



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that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.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

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UL 508A

Standard for Industrial Control Panels

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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.

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.

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 circuit 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.

5 Units of Measurement

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

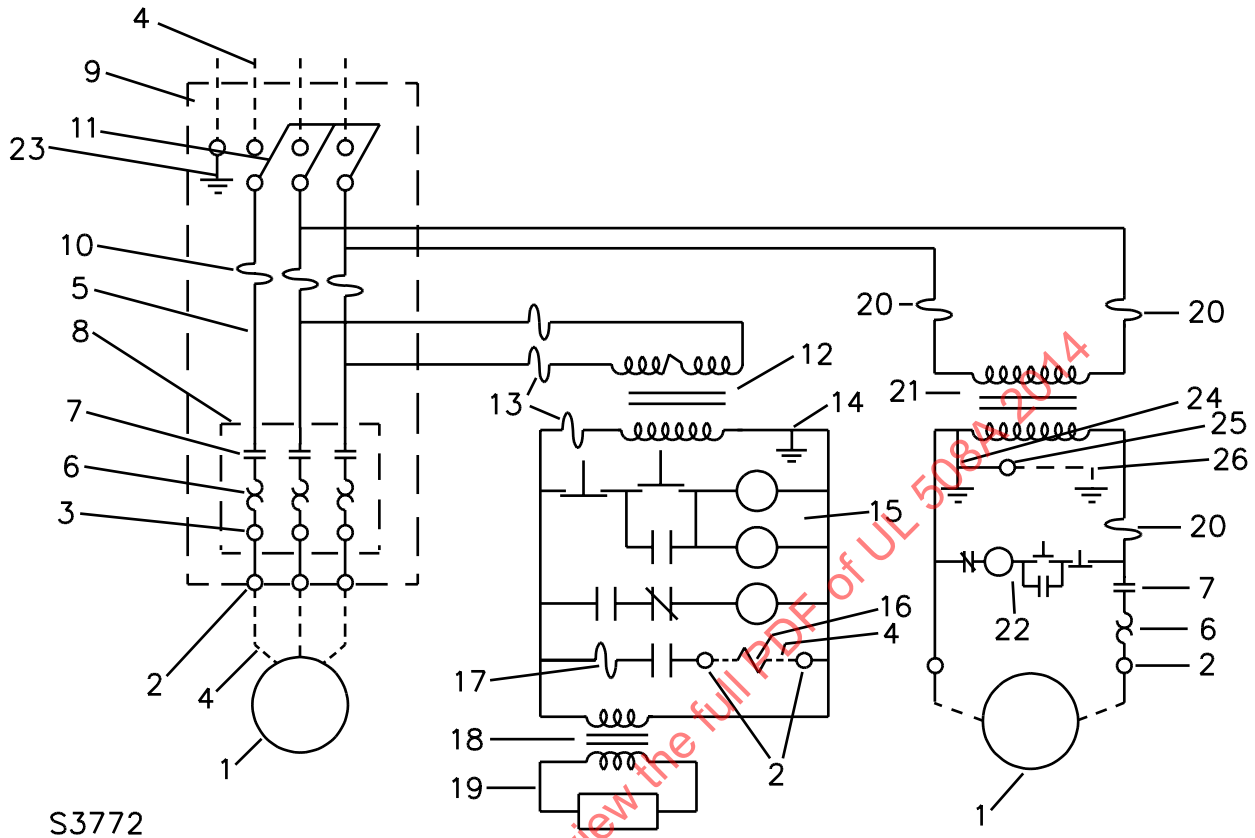
5.2 For calculations involving amperes, calculations resulting in a fraction of less than 0.5 shall be rounded down to the next whole number. Calculations resulting in a fraction of 0.5 or more shall be rounded up to the next whole number.

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



S3772

- | | |
|--|--|
| 1 Load (provided in field) | 14 Control transformer ground (for 1000 VA max control transformer) |
| 2 Field wiring terminals | 15 Control circuit devices and wiring/Class 1 circuit/isolated secondary circuit |
| 3 Alternate field terminals | 16 Solenoid or other control device – provided in field |
| 4 Field wiring | 17 Supplementary protection |
| 5 Power circuit internal wiring | 18 Class 2 transformer |
| 6 Overload relay & heater elements | 19 Class 2 circuit |
| 7 Contactor/Controller | 20 Power transformer fuse/branch circuit protection |
| 8 Starter | 21 Power transformer – for motor load and control circuit |
| 9 Combination motor controller | 22 Control circuit/Class 1 circuit/common control circuit |
| 10 Branch circuit protection | 23 Equipment ground and equipment ground terminal |
| 11 Fused disconnect switch or circuit breaker | 24 Bonding conductor/bonding jumper |
| 12 Control transformer | 25 Grounding electrode conductor terminal |
| 13 Control transformer fuse/supplementary protection | 26 Grounding electrode conductor (provided in field) |

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Figure 6.2
Description of control circuits and power circuits

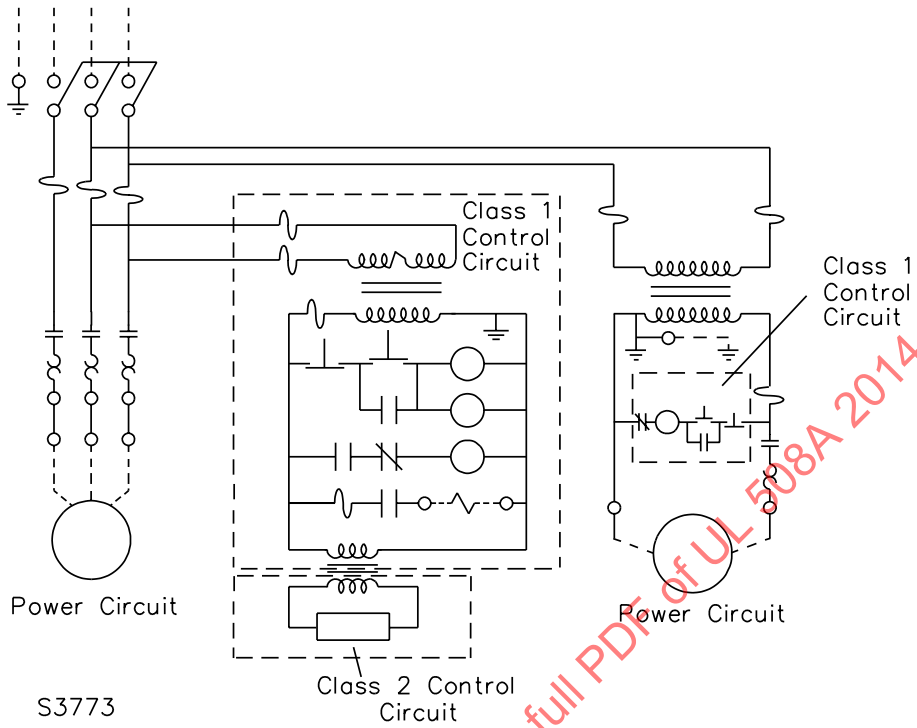
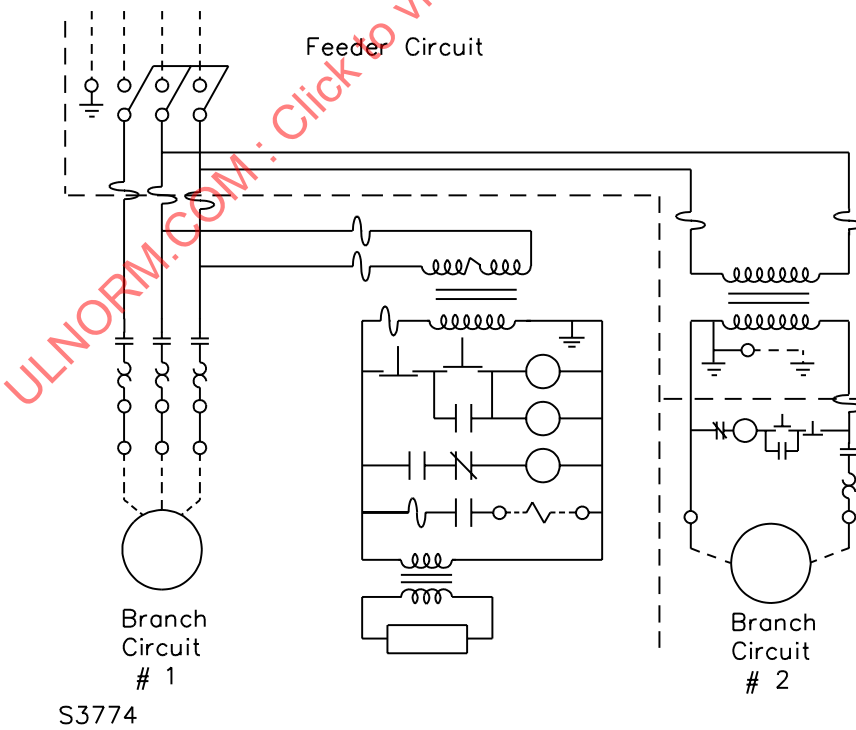


Figure 6.3
Description of branch circuits and feeder circuits



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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,9}	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.							

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Table 10.1 Continued on Next Page

Table 10.1 Continued

Potential involved in volts rms ac or dc	Minimum spacing, inch (mm)						
	A			B		C	
	General industrial control equipment			Devices having limited ratings ^a		All circuits ^d	
	51 – 150	151 – 300	301 – 600	51 – 300	301 – 600	0 – 50	
<p>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.</p> <p>^a See 10.5.</p> <p>^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.</p> <p>^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.</p> <p>^d Spacings do not apply within a low-voltage limited energy circuit or a Class 2 circuit.</p> <p>^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).</p> <p>^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.</p> <p>^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.</p>							

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.

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.

Table 11.1
Dimensions of bushings

Trade size of conduit, inches	Bushing dimensions, inches (mm)			
	Overall diameter		Height	
1/2	1	(25.4)	3/8	(9.5)
3/4	1-15/64	(31.4)	27/64	(10.7)
1	1-19/32	(40.5)	33/64	(13.1)
1-1/4	1-15/16	(49.2)	9/16	(14.3)
1-1/2	2-13/64	(56.0)	19/32	(15.1)
2	2-45/64	(68.7)	5/8	(15.9)
2-1/2	3-7/32	(81.8)	3/4	(19.1)
3	3-7/8	(98.4)	13/16	(20.6)
3-1/2	4-7/16	(112.7)	15/16	(23.8)
4	4-31/32	(126.2)	1	(25.4)
4-1/2	5-35/64	(140.7)	1-1/16	(27.0)
5	6-7/32	(158.0)	1-3/16	(30.2)
6	7-7/32	(183.4)	1-1/4	(31.8)

12 Insulating Barriers

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

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

- a) The material shall be:
 - 1) An insulating material described in Table 12.1; or
 - 2) Tubing or sleeving complying with 29.2.3 and rated for the voltage involved;
- b) The material is able to be in direct contact with uninsulated live parts; and
- c) The material does not serve to physically support or maintain the position of an uninsulated live part.

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

Table 12.1
Generic materials for use as barriers

Generic material	Minimum thickness	
	inches	(mm)
Aramid Paper	0.010	(0.25)
Electrical Grade Paper	0.028	(0.71)
Epoxy	0.028	(0.71)
Mica	0.006	(0.15)
Mylar (PETP)	0.007	(0.18)
RTV	0.028	(0.71)
Silicone Rubber	0.028	(0.71)
Vulcanized Fiber	0.028	(0.71)

13 Insulating Materials

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

- a) It is in direct physical contact with the uninsulated live part; and
- b) It serves to physically support or maintain the relative position of the uninsulated live part.

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

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

- a) The material shall be an insulating material described in Table 13.1; and
- b) The dimensions of the insulating material shall comply with the required spacings of Section 10, Spacings.

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

Table 13.1
Generic materials for direct support of uninsulated live parts

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

14 Grounding – General

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

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.

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 mm²) copper conductor. The jumper is not otherwise required to be larger than the phase conductors connected to the transformer secondary.

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

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

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

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

16.5 An industrial control panel that contains a transformer or power supply with a 3-phase, 4-wire delta secondary, as described in 16.1(d), and provided with field wiring terminals for loads to be connected between a phase and the neutral, shall comply with 29.3.13.

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 mm²) 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 mm²) 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 mm²) 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.

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
<p>^a When a drain is added.</p> <p>^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.</p> <p>^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.</p>		

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 opening to uninsulated live parts or moving parts.

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

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

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

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

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

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 m²).

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 mm²) 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 mm²) 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 cm²) and has no dimension greater than 12 inches (305 mm); or*
- b) *The width of the opening protected is not greater than 3.50 inches (88.9 mm).*

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

22 Barriers Used with Ventilation Openings

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

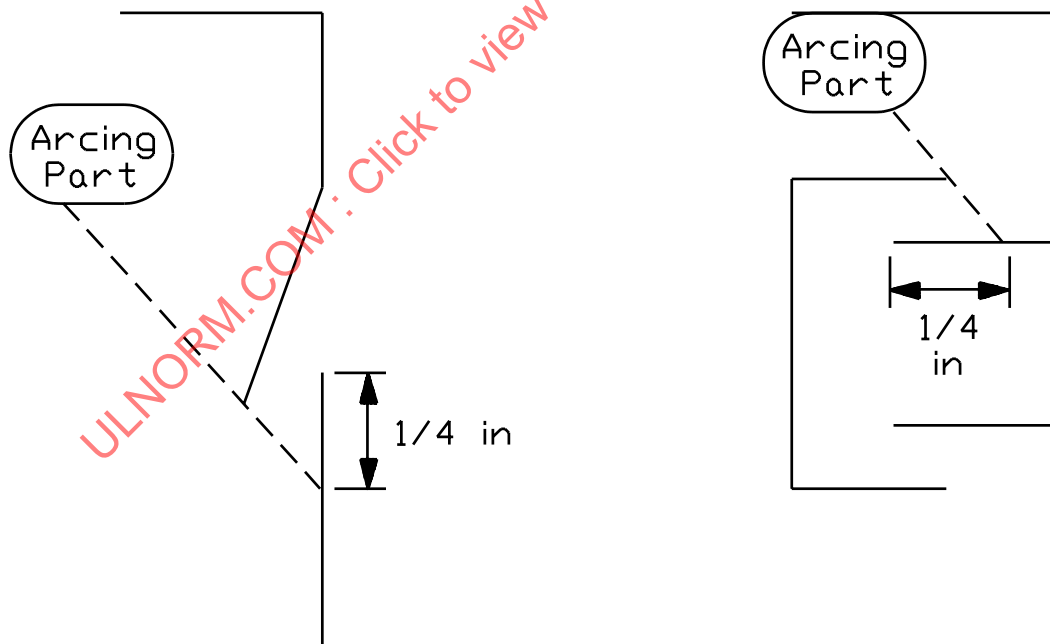
22.2 A barrier shall be of such dimension and so located that any straight line drawn from any arcing part past the edge of the barriers intersects a point in the ventilation opening plane that is at least 0.25 inch (6.35 mm) outside the edge of the ventilation opening. A barrier shall be secured in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

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

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

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

Figure 22.1
Barriers for ventilation openings



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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 cm²).

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.