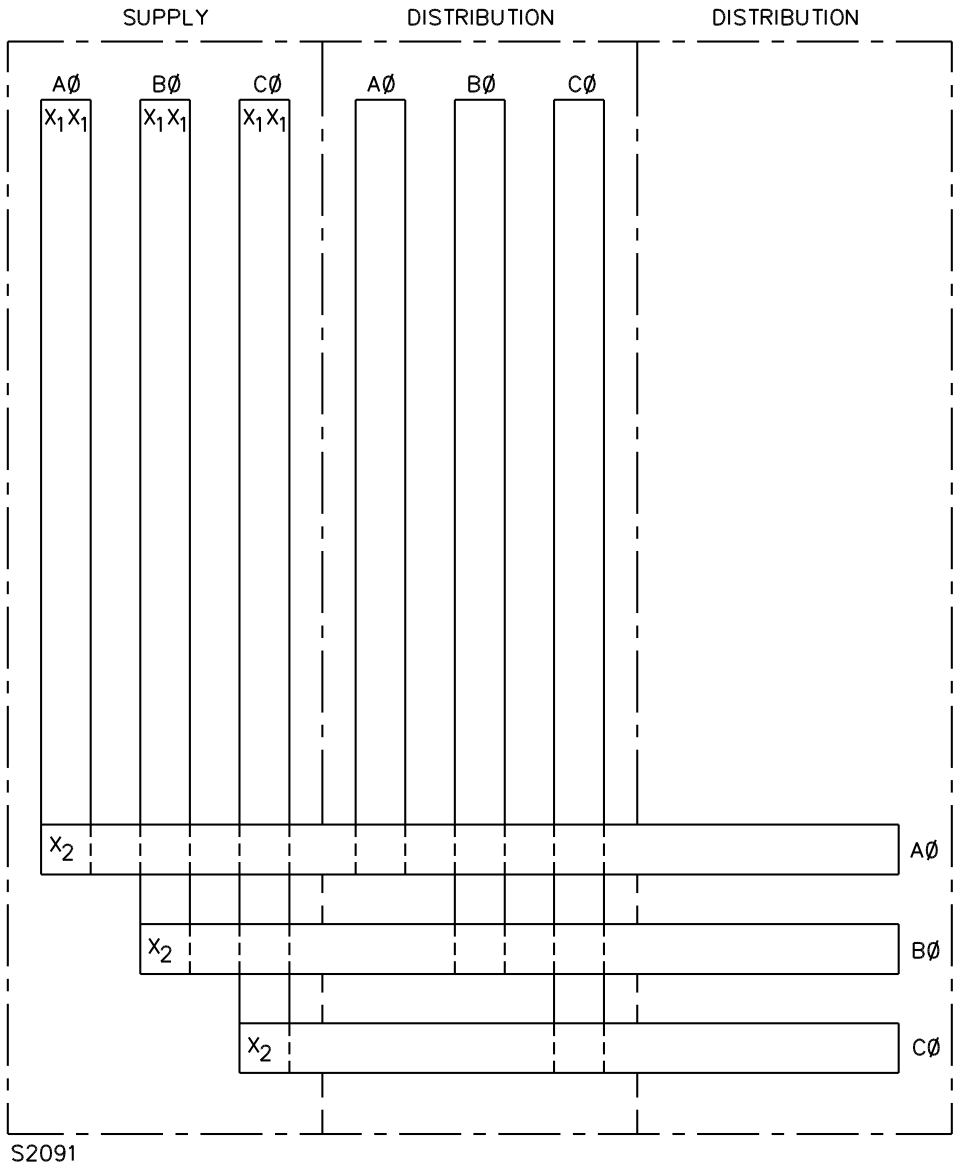
X_4 – One support required at end of horizontal bus.

X_5 – One support required at intervals as described in Table D3.1. Connection of vertical bus to horizontal bus may serve as a support for the vertical bus but not for the horizontal bus. See D3.2.3 for spacings between bus bars at cross-overs.

X_6 – At the load of splice bus, one support required.

Figure D3.3

Location of supports for right-angle connection of edge-to-edge bus bars for a bus bar assembly in an industrial control panel without a main or marked for use with a remote main



In which:

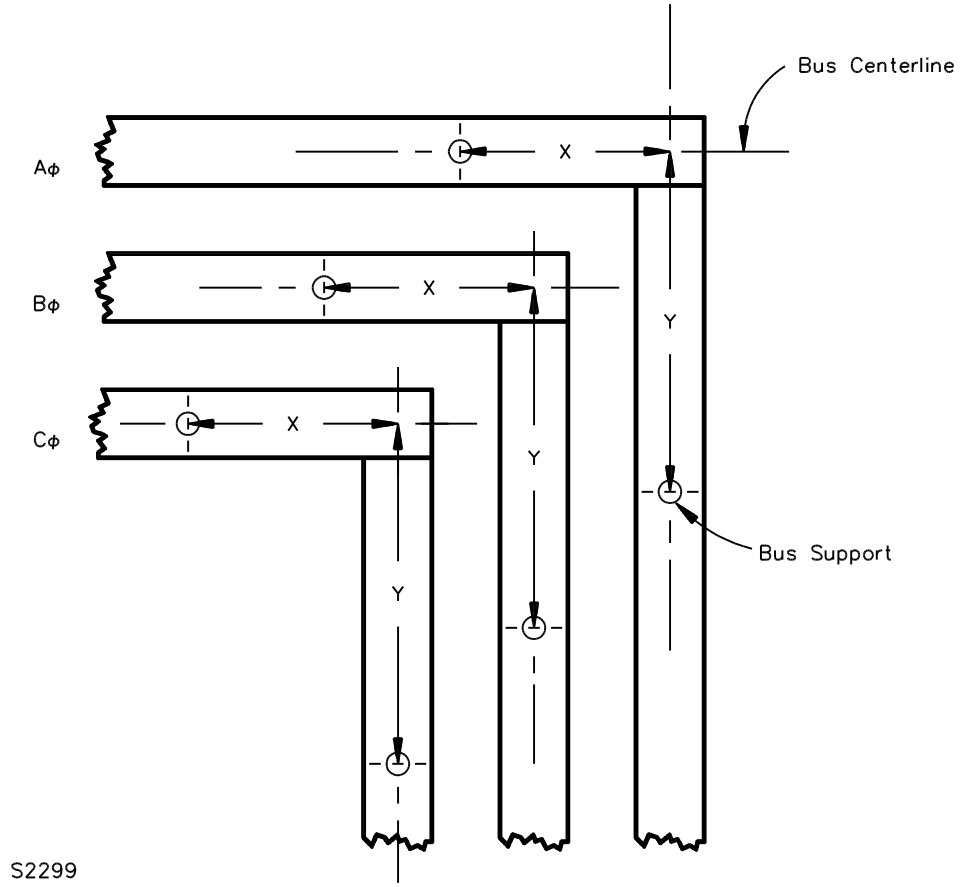
X_1X_1 – Two supports required at line terminal end except one support may be used for single bus bar 2 – 3 in (50.8 – 76.2 mm) wide with a short-circuit current rating of 50,000 A or less.

X_2 – One support required at connection of vertical to horizontal bus or as shown in Figure D3.4.

Note – For all other supports see Figure D3.2.

Figure D3.4

Distance between supports

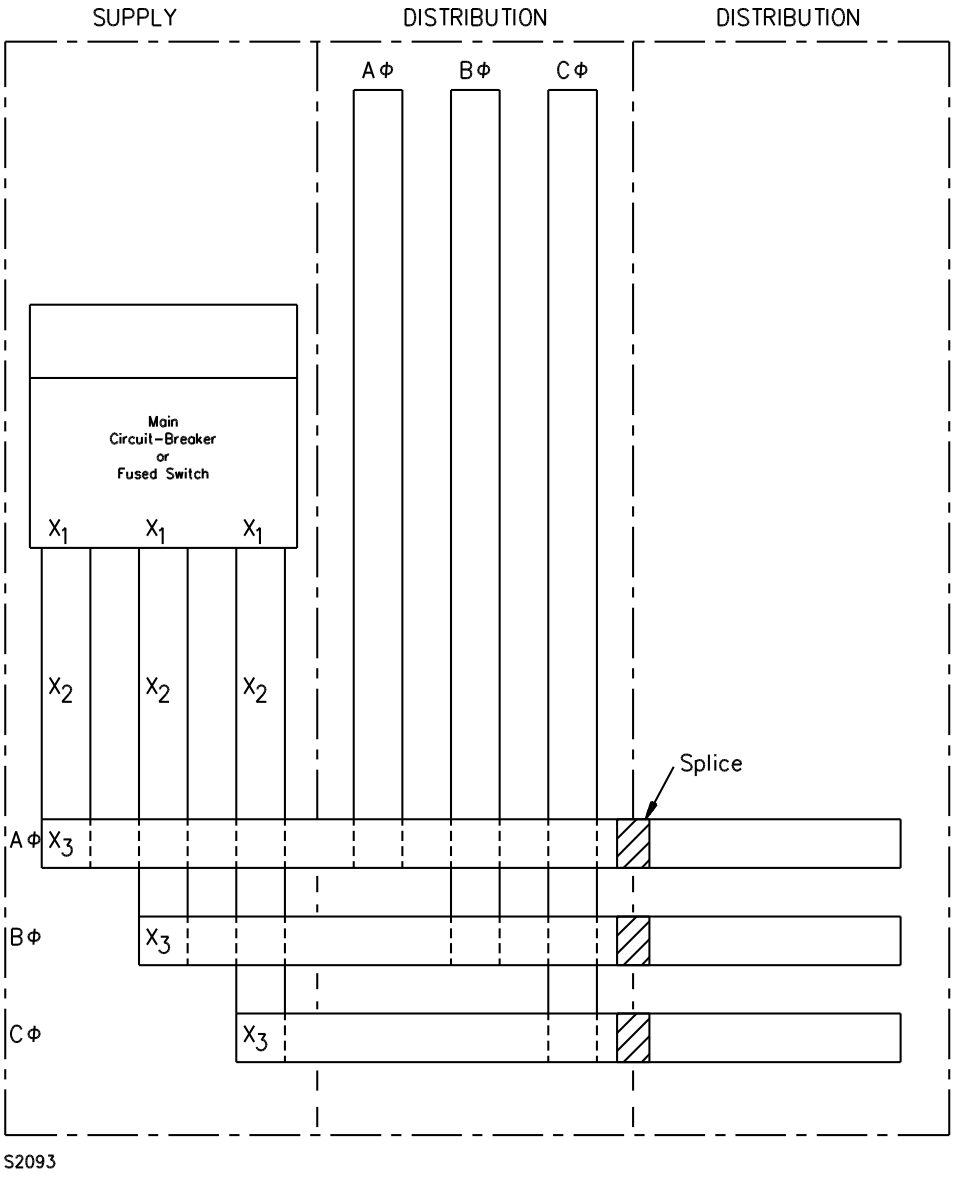


Distance X+Y equals maximum distance allowed between supports.

Distance X plus Y is maximum distance between supports as shown in Table D3.1.

Figure D3.5

Location of supports for edge-to-edge connection of bus bar with cables connected directly to main



In which:

X_1 – For the purposes of determining distances from Table D3.1, this point is considered a support.

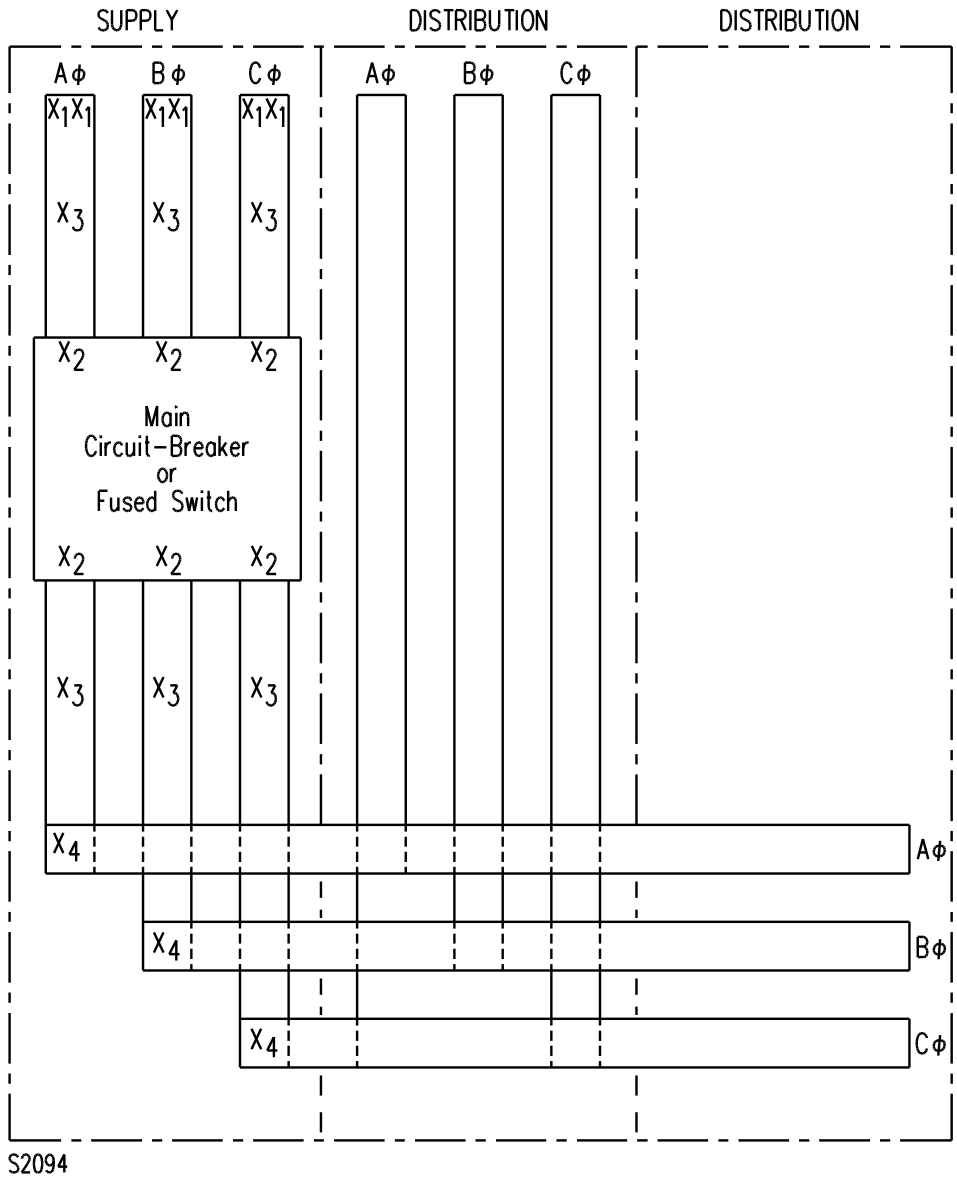
X_2 – One support required at intervals as specified in Table D3.1.

X_3 – Support at connection of vertical bus to horizontal or as shown in Figure D3.4.

Note – For all other supports see Figure D3.2.

Figure D3.6

Location of supports for right-angle connection of edge-to-edge bus bar with cables not connected directly to main



In which:

X_1X_1– Two supports required at line terminal and except only one support may be used for a single bus bar 2 – 3 in (50.8 – 76.2 mm) wide with a short-circuit current rating of 50 000 A or less.

X_2 – For the purposes of determining distances from Table D3.1, this point is considered a support.

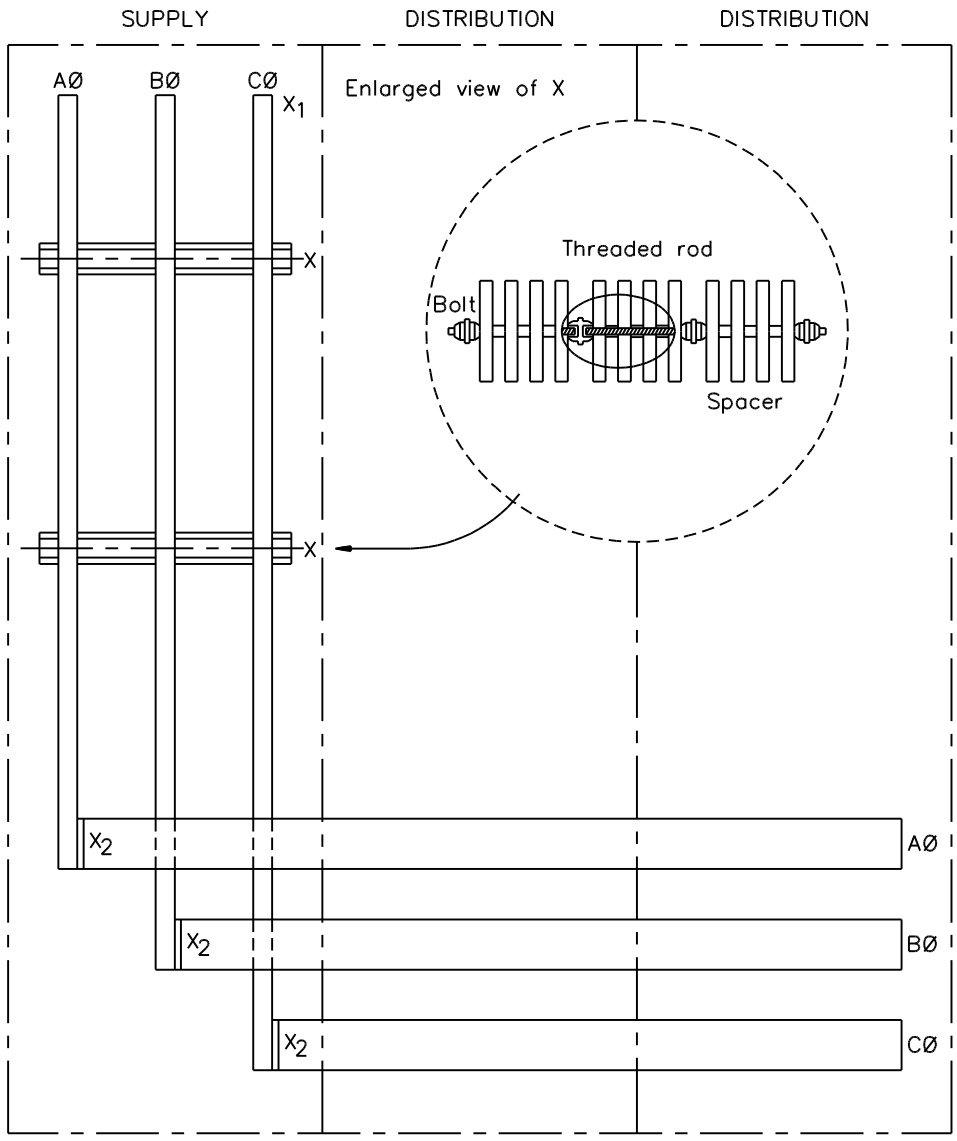
X_3 – One support required at intervals as specified in Table D3.1.

X_4 – One support required at connection of vertical to horizontal bus or as shown in Figure D3.4.

Note – For all other supports see Figure D3.2.

Figure D3.7

Location of supports and braces for face-to-face connection of bus bars



In which:

X_1– Line connection – support provided by transformer or busway stub connected to enclosure.

X – Mechanical bracing between bus bars, support located at intervals described in Table D3.1 starting at X_1. Bracing not required to be secured to enclosure.

X_2 – One support located not more than 48 in (1.2 m) from X_1. For supports along horizontal bus see Figure D3.2 and Figure D3.3. See D3.2.3 for spacing between bus bars at cross over.

Figure D3.8

Distances between edge-to-edge bus bars of opposite polarity

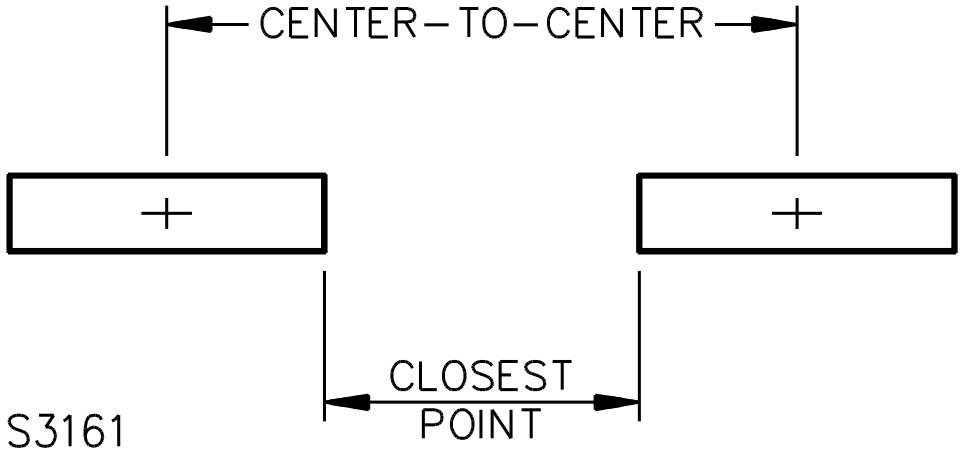


Figure D3.9

Distances between face-to-face bus bars of opposite polarity

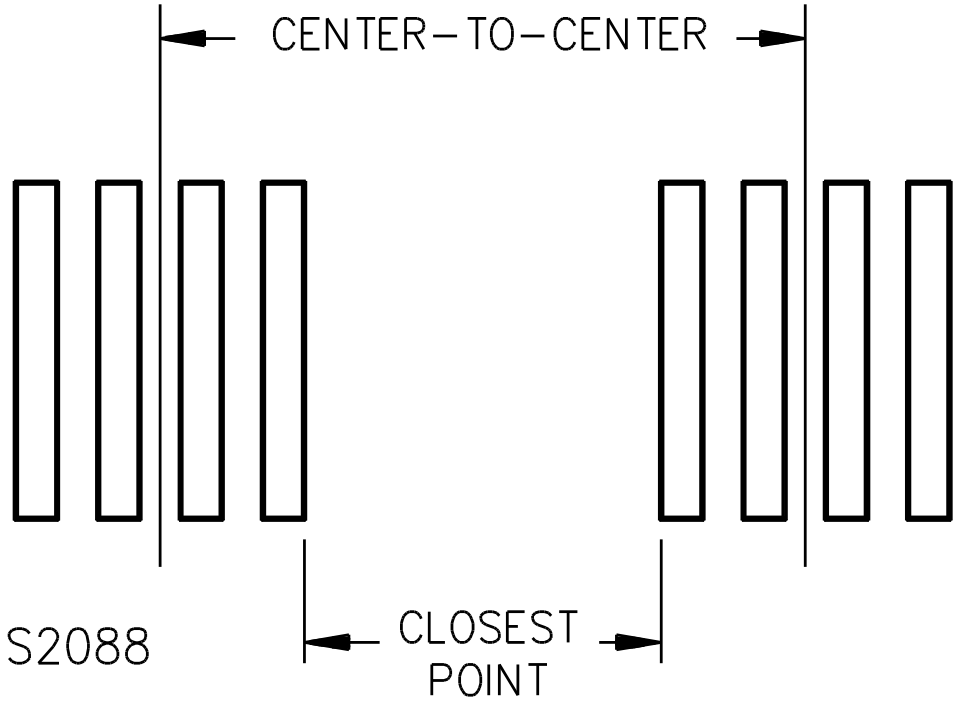


Figure D3.10

Steel channel bus bar support dimension

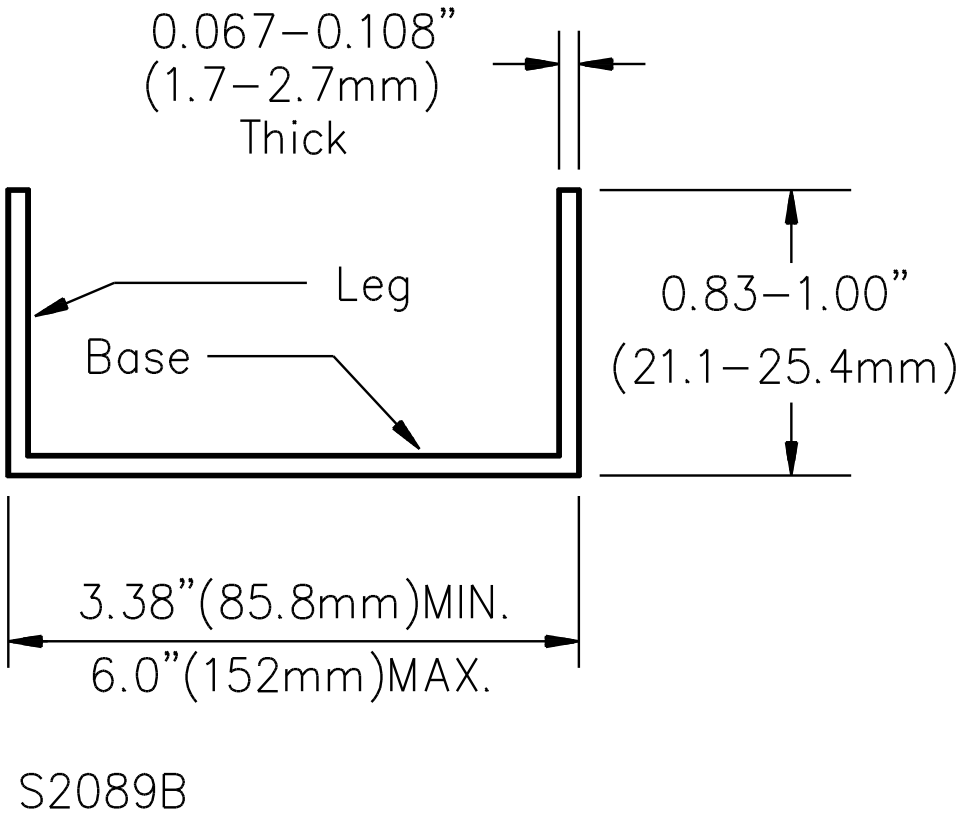


Figure D3.11

Bus bar support with standoff insulators mounted on leg of steel channel

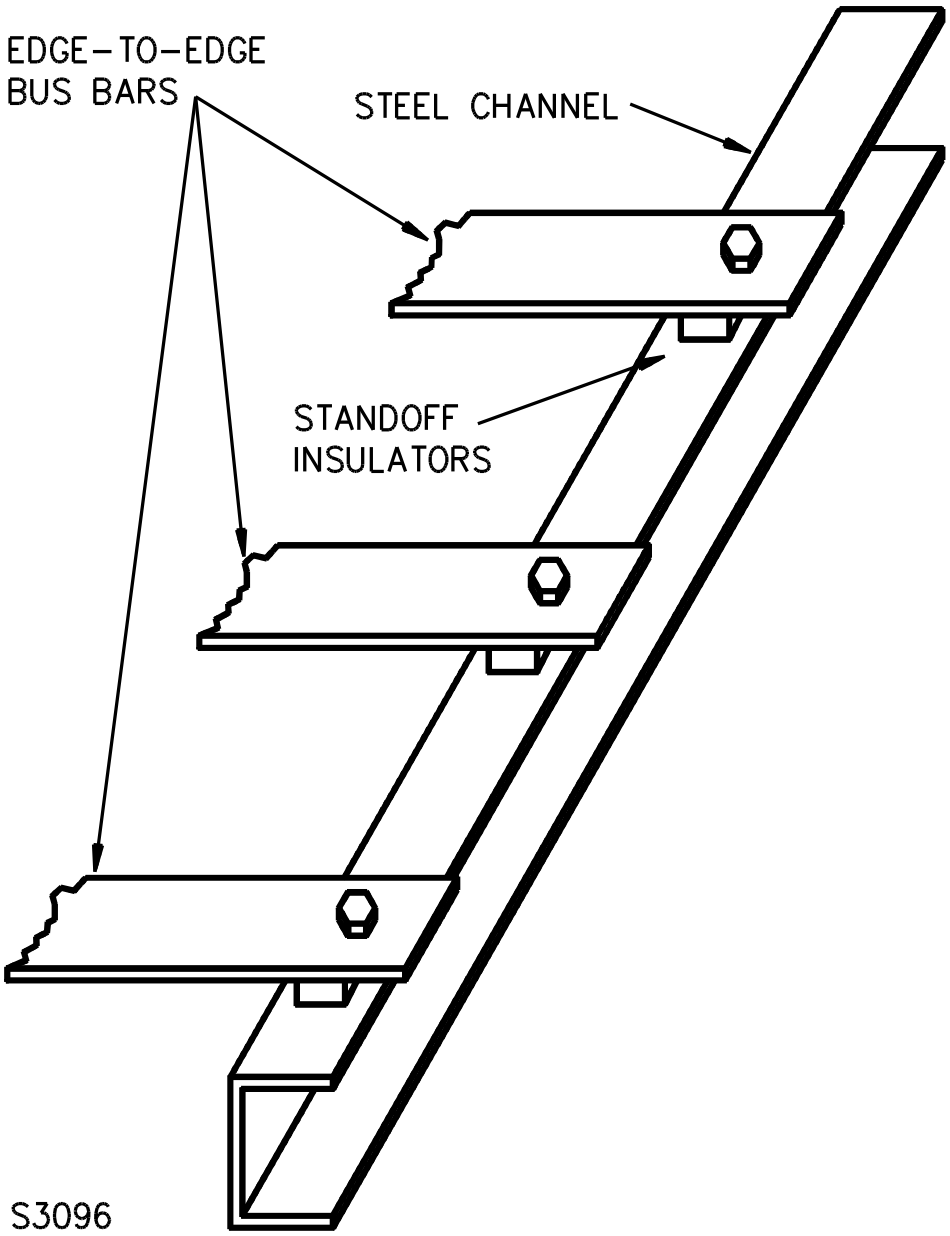
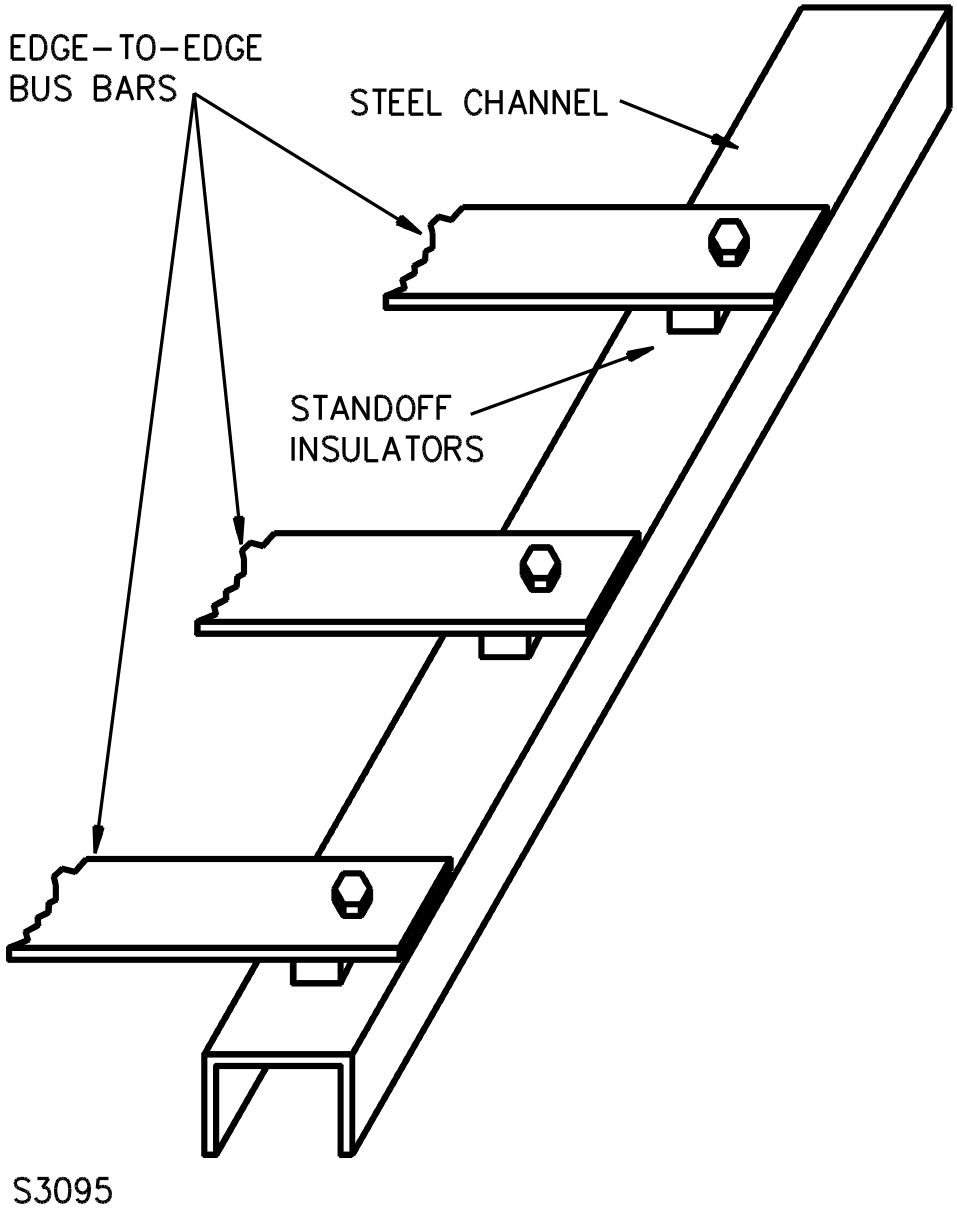


Figure D3.12

Bus bar support with standoff insulators mounted on base of steel channel



D3.1.5 Bus bar configurations shall be flat and rectangular.

Exception: An L-shaped bus bar may be used if:

a) considered as a face to face configuration or

b) the unsupported leg does not extend more than 2 in (50.8 mm) from the bus support.

D3.1.6 The number of bus bars shall not exceed four for each phase.

D3.1.7 Phase bus bars, including neutral bus bars, shall be arranged edge-to-edge or face-to-face as described in Table D3.1 and as shown in Figure D3.1 – Figure D3.9.

Exception: A neutral bus bar need not comply with this requirement if the spacing between the adjacent surface of the neutral bus bar and the nearest phase bus bar is:

a) at least 5-1/4 in (133 mm) or

b) 5 in (127 mm) if the short-circuit current rating of the bus bar assembly does not exceed 50 000A.

D3.1.8 Stacked bus bars shall not exceed a height of 1-3/4 in (44.5 mm) measured from the top of the standoff insulator or non-metallic channel base to the top of the highest bus bar.

Exception No. 1: At a splice bus or a joint, the height of stacked bus bars shall not exceed 2 in (50.8 mm).

Exception No. 2: The height may be greater than 1-3/4 in for constructions using L-shaped bus bars as specified in the Exception to D3.1.5.

D3.2 Spacings

D3.2.1 The spacing between adjacent edges of bus bars of opposite polarity, arranged or mounted edge-to-edge as shown in Figure D3.8, shall not be less than as described in Table D3.1. The center-to-center distance shall also be not less than as shown in Table D3.1. The distance between bolts to standoff insulators or non-metallic channels along the bus bar shall comply with the dimensions specified in Table D3.1. Bus bars to which terminal connectors are secured shall extend not more than 4 in (102 mm) from the center of the first bolt to a standoff insulator on a non-metallic channel.

D3.2.2 The center-to-center spacing between adjacent groups of bus bars of opposite polarity, arranged or mounted face-to-face as shown in Figure D3.9, shall not be less than as described in Table D3.1. The distance between closest points of opposite polarity shall also be not less than as shown in Table D3.1.

D3.2.3 The spacing between bus bars crossing at right angles as shown in Figure D3.2, Figure D3.3, Figure D3.5, Figure D3.6, and Figure D3.7 shall not be less than 1 in (25.4 mm).

D3.2.4 The spacing between live parts of bus bars mounted or arranged edge-to-edge and grounded dead metal shall not be less than 1-3/8 in (34.9 mm) in any direction. A barrier is to be disregarded when measuring this spacing.

Exception: The spacing between the flat face of an insulated neutral bus bar and grounded dead metal shall not be less than 1/2 in (12.7 mm) for a short-circuit current rating of 42 000 A or less.

D3.2.5 The spacing between live parts of bus bars mounted or arranged face-to-face and grounded dead metal, measured perpendicular to the face of the bus bar, shall not be less than 6 in (152 mm); and, measured perpendicular to the edge of the bus bar, shall not be less than 1-3/8 in (34.9 mm). A barrier is to be disregarded when measuring this spacing.

Exception No. 1: The spacing between the flat face of a neutral bus bar measured perpendicular to the face of the bus bar and grounded dead metal shall not be less than 2 in (50.8 mm).

Exception No. 2: The spacing to grounded metal may be 1-3/8 in minimum within 3 in (76.2 mm) of the bus bar support.

D3.3 Supports

D3.3.1 A standoff insulator support used for direct support of live parts shall be secured by a bolt of the type described in D3.3.3 to a steel channel having the dimensions shown in Figure D3.10. The bolt shall pass through a clearance hole in the steel channel and shall not thread into it. Typical constructions are shown in Figure D3.11 and Figure D3.12.

Exception: A non-metallic channel that is investigated in accordance with D4.1.1 – D4.3.1 may be used in place of the standoff insulator and steel channel.

D3.3.2 A bus bar shall be secured to a standoff insulator, a non-metallic channel, or a splice bus bar by a bolt of the type described in D3.3.3.

D3.3.3 A bolt used to secure a bus bar or standoff insulator shall be 3/8-16 steel or larger and shall be torqued to 20 pound-feet (27.1 N·m). A steel washer with an outside diameter of 1 in (25.4 mm) or larger and a maximum inside diameter of 9/16 in (14.3 mm) shall be located between the bolt head and the bus bar and also between the bolt head or nut and a steel or non-metallic channel. The washer shall be minimum 0.078-in (2.0-mm) thick. A bolt or threaded rod shall be SAE grade 5 minimum.

D3.3.4 The spacing and number of bus supports shall be in accordance with Figure D3.1 – Figure D3.7 as applicable.

D3.3.5 The line terminal brace shown in Figure D3.1 shall be secured to the line terminal bus bars by bolts of the type described in D3.3.3.

D4 Performance

D4.1 General

D4.1.1 A standoff insulator or non-metallic channel shall be subjected to the tests described in D4.2.1 and D4.3.1. Three samples shall be subjected to each test. The results are acceptable if the standoff insulator or non-metallic channel does not crack.

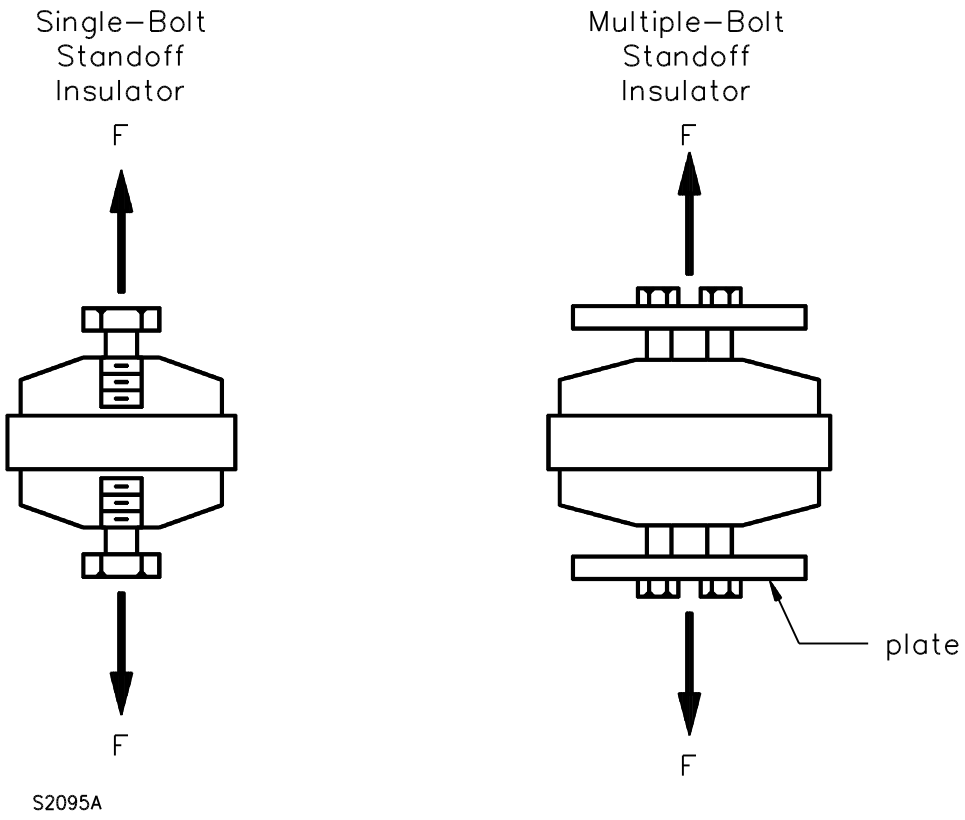
Exception: A standoff insulator or non-metallic channel molded from a plastic that has been previously found to comply with Annex G of UL 891, Standard for Dead-front Switchboards, is not required to be subjected to these tests.

D4.2 Tensile

D4.2.1 The bus bar support or representative samples shall be subjected to a minimum tensile force of 1850 pounds (8229 N) applied between the simulated enclosure supporting means and bus bar support along the centerline of the mounting bolts. See Figure D4.1 for typical constructions. The force is to be applied by machine parts moving apart at a rate of 10 in (254 mm) per minute.

Figure D4.1

Method of applying tensile force

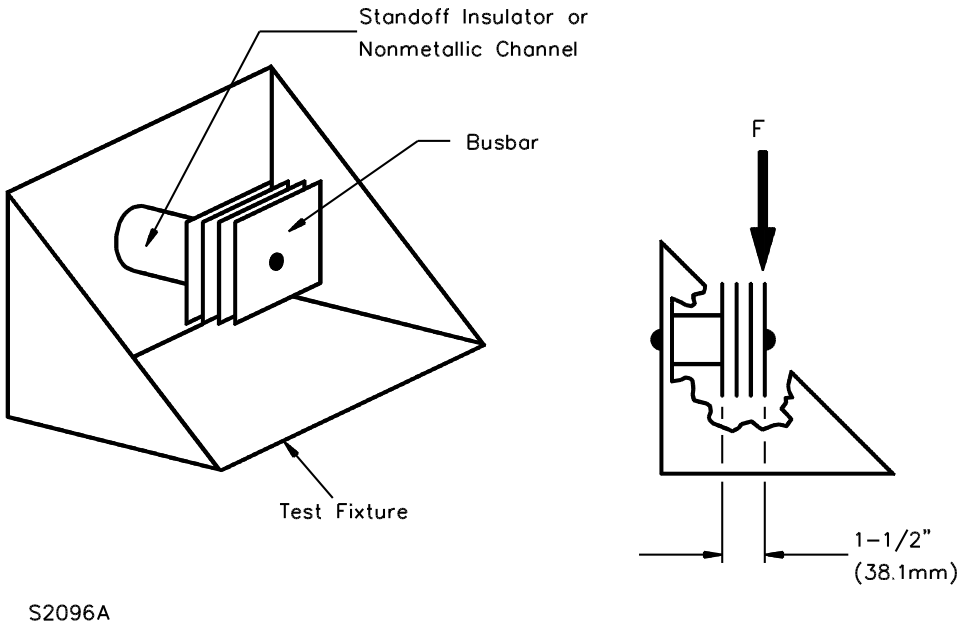


D4.3 Cantilever

D4.3.1 The standoff insulator or non-metallic channel or representative sample is to be mounted to a simulated enclosure steel plate and subjected to a minimum force of 675 pounds (3003 N), applied as specified and as shown in Figure D4.2. A 4-in (102-mm) lendth of 2 by 1/4-in (50.8 by 6.4-mm) copper bus bar is to be mounted to the support at a distance of 1-1/2 in (38.1 mm) from the standoff insulator or non-metallic channel. Single or multiple spacers not greater than 1 by 1 in (25.4 by 25.4 mm) are to be used. The force is to be applied perpendicular to the 2 by 1/4-in edge of the bus bar. The force is to be applied by parts of a machine moving apart at a rate of 10 in (254 mm) per minute.

Figure D4.2

Method of applying force in cantilever test

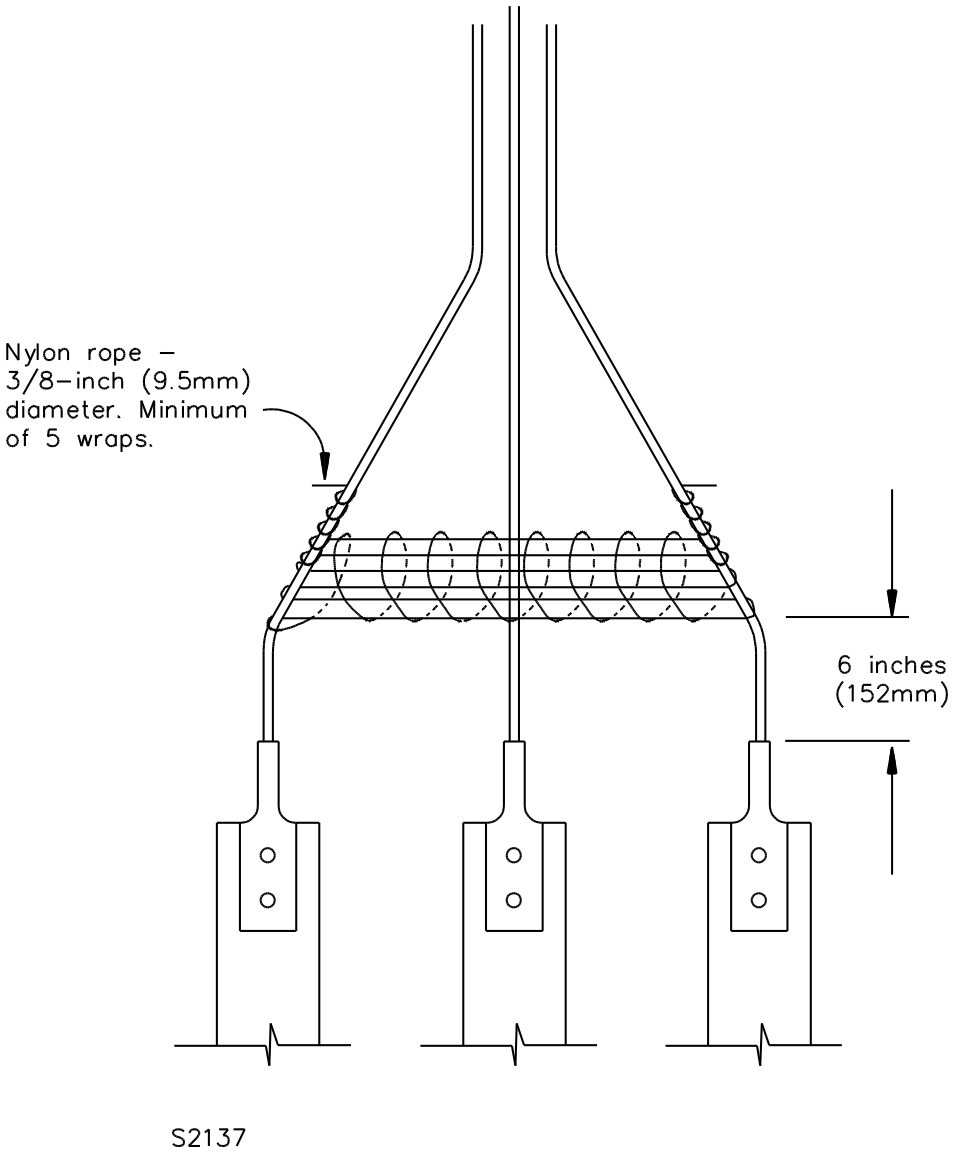


D5 Marking

D5.1 When provided with bus bars on the line side of the main, the industrial control panel shall be marked with the following or the equivalent: ″Wrap line cables together and, if provided, tap cables together with nominal 3/8-in (9.5-mm) nylon rope or rope having a minimum tensile strength of 2000 pounds (8896 N) at (1) 6 in (152 mm) and 12 in (305 mm) from the line terminals with five wraps and (2) every additional 6 in with five wraps or every 1 in (25.4 mm) with one wrap.″ This marking indicating the type of bracing to be added to cables between the point of entry into the enclosure or exit from the enclosure and the field wiring terminals shall be located adjacent to the incoming terminals or load terminals, or provided in the installation instructions. It is also recommended that a drawing as shown in Figure D5.1, or the equivalent, be provided with the industrial control panel.

Figure D5.1

Securement of cable



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