UL 508A

STANDARD FOR SAFETY

Industrial Control Panels

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

Second Edition, Dated December 20, 2013

Summary of Topics

This revision of UL 508A is issued to correct Table SB4.1 to remove the reference for Multiwire (power distribution) lug, which did not reach consensus during the proposal process.

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 December 2, 2011 and January 11, 2013.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

The following table lists the future effective dates with the corresponding reference.

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Future Effective Date	References
December 20, 2014	Entire Standard

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DECEMBER 20, 2013
(Title Page Reprinted: January 13, 2014)

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UL 508A

Standard for Industrial Control Panels

First Edition – April, 2001

Second Edition

December 20, 2013

This UL Standard for Safety consists of the Second Edition including revisions through January 13, 2014.

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 http://csds.ul.com.

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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 600 volts or less. This equipment is intended for installation in ordinary locations, in accordance with the National Electrical Code, ANSI/NFPA 70, where the ambient temperature does not exceed 40°C (104°F) maximum.

1.2 These requirements also cover industrial control panel enclosures and industrial control panels intended for flame safety supervision of combustible fuel type equipment, elevator control, crane or hoist control, service equipment use, marine use, air conditioning and refrigeration equipment, and for control of industrial machinery including metalworking machine tools, power press controls, and plastic injection molding machinery.

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 Industrial Control Equipment for Use in Hazardous (Classified) Locations, UL 698.

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.

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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 circuit breakers and busses for control of electric light and power circuits or equipment intended for field installation in dead-front switchboards are covered by 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, UL 60950.

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.

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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.

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 2.36.

2.5 BRANCH CIRCUIT PROTECTIVE DEVICE – A fuse or circuit breaker that has been evaluated to a safety standard for providing overcurrent protection. See 2.22 and 2.29.

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.

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2.17 DUTY, INTERMITTENT – Operation for alternate intervals of (1) load and no load; or (2) load and rest; or (3) 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 ampere 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.

2.29 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 circut protection.

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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 42.4 volts (dc or peak) 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 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 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.

2.37 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.

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

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

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

2.41 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.

2.42 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 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.

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

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2.45 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.

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

2.47 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. See SA2.1 – SA2.5.

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

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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 Figures 6.1, 6.2, and 6.3 shall apply.

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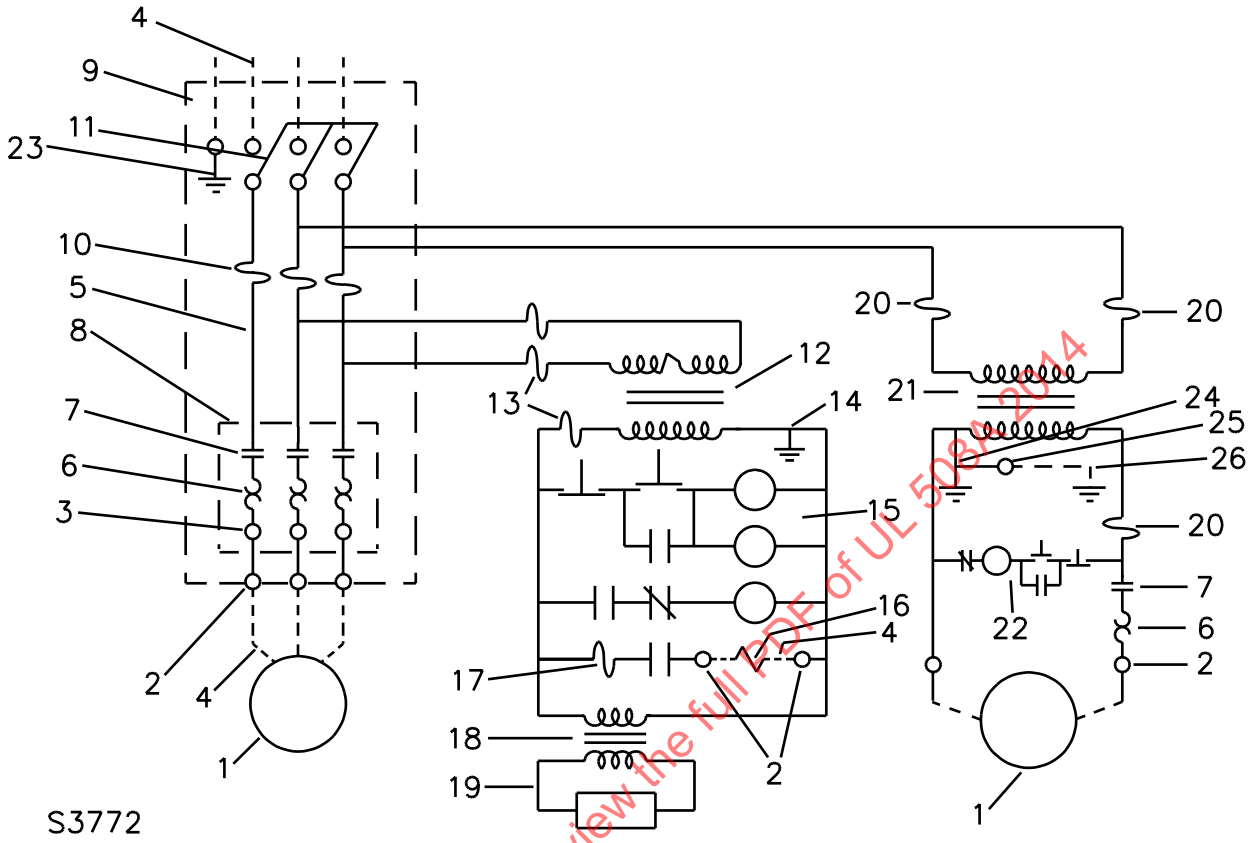
Figure 6.1
Description of terminology



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)

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Figure 6.2
Description of control circuits and power circuits

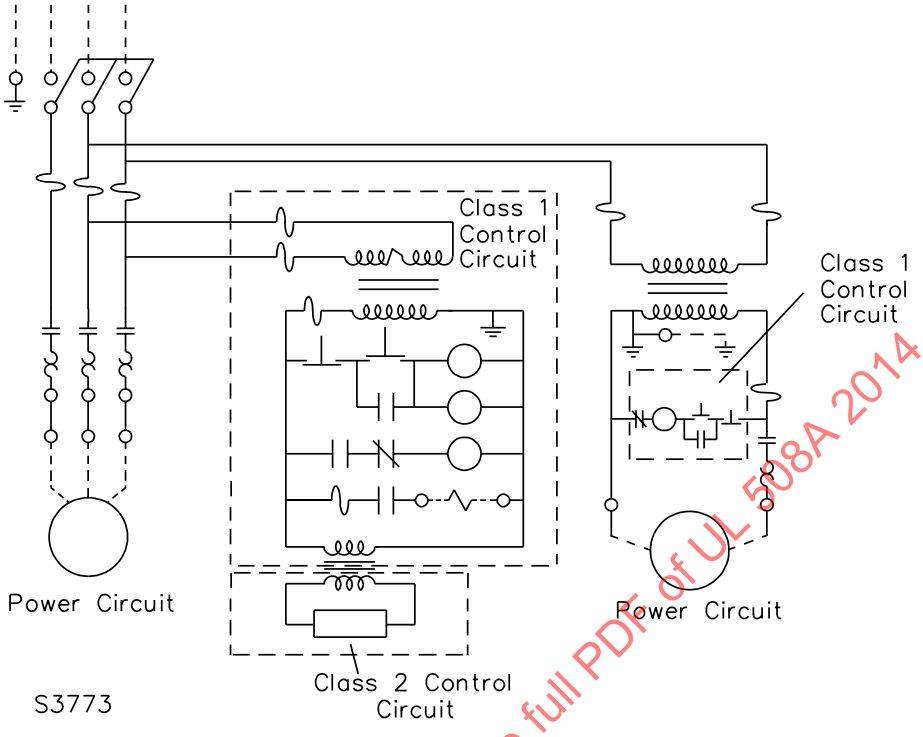
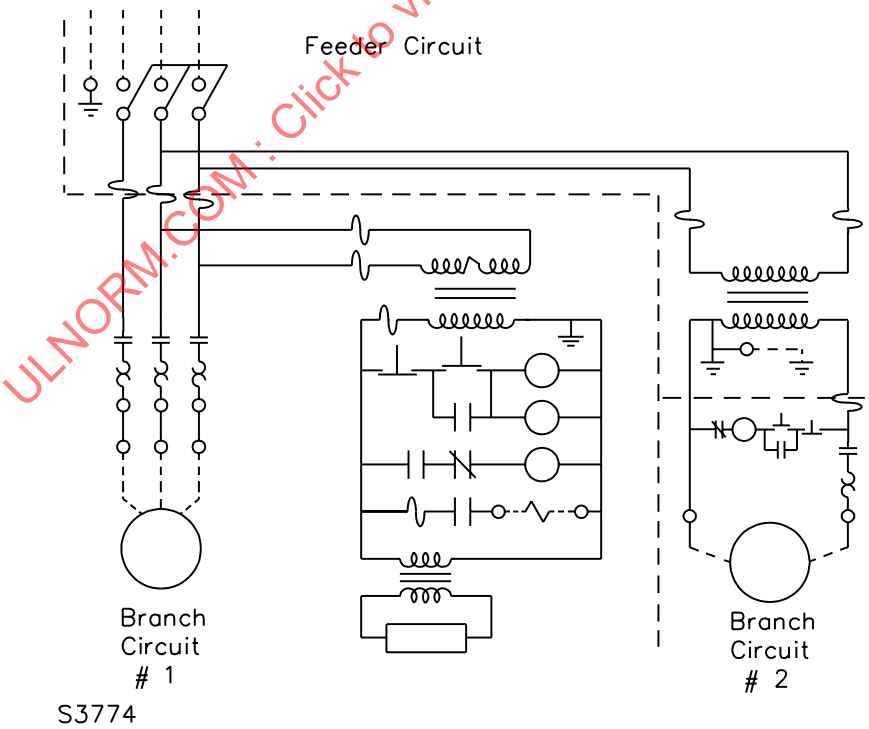


Figure 6.3
Description of branch circuits and feeder circuits



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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;

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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), 29.3.6, 29.3.8, and 36.2.2, spacings at and within a component or device shall be investigated based on the requirements for that component or device.

10.2 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 maintained as shown in Table 10.1 and Table 10.2.

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.

Table 10.1 Continued on Next Page

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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

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.

[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 10.2
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 – 600	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.

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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.

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.

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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.

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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)
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.

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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.

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 – 29.3.8.

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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.

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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 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.

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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 29.3.13.

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 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.

Exception No. 3: Insulated conductors that are not manufactured in this color, such as SIS, shall be identified at each termination point by a green marking, such as tape wrapped around the conductor.

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 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 that are not manufactured in this color, such as SIS, shall be identified at each termination point by a white marking, such as tape wrapped around the conductor.

Exception No. 4: 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

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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, UL 50; 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;

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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, UL 50, 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)	Required construction (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.

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19.3 Openings provided in enclosures for mounting components shall be covered with components intended for such mounting. For an enclosure type specified in column 1 of Table 19.2, 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 column 2 of Table 19.2.

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, UL 50, corresponding to the required enclosure type rating.

Table 19.2
Openings for components in enclosures with environmental rating other than Type 1

Enclosure type (Column 1)	Openings are able to be closed by equipment marked (Column 2)
2[a]	2, 3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, 13, ″Wet Location″, or ″Raintight″
3	3, 3S, 3SX, 3X, 4, 4X, 6, 6P
3R[b]	3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 6, 6P, ″Wet Location,″ or ″Raintight″
3RX	3RX, 3SX, 3X, 4X
3S[c]	3, 3S, 3SX, 3X, 4, 4X, 6, 6P
3SX[c]	3SX, 3X, 4X
3X	3SX, 3X, 4X
4	4, 4X, 6, 6P
4X	4X
5	3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, 13, ″Wet Location,″ or ″Raintight″
6	6, 6P
6P	6P
12, 12K	12, 12K, 13
13	13

[a] Type 1 components, ventilation openings, or observation windows are able to be installed when their profile outside the enclosure is completely protected by the drip shield from water dripping vertically downward from above.

[b] Components marked ″Weatherproof″ or ″Rainproof″ are able to be installed below all other live parts within the enclosure.

[c] Components with external operating mechanisms shall be Type 3S or 3SX for use on a Type 3S enclosure, or Type 3SX for use on a Type 3SX enclosure.

19.4 An enclosure as specified in column 1 of Table 19.3, provided with conduit fittings that do not comply with Table 19.1 or components that do not comply with Table 19.2 as specified in column 2 of Table 19.3 shall be marked as in 53.1 with an environmental rating:

a) As specified in column 3 of Table 19.3; or

b) As a Type 1 enclosure.

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Table 19.3
Alternate enclosure ratings

Enclosure type (including components and fittings that comply with Tables 19.1/19.2) (Column 1)	Component/fittings ratings that do not comply with Tables 19.1/19.2 (Column 2)	Resulting enclosure rating (Column 3)
3, 3RX, 3S, 3SX, 3X,4, 4X, 6, 6P	3R, ″Wet Location″, ″Raintight″, ″Weatherproof″[c], ″Rainproof″[c]	3R[a,b,c]
4X	3RX, 3SX, 3X	3RX[a, b]
4, 4X, 6, 6P	3, 3S	3[b]
4X	3X, 3SX	3X[b]
6, 6P	4, 4X	4
6P	6	6
13	12, 12K	12
12, 12K, 13	3, 3S, 4, 4X, 5, 6, 6P, ″Wet Location″, ″Raintight″	5[b]

[a] When a drain is added.

[b] When provision is made for locking the door (such as loop for padlock, key-locking type handle or latch) or tools are required to open the enclosure.

[c] Components marked ″Weatherproof″ or ″Rainproof″ shall be installed below all other live parts within the enclosure. Openings for conduit or conduit fittings shall comply with note a, b, or c in Table 19.1 for type 3R enclosures.

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.

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 openeing to uninsulated live parts or moving parts.

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

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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) x (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) x (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 6.3, Sections 15, 15A, 15B, and Sections 30, 31, 38, 39 of the Standard for Enclosures for Electrical Equipment, UL 50, 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.

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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 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.

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).

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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.

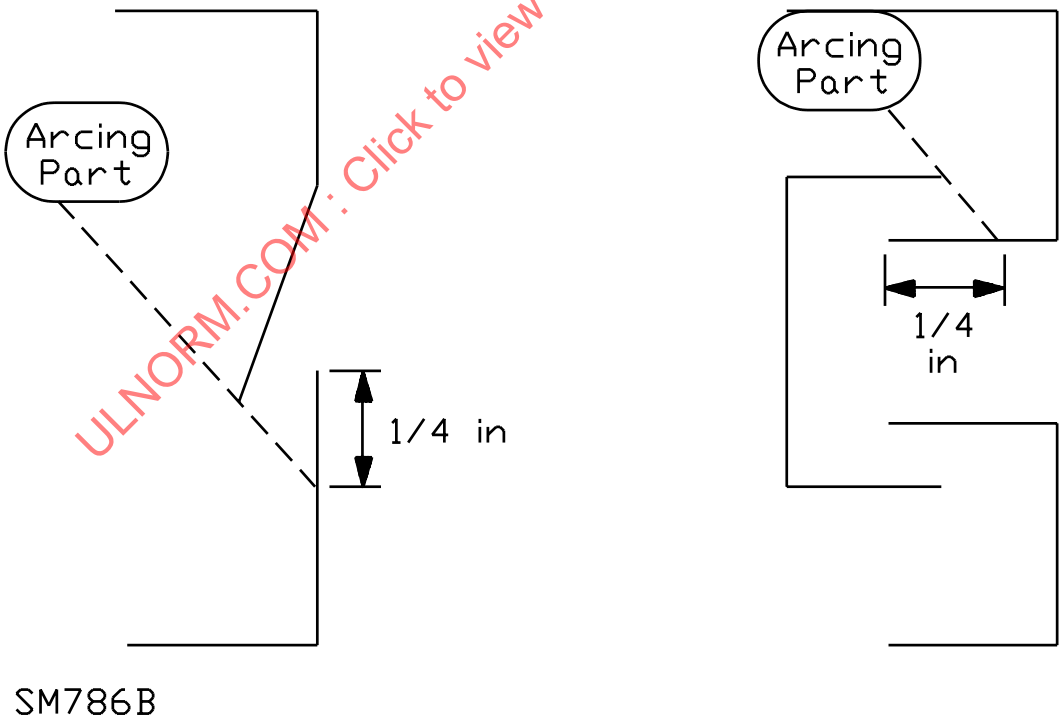
22.2 A barrier shall be of such dimension and so located that any straight line drawn from any arcing part past the edge of the barriers intersects a point in the ventilation opening plane that is at least 0.25 inch (6.35 mm) outside the edge of the ventilation opening. A barrier shall be secured in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



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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 6.3, Sections 9, 14, 15, 15A, 15B, and Sections 30 – 40 and 43 of the Standard for Enclosures for Electrical Equipment, UL 50, 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.

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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 AWG or MCM (mm^2)		Minimum bending space, terminal to wall, inches (mm)							
		Wires per terminal[a]							
		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)
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.

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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 and a heater that complies with 26.4.1 are able to be supplied from the isolated secondary of a control transformer 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 Overheating Protection for Motors, UL 2111, or 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.

UL 1004-3 will replace Part III of UL 2111 effective September 15, 2014

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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.

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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: 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.

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.

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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.

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.

28.2 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

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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, Subject 1953, for use in branch or feeder circuits; or

b) 28.2.1.

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
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

Table 28.1 Continued on Next Page

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Table 28.1 Continued

Wire size		60°C (140°F)		75°C (167°F)	
AWG	(mm^2)	Copper	Aluminum	Copper	Aluminum
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 equipment 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 amperes 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.

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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).

28.4 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.

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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,″

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, 28.5.8, and 28.5.8. A multi-pin connector attached to the cable assembly shall comply with the requirements for receptacles in 28.6.

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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
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.

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28.5.8 In reference to 28.5.8, 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.

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.

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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 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.

29.2 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 29.3.11;

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 29.3.11.

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.

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 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 29.3.9 and 29.3.10 and sized as specified in 29.6.2.

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

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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 – 29.3.6.

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;

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e) Wire-binding screw specified in 29.3.3; or

f) Open-type eyelet specified in 29.3.5.

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 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.

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

29.3.8 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.

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

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

29.3.11 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.

29.3.12 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.

29.3.13 An industrial control panel constructed specifically for connection to a 3-phase, 4-wire delta supply, such as shown in Figure 75.7 and 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.

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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.

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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 ampere 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).

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 ampere 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.

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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 disconnect switch with provisions for a fuse rated greater than 600A shall comply with 30.1.4 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. For three-phase motors, the locked rotor current is as in Table 50.3.

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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.

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 30.1.4 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.

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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, 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 added in ″the Standard for″ herethe 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.

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.

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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.

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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 ampere rating corresponding to the motor horsepower rating from Table 50.1 or Table 50.2;

2) Determining the maximum percentage of full-load amperes 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. 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 set for the motor full load current rating as determined from 31.3.1. The cautionary markings in 55.7 shall be provided.

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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 amperes

Type of Branch Circuit Protective Device	Ampere Rating	Nominal rating of motor branch circuit protective device, percent of full load amperes	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.

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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, 600 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

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c) When all power circuit devices included on the load side of the branch circuit protection are 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, 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 ampere 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 ampere 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.

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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 Resistance heating element loads shall be provided with branch circuit protection sized:

a) Not less than 125 percent of the heater load current;

b) Not larger than 60 amperes; and

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

Exception No. 1: Resistance heating element loads contained in a water heater or steam boiler having an ASME rated and stamped vessel are not required to comply with this requirement. See 31.6.2.

Exception No. 2: 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 (a) and (c) only.

Exception No. 3: Branch circuit protective devices rated more than 60 amperes are able to be used within the industrial control panel when the field wiring diagram specifies additional branch circuit protective devices rated at not more than 60 amperes are to be provided in the field. See 60.1.

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.

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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.

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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:

a) The rating of the largest branch circuit protective device in the circuit plus the full-load currents of all other motors or other loads in the group; or

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

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 Power Conversion Equipment, UL 508C.

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.

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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 ampere rating not less than the sum of the ampere ratings of loads controlled with horsepower ratings converted to a full-load ampere rating in accordance with Tables 50.1 and 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

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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:

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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 amperes 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 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.

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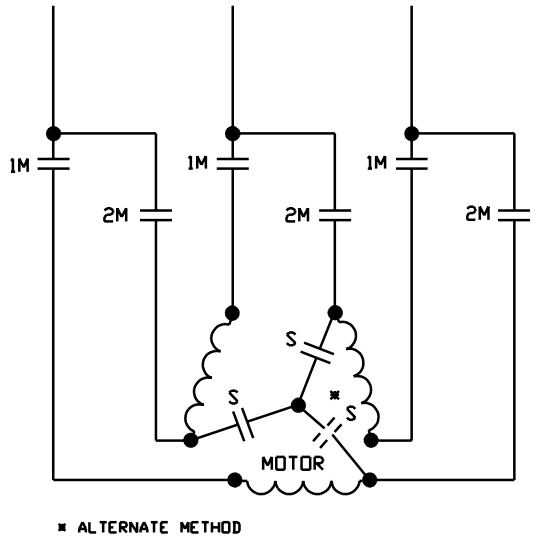
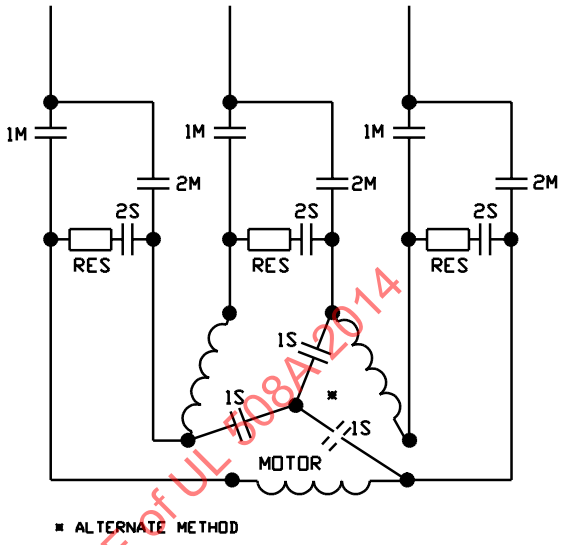
Figure 33.1
Contactor sequencing

OPEN-CIRCUIT TRANSITION



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

CLOSED-CIRCUIT TRANSITION



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	

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Table 33.2
Contactor sizing for wye-delta controller

Contactor designation	Required contactor ampere 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			
	M1 and M2	S	60 Hz	60 Hz	50 Hz	60 Hz
			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.

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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 Power Conversion Equipment, UL 508C. 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.

34.2 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.

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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.

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.

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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

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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.

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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.

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.

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36.2 Resistors

36.2.1 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.

36.2.2 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.

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

36.2.4 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.

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 Surge control devices

36.3.1 A metal-oxide varistor (MOV) shall comply with the requirements in the Standard for Surge Protective Devices, UL 1449.

36.3.2 A surge arrester of the metal-oxide type shall comply with ANSI/IEEE C62.11-1993, Standard for Metal Oxide Surge Arresters for AC Power Circuits. All other types of surge arresters shall comply with IEEE C62.1-1994, Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits.

36.3.3 The rated voltage of the MOV or surge arrester shall not be less than the rated circuit voltage.

36.3.4 Where provided, a surge arrester shall be connected to each ungrounded conductor. The conductors used to connect the surge arrester 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 surge arrester shall not be smaller than 14 AWG (2.1 mm^2).

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36.3.5 A surge arrestor or a transient voltage surge suppressor 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. A surge arrestor or transient voltage surge suppressor marked for use on a delta system, such as ″600V delta″, can be used on either a wye or a delta system.

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.

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
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

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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.

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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)
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.
[b] These sizes of conductors are only for connection of control circuits for electronic programmable input/output and static control (having no moving parts).

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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.

40.2 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.

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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.

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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 and 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

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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.

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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 the Standard for Power Units Other Than Class 2, UL 1012, or the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1.

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.

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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, 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 ampere 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 Power Conversion Equipment, UL 508C, 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 and Table 38.1, based on the secondary fuse rating or the rated current of the power supply secondary.

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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 Vac rms (42.4 Vdc or peak).

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.

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Table 43.1
Overcurrent protection for a low-voltage limited energy circuit

Open-circuit secondary voltage, volts (peak)	Maximum overcurrent device, amperes
0 – 20	5
20.1 – 42.4	100/V[a]
[a] 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 A limited energy circuit for information technology equipment shall comply with the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1.

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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, 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 Special-Use Switches, UL 1054, or 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 for Household and Similar Use, 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.

UL 1054 will be withdrawn on June 23, 2015

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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 ampere 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

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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.

[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

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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.

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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 Signal Appliances, 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.

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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

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47 Miscellaneous Devices

47.1 Surge control devices

47.1.1 A transient voltage surge suppressor, such as a metal-oxide varistor (MOV), shall comply with the Standard for Surge Protective Devices, UL 1449.

47.1.2 An electromagnetic interference filter, such as an EMI, RFI, or line filter, shall comply with the Standard for Electromagnetic Interference Filters, UL 1283.

47.1.3 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.

47.1.4 A capacitor, an axial lead diode, a transient voltage surge suppressor, and an electromagnetic interference filter shall have a rated voltage not less than the rated circuit voltage. An electromagnetic interference filter shall 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.

47.2 Resistors

47.2.1 A resistor, including a potentiometer or thumbwheel, shall comply with 36.2.1 – 36.2.3.

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).

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 amperes, ampere 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 ampere rating of the panel shall, at a minimum, include the sum of the ampere ratings of all loads that are able to be operated simultaneously plus the primary ampere rating of all control transformers connected to the input voltage.

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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 FLA 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.

Table 50.1
Full-load motor-running currents 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

Table 50.1 Continued on Next Page

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Table 50.1 Continued

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
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 motor-running currents 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	–	–
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

Table 50.2 Continued on Next Page

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Table 50.2 Continued

Horsepower	90 volts	110 – 120 volts	180 volts	220 – 240 volts	500 volts	550 – 600 volts
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)

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
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
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.

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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 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; and

b) ″Impedance protected″ or ″Z.P.″ for an impedance 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) 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; and

d) Factory identification as specified in 52.5.

e) Enclosure Type rating (for enclosed panels only) as specified in 53.1.

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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, total FLA, largest motor FLA, phase, frequency, field wiring diagram, short circuit current rating	a or b	f
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	–
	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

Table 52.1 Continued on Next Page

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Table 52.1 Continued

Paragraph	General description	Location categories (see notes)	
		Enclosed	Open
55.7	Self-protected combination motor controller, including manual type	a, b, or c	c or d
	Fuseholders		
56.1	Fuse replacement marking	b or c	c or d
	Switches		
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
	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.

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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.

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.

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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			
AWG or kcmil	(mm^2)	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	
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.

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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:

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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

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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 Cautionary Markings

55.1 Cautionary markings shall be located on a part that is not removable without impairing the operation or appearance of the equipment.

55.2 A cautionary 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 cautionary 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″ and the following or equivalent: ″Risk of Electric Shock – More than one disconnect switch may be required to de-energize the equipment before servicing.″

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.″

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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.″

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 overload relay having replaceable current elements shall have the overload relay element selection chart or heater table provided with the industrial control panel.

Exception: An industrial control panel provided only with adjustable type overload relays is not required to comply with this requirement.

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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.

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.

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. 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.

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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 in 6.3, Section 7, 8.3, 8.4, 8.5, Section 14, Sections 15, 15A, and 15B, performance requirements in Sections 30 – 43, and marking requirements in 49.1 – 49.6 applicable to the enclosure environmental Type(s) in the Standard for Enclosures for Electrical Equipment, UL 50.

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 requirements in 6.3, 8.3, 8.4, 8.5, Section 14, Sections 15, 15A, and 15B, performance requirements in Sections 28 – 40 and 43 – 46, and marking requirements in 49.1 – 49.6 applicable to the enclosure environmental Type(s) in the Standard for Enclosures for Electrical Equipment, UL 50.

c) A Type 3RX, 3SX, and 3X enclosure shall additionally comply with the corrosion resistance test in the Standard for Enclosures for Electrical Equipment, UL 50.

62.4 In addition to complying with 62.2 and 62.3, a Type 4 or 4X enclosure or compartment having ventilation openings shall be subjected to the indoor Circulating Dust Test, Section 8.4.2, and the Rod Entry Test, Section 8.14, 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 or 4X rating.

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 Tables 63.1 and 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, UL 50, is not required to comply with this requirement at points other than where a wiring system is to be connected.

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63.1.3 Tables 63.1 and 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 Tables 63.1 and 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 Tables 63.1 and 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.

Table 63.1 Continued on Next Page

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Table 63.1 Continued

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)
[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)		
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.

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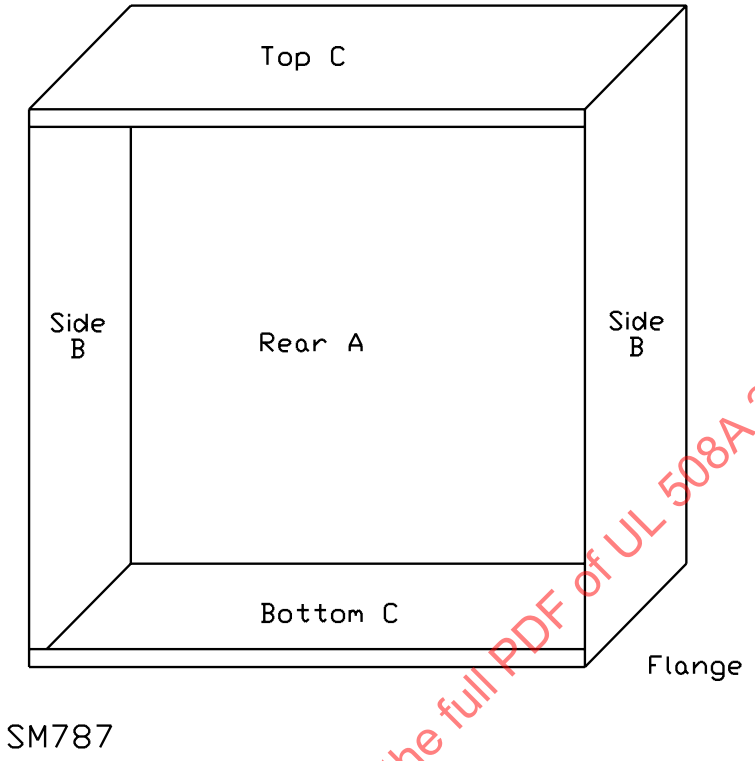
Figure 63.1
Supported and unsupported enclosure surfaces



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 Tables 63.1 and 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.

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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;

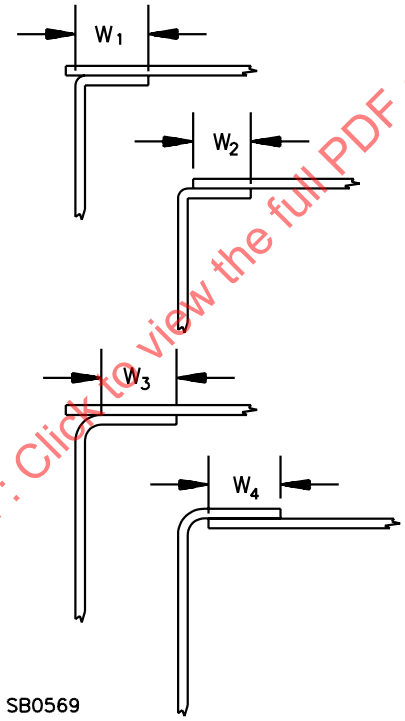
b) Metal surfaces overlapping adjacent surfaces or supporting frame;

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 Tables 63.1 and 63.2. The inclusion of a single support does not constitute a supporting frame with regard to Tables 63.1 and 63.2.

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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 Tables 63.1 or 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.

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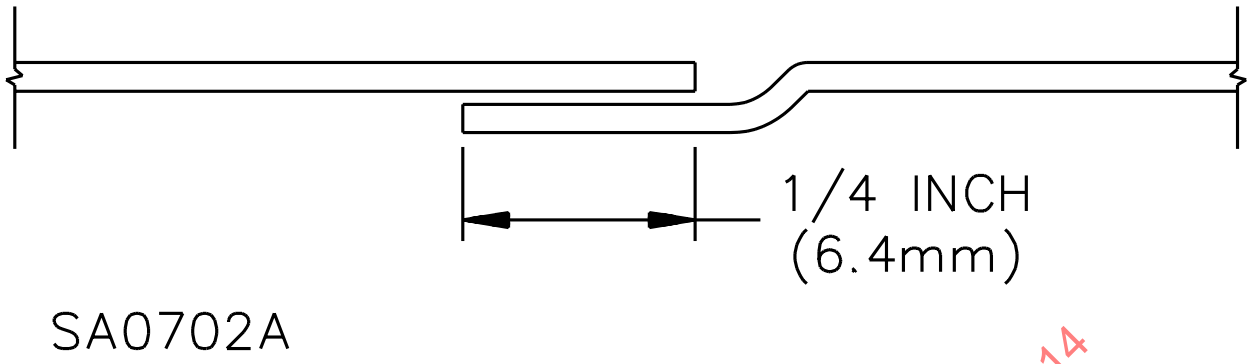
Figure 63.3
Rabbet



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, UL 50.

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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.

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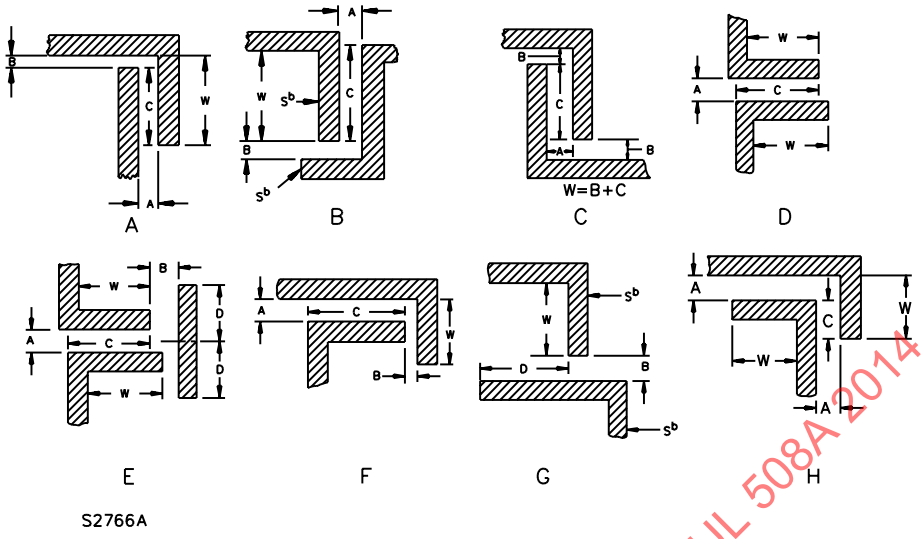
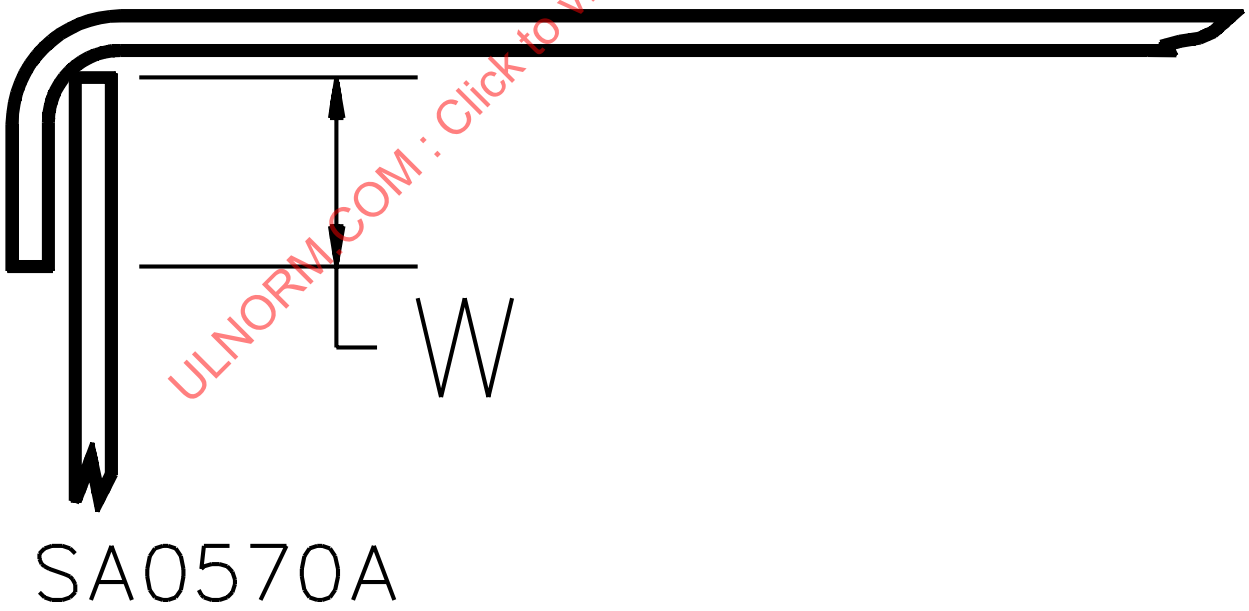
Figure 63.4
Flanged cover or door constructions[a]



[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



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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.″

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.

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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 A door of an enclosure that gives access to uninsulated live parts operating at 50 volts rms ac or 60V dc or more shall be interlocked with the disconnecting means such that none of the doors can be opened unless the power is disconnected.

Exception: A disconnecting means for maintenance lighting circuits or for power supply circuits to control devices with memory requiring power at all times are not required to be interlocked with the enclosure doors. The cautionary marking in 55.4 shall be provided.

66.1.3 The interlocking means required by 66.1.2 shall be provided with all the following:

a) Means to defeat the interlock without removing power and which requires the use of a tool to operate;

b) Means to prevent restoring power while the enclosure doors are open unless a defeat mechanism is operated; and

c) Reactivated automatically when all the doors are closed.

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.

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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.

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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.

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, and is rated for the voltage involved.

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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.

66.5.2 All conductors shall be identified at each termination by letter(s) or number(s) corresponding with the wiring diagrams provided with the industrial control panel.

66.5.3 The following color coding shall be used throughout the panel:

a) Black – all ungrounded power circuit conductors regardless of voltage; and

b) White or gray or three continuous white stripes on other than green, blue, orange or yellow – grounded ac current-carrying power circuit conductor regardless of voltage.

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.

66.5.4 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.

66.5.5 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.

66.5.6 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 ampere 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.

66.5.7 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 66.5.4 and Table 28.1.

66.5.8 Conductors and cable shall be run without splices from terminal to terminal.

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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.

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.

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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, 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 15: Class T Fuses, UL 248-15, the Standard for Low-Voltage Fuses – Part 4: Class CC Fuses, UL 248-4, or the Outline of Investigation for Low-Voltage Fuses – Part 17: Class CF Fuses, UL 248-17. 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 on the sum of:

a) The largest ampere rating of branch circuit protective devices in the panel;

b) 125 percent of all heater loads;

c) 125 percent of the largest motor load; and

d) The full-load currents of all remaining motors and other loads that are simultaneously operable.

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 66.5.6, 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 66.2 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.

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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 nontime-delay fuse or inverse time circuit breaker, amperes	Time delay or dual element fuse, amperes
AWG	(mm^2)		
14	(2.1)	60	30
12	(3.3)	80	40
10	(5.3)	100	50
8	(8.4)	150	80
6	(13.3)	200	100
4	(21.2)	250	125
3	(26.7)	300	150
2	(33.6)	350	175
1	(42.4)	400	200
1/0	(53.6)	500	250
2/0	(67.4)	600	300
3/0	(85.0)	700	350
4/0	(107.2)	800	400

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.

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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 The following color coding shall be employed throughout the panel:

a) Black – all ungrounded control circuit conductors operating at the supply voltage.

b) Red – ungrounded ac control circuits operating at a voltage less than the supply voltage.

c) Blue – ungrounded dc control circuits.

d) Yellow or orange – ungrounded control circuits or other wiring, such as for cabinet lighting, that remain energized when the main disconnect is in the ″off″ position.

e) White or gray or three white stripes on other than green, blue, orange or yellow – grounded ac current-carrying control circuit conductor regardless of voltage.

f) White with blue stripe – grounded dc current-carrying control circuit conductor.

g) White with yellow stripe or white with orange stripe – grounded ac control circuit current-carrying conductor that remains energized when main disconnect switch is in the ″off″ position.

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.

66.9.2 Control circuit conductors shall not be smaller than 18 AWG (0.82 mm^2).

Exception: Control circuit conductors for programmable input/output and static control wiring are able to be sized 18 – 30 AWG (0.82 – 0.05 mm^2).

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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 The emergency stop button shall have an actuator that is a mushroom or palm type, and of the self-latching type.

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 ampere rating of the largest heater load.

67.1.2 When provided with main overcurrent protection, the nameplate shall include ″short circuit current rating of the protective device″ in amperes.

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.”

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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.

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 button 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)

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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.

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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

Table 70.2 Continued on Next Page

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Table 70.2 Continued

Size of conductors		90°C (194°F) conductor ampacity		
AWG or kcmil	(mm^2)	60 minutes	30 minutes	15 minutes
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.

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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.

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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.

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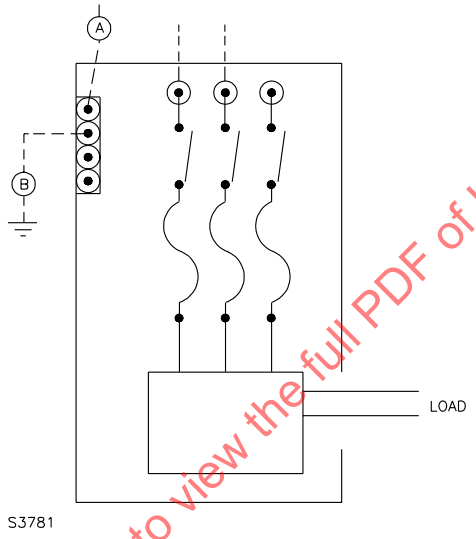
75 Construction

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 Figures 75.1 – 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

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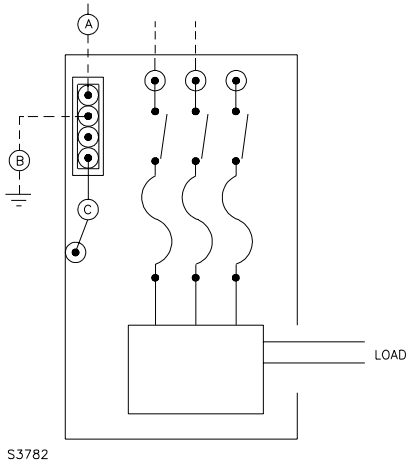
Figure 75.2
Single-phase, 3-wire (insulated neutral)

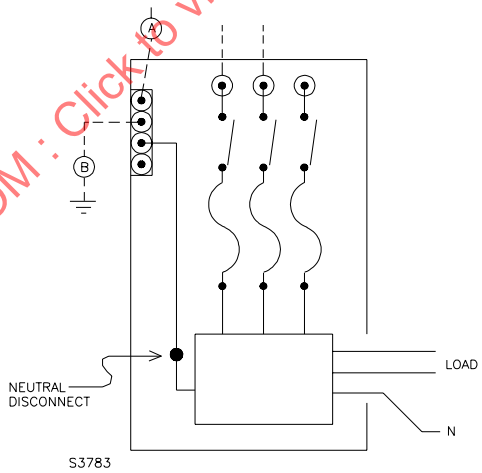


A – Grounded service conductor

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

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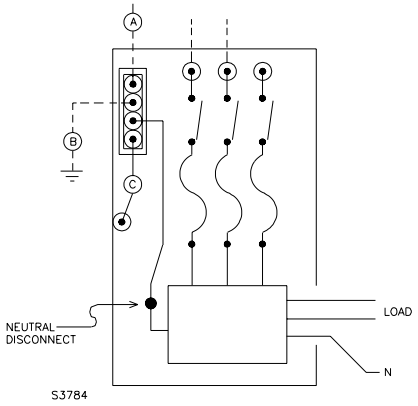
Figure 75.4
Single-phase, 3-wire with load neutral connection (insulated neutral)



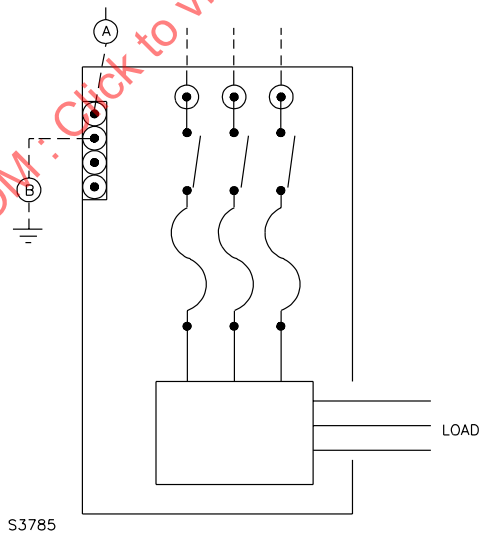
A – Grounded service conductor

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

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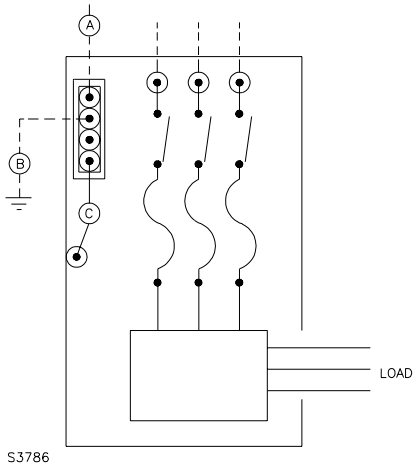
Figure 75.6
Three-phase, 4-wire (insulated neutral)

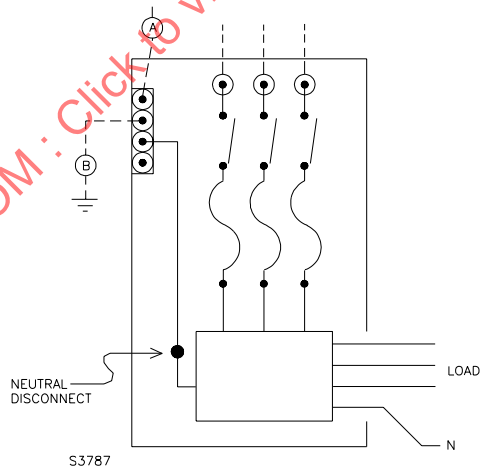


A – Grounded service conductor

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

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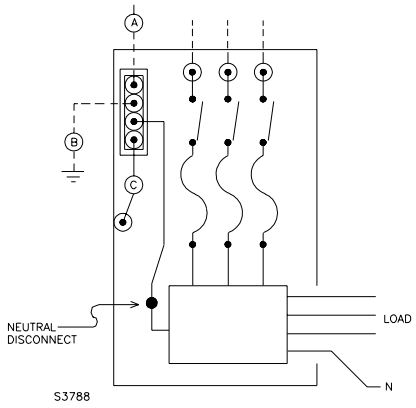
Figure 75.8
Three-phase, 4-wire with load neutral connection (insulated neutral)



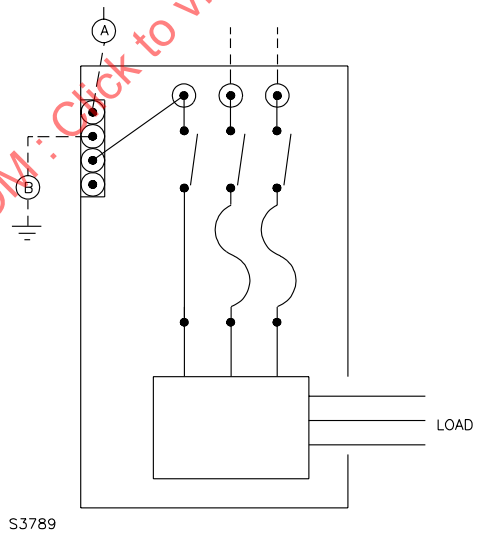
A – Grounded service conductor

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

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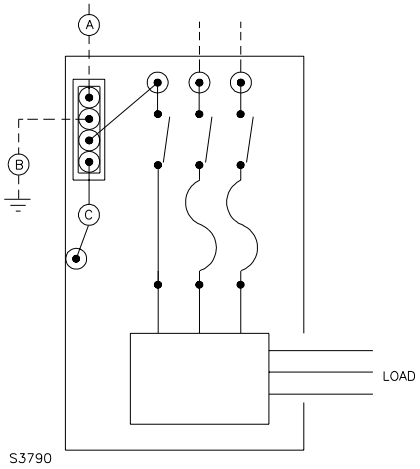
Figure 75.10
Three-phase, delta end-grounded (insulated neutral)



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.

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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)

[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.

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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 transient surge protection, 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.

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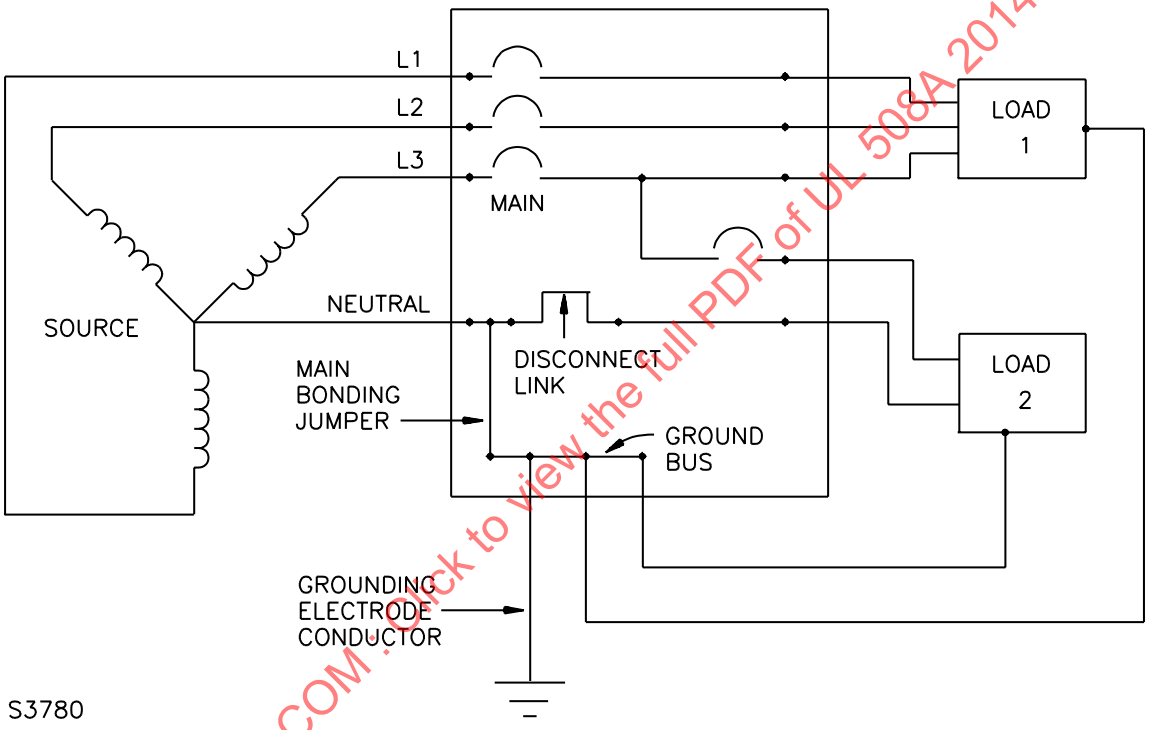
75.5.3 With respect to 75.5.2 (b), (c), and (d), the disconnecting means is the joint between the load conductor and the load conductor connector.

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



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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 600 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.

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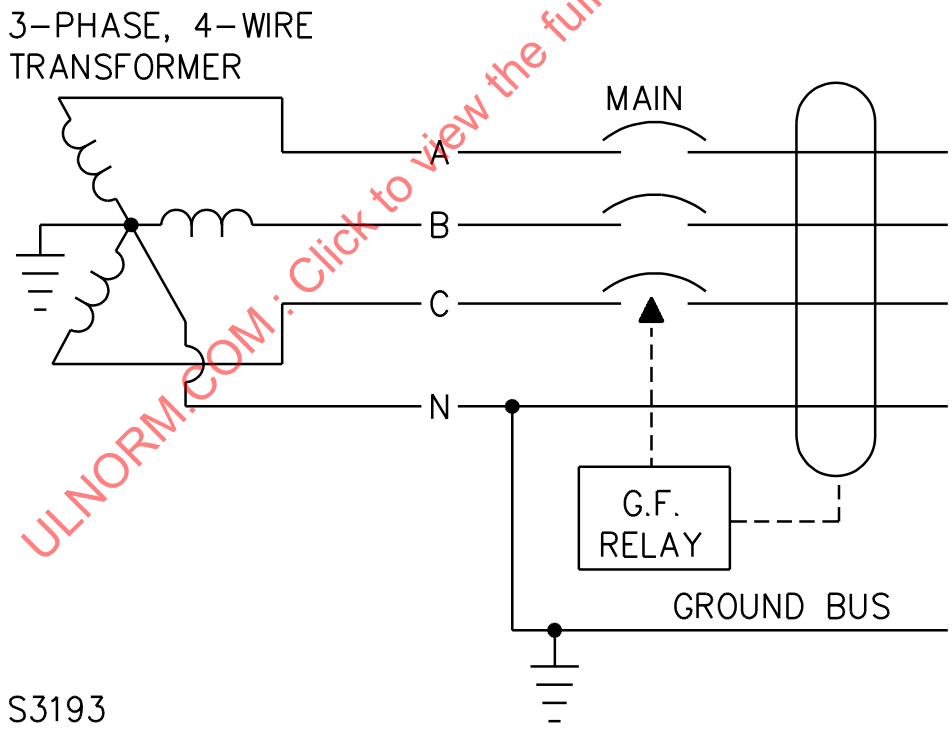
Exception: Ground-fault protection is not required to be provided for equipment marked in accordance with 77.5.4.

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

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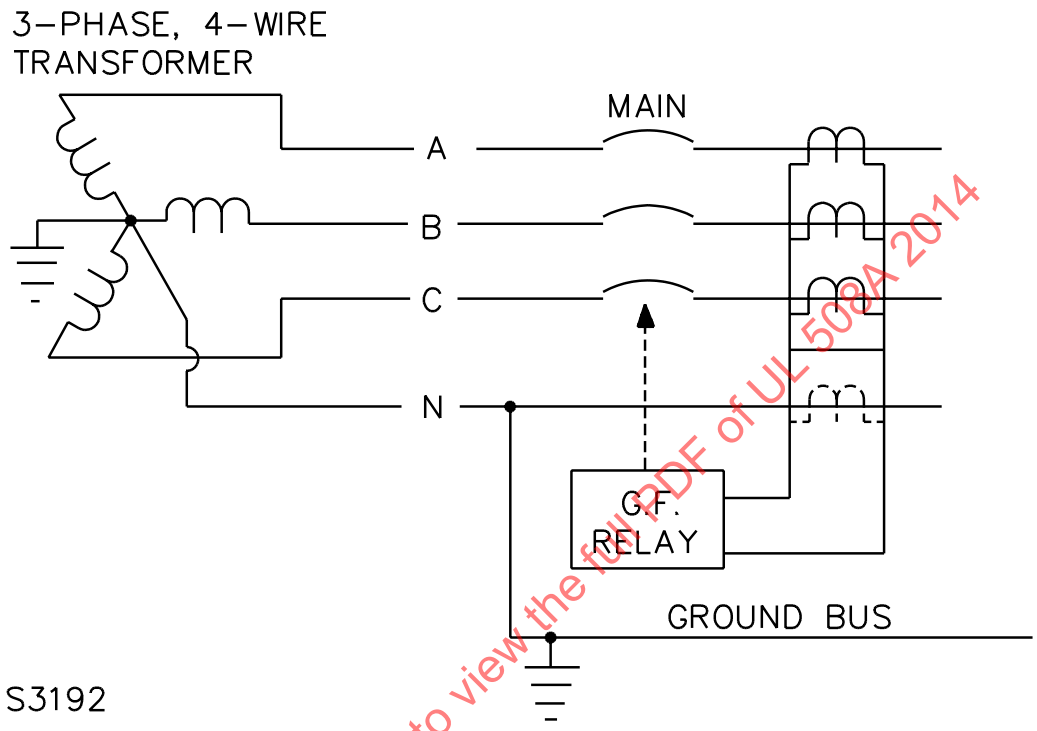
side of any grounding or bonding connection to the grounded service conductor. The ungrounded conductor sensors are able to be within or on the line or load side of the disconnecting device for the protected circuits. A typical residual type system is shown in Figure 75.13.

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.

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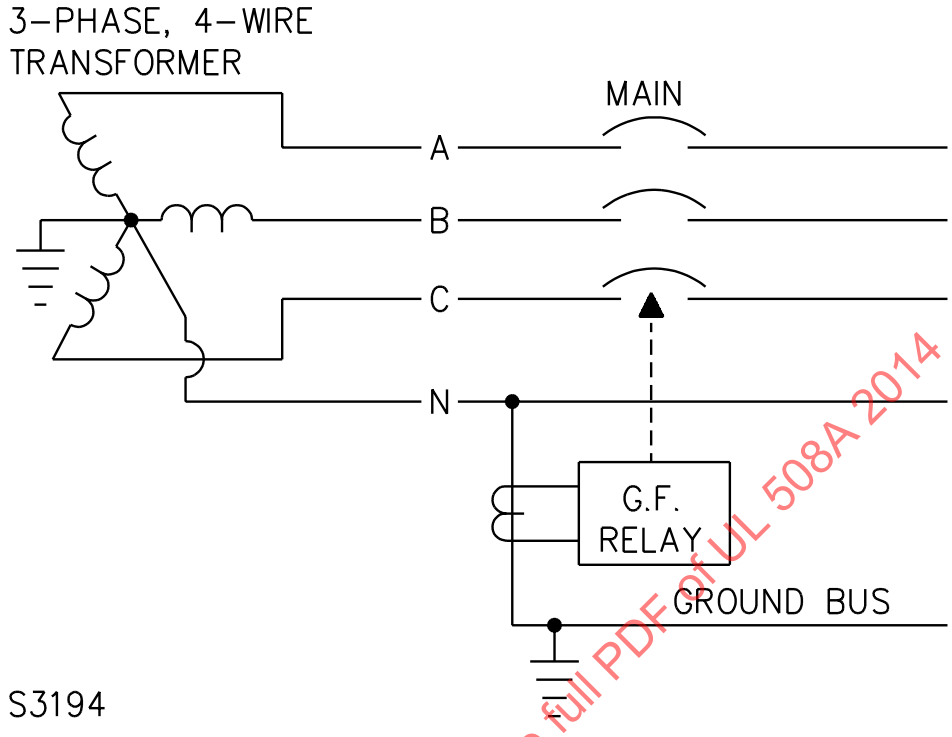
Figure 75.14
Ground return system



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.

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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 surge arrester of the metal-oxide type shall comply with ANSI/IEEE C62.11-1993, Standard for Metal Oxide Surge Arresters for AC Power Circuits. All other types of surge arresters shall comply with IEEE C62.1-1994, Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits.

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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.″

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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.

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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 600 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.

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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

80.1 These requirements cover industrial control panels intended for control of elevators, dumbwaiters, escalators, moving walks, inclined lifts, and associated equipment.

80.2 An elevator control panel to be evaluated for risks of fire and electric shock only shall comply with Sections 4 – 61 of this standard. The marking on the panel shall indicate that the panel is intended for elevator control and the extent of the investigation.

80.3 An elevator control panel complying with Sections 4 – 61 of this standard, and additionally complying with ANSI/ASME A17.1, American National Standard Safety Code for Elevators and Escalators, and with ANSI/ASME A17.5, American National Standard Safety Code for Elevator and Escalator Equipment, shall be marked to indicate the panel is intended for elevator control and the extent of the investigation.

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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.

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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.″

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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.

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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.

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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.

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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 Power Conversion Equipment, UL 508C.

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 an FLA (full-load ampere) 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.″

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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 Outline of Investigation 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 Outline of Investigation for Power Units for Fountain, Swimming Pool, and Spa Luminaires, UL 379.

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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.

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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 FLA 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 FLA 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 FLA 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, 600 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.

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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.

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SUPPLEMENT SA - SPECIFIC COMPONENT REQUIREMENTS

COMPONENT REQUIREMENTS

SA1 Listed Components

SA1.1 Listed devices that comply with specific component requirements of this standard are specified in Table SA1.1. Listed equipment other than as described in Table SA1.1 that is intended to comply with specific component requirements in this standard shall be described in the manufacturer's Procedure. Listed equipment described in Table SA1.1 as requiring procedure description shall be described in the manufacturer's Procedure in order to be used.

Table SA1.1
Components that comply with specific requirements

Paragraph reference	Component description	UL Standard	Category control number(s)	Notes
Section 12 – Insulating Barriers meeting component selection requirements of 12.2				
12.2(a)(1)	Generic materials	–		Type and minimum thickness as specified in Table 12.1, dimensions of barrier shall also comply with 12.1
12.2(a)(2)	Recognized Sleeving	UL 1441	UZFT2	90°C (194°F) minimum and for voltage involved, as noted on Recognition Information Page, dimensions of sleeving applied shall also comply with 12.1
12.2(a)(2)	Recognized Tubing	UL 224	YDPU2	90°C (194°F) minimum and for voltage involved, as noted on Recognition Information Page, dimensions of sleeving applied shall also comply with 12.1
12.2 Exception	Other insulating barriers	UL 508	–	Construction described in Procedure
Section 13 – Insulating materials meeting component selection requirements of 13.2				
13.2	Generic materials	–	–	Material type and minimum thickness as specified in Table 13.1, shall also comply with 13.2(b)
13.2	Recognized Standoffs	UL 67, UL 891	QEUY2	Any insulating standoff that complies with 13.2(b)
13.2 Exception	Other insulating materials	UL 508	–	Construction described in Procedure
Section 14 – Grounding Terminals meeting component selection requirements of 14.2				

Table SA1.1 Continued on Next Page

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