UL 508

STANDARD FOR SAFETY

Industrial Control Equipment

UL Standard for Safety for Industrial Control Equipment, UL 508

Nineteenth Edition, Dated October 28, 2024

Summary of Topics

This new Nineteenth Edition of ANSI/UL 508 dated October 28, 2024 includes the following changes in requirements:

– Revisions to Address Changes to UL 869A; Section 133.

– Clarification of Ambient for Tests; 44.3 and 44.4.

– Remove Exception to 72.5 for Definite Purpose Motor Controllers.

– Move Pressure Test to General Section 71 and Table 102.1.

– Remove Programmable Controllers from UL 508; 1.3, 1.12, 37.1, Table 77.1, and Index.

– Correction to Section 50; 50.2, Table 50.1, 73.41, and Table 77.1.

– Correction to UL 50 References; 7.3.1, 7.4.7, 7.5.2, 7.15.3, 7.15.14, 8.2.1, 9.2 – 9.4, 9.7, 9.8, 12.1, 12.2, 12.18, A2.4, A2.5, and A2.7.

– Editorial Update to Remove Standard for Components Appendix; 4.1, and Section 5.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated August 11, 2023, June 7, 2024, and September 20, 2024.

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ANSI/UL 508-2024

UL 508

Standard for Industrial Control Equipment

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Nineteenth Edition

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This ANSI/UL Standard for Safety consists of the Nineteenth Edition.

The most recent designation of ANSI/UL 508 as an American National Standard (ANSI) occurred on October 28, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

The Department of Defense (DoD) has adopted UL 508 on June 5, 1989. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover industrial control devices, and devices accessory thereto, for starting, stopping, regulating, controlling, or protecting electric motors. These requirements also cover industrial control devices or systems that store or process information and are provided with an output motor control function(s). This equipment is for use in ordinary locations in accordance with the National Electrical Code, NFPA 70. These requirements do not include requirements for the evaluation of equipment intended for use in functional safety applications.

1.2 These requirements cover devices rated 1500 volts or less. Industrial control equipment covered by these requirements is intended for use in an ambient temperature of 0 – 40 °C (32 – 104 °F) unless specifically indicated for use in other conditions.

1.3 Examples of industrial control devices described in 1.1 are:

a) Solid-state starters and controllers.

b) Pushbutton stations, including selector switches and pilot lights.

c) Control circuit switches and relays.

d) Float, flow, pressure, and vacuum-operated switches.

e) Resistors and rheostats.

f) Proximity switches.

g) Time-delay relays and switches.

h) Resistors and rheostats intended for industrial heating and lighting, including those for motor generator fields.

i) Control devices intended for industrial heating and lighting.

j) Solid-state time-delay relays.

k) Numerical control systems.

l) Lighting dimmer systems and controls.

m) Mercury-tube switches.

n) Solid-state logic controllers.

o) Industrial microprocessor/computer systems.

p) Variable voltage autotransformer.

q) Motor starting autotransformer.

1.4 Industrial control panels are covered by the requirements in the Standard for Industrial Control Panels, UL 508A.

1.5 Fire pump controllers are covered by the requirements in the Standard for Fire Pump Controllers, UL 218.

1.6 An adjustable-speed drive and accessories or modules for use with an adjustable-speed drive are covered by the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal, and Energy, UL 61800-5-1.

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

1.8 Devices that regulate temperature and/or control refrigeration equipment are covered by the Standard for Temperature-Indicating and -Regulating Equipment, UL 873, and other applicable standards. 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.

1.9 Electrical instruments are covered by the Standard for Electrical Analog Instruments– Panel Board Types, UL 1437.

1.10 Products consisting of interlocked controllers and similar assemblies, intended to transfer power to a common load or output between multiple inputs or sources, are covered by the Standard for Transfer Switch Equipment, UL 1008.

1.11 Magnetic motor controllers, manual motor controllers, combination motor controllers, and overload relays are covered by the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1.

1.12 Programmable controllers are covered by the Standard for Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-201: Particular Requirements for Control Equipment, UL 61010-2-201.

2 Glossary

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

2.2 AMBIENT TEMPERATURE – The temperature of the air medium into which the heat of the equipment is dissipated. See 45.12.

2.3 AMBIENT TEMPERATURE RATING – A rating assigned to equipment that refers to the maximum ambient temperature of the room or space outside of the device enclosure or intended enclosure. See 45.13.

2.4 CLOSED-OPEN OPERATION – An operation of closing the test device on the circuit. The letters "CO" signify this operation.

2.5 COMBINATION CONTROLLER – An open or enclosed device containing both a magnetic or solid-state controller and a disconnecting means. The controller may or may not contain overload protection, short circuit protection, or both. Where an individual controller is enclosed, it includes an external means for operating the disconnecting means.

2.6 COMBINATION MOTOR CONTROLLER – A controller intended for motor service that provides a disconnecting means, branch circuit (short-circuit and ground fault) protection, motor controller, and motor overload protection. In addition, where an individual controller is enclosed, it includes means for locking the disconnecting device in the "OFF" position.

2.7 COMPONENT FOR GROUP INSTALLATION – A motor control, overload relay, or other switching device evaluated for use in group installation. See 2.18.

2.8 CONTACTOR – A two-state (ON-OFF) device for repeatedly establishing and interrupting an electric power circuit. Interruption is obtained by introducing a gap or a very large impedance.

2.9 CONTROL CIRCUIT – A circuit that carries the electric signals directing the performance of a controller, but which does not carry the main power circuit (see IEEE Standards Dictionary of Electrical and Electronic Terms). A control circuit is generally limited to 15 amperes.

2.10 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.

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

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

2.13 END-OF-LINE ENCLOSURE – An enclosure that is intended to be connected at the end of a run of conduit.

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

2.15 FUNCTIONAL SAFETY – Part of the overall safety of equipment or systems that depends on the correct functioning of the process, equipment, and/or safety-related control system to prevent potentially-hazardous conditions from arising or provide mitigation to reduce the severity of the hazard.

2.16 GENERAL PURPOSE RATING – This term is synonymous with "General Use Rating."

2.17 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) If AC rated, a load that has a power factor of 0.75 to 0.80 (inductive); and

c) If DC rated, a load that is resistive (noninductive).

2.18 GROUP INSTALLATION – A motor branch circuit for two or more motors, or one or more motors with other loads and protected by a circuit breaker or a single set of fuses.

2.19 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 considered part of the primary circuit.

2.20 MANUAL CONTROLLER – A hand-operated switching device whose contacts are controlled by the position of a mechanical actuator.

2.21 MANUAL CONTROLLER WITH INSTANTANEOUS TRIP – A manual controller provided with an instantaneous trip element for short circuit protection only and optionally provided with an overload relay.

2.22 MOTOR CONTROL DEVICE – Any product or equipment rated in horsepower and/or full load-locked rotor current capable of interrupting the maximum operating overload current of a motor of the same horsepower or full load-locked rotor current rating as the product or equipment at the rated voltage. Such devices may include, but is not limited to, contactors, controllers, starters, and switches.

2.23 NON-COMBINATION MOTOR CONTROLLERS – Motor control devices of the non-combination type are for use with separate protective devices, such as fuses or inverse-time circuit breakers, installed in the supply side of the motor control device.

2.24 OPEN OPERATION – An operation of closing the circuit on the test device. The letter "O" signifies this operation.

2.25 PILOT DUTY – The rating assigned to a relay or switch that controls the coil of another relay or switch.

2.26 POLE LEAST LIKELY TO STRIKE GROUND – A pole that is referenced to ground or by virtue of its position or potential or both relative to other poles of the device to be less likely than any other to strike ground. In a three pole device, this pole would usually be the middle pole. It is possible for several poles to be equally least likely to strike to ground. In this case any may be used for the test.

2.27 POLLUTION DEGREE 1 – No pollution or only dry, nonconductive pollution occurs. The pollution has no influence.

2.28 POLLUTION DEGREE 2 – Normally, only nonconductive pollution occurs; however, temporary conductivity caused by condensation may be expected.

2.29 POLLUTION DEGREE 3 – Conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation that is expected.

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

2.31 PRIMARY CIRCUIT – A circuit in which the wiring and components are conductively connected to the branch circuit.

2.32 RECOVERY VOLTAGE – The voltage impressed upon the equipment under test after a circuit is cleared.

2.33 SELF-PROTECTED – A qualifying term applied to a controller that contains coordinated overload and short circuit protection. A self-protected controller is evaluated as a complete unit whether comprised of a single or multiple components. Coordinated protection is able to be inherent or obtained by correct selection of components or accessory parts in accordance with the manufacturer’s instructions.

2.34 STARTER – A form of controller that includes the switching means necessary to start and stop the connected load in combination with suitable overload protection.

2.35 SURROUNDING AIR TEMPERATURE RATING – A rating assigned to open type equipment that refers to the maximum ambient temperature of air immediately surrounding the equipment inside of the ultimate enclosure. See 45.13.

2.36 SWITCH – A device for opening and closing, and for changing the connections of a circuit. A switch is understood to be manually-operated, unless otherwise stated.

2.37 TRANSIENT SUPPRESSIVE DEVICE – A component or assembly that limits the transient voltage such as an overvoltage protective device, a transformer with isolated windings, or a damping impedance suitably located.

3 Units of Measurement

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

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.

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.

5 Referenced Publications

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

5.2 The following publications are referenced in this Standard:

ANSI C82.11, *Lamp Ballasts – High-Frequency Fluorescent Lamp Ballasts*

ANSI C82.14, *Lamp Ballasts – Low-Frequency Square Wave Electronic Ballasts*

ASTM E230, *Standard Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples*

IEC 60584-2, *Standard for Thermocouples Part 2: Tolerances*

IEEE 4, *Techniques for High-Voltage Testing*

IEEE C37.09, *Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*

JIS C 1602, *Standard for Tolerances*

NEMA 410, *Performance Testing for Lighting Controls and Switching Devices with Electronic Drivers and Discharge Ballasts*

NEMA ICS2, *Controllers, Contactors and Overload Relays Rated 600 V*

NEMA ICS5, *Control Circuit and Pilot Devices*

NEMA WD6, *Wiring Devices – Dimensional Requirements*

NFPA 70, *National Electrical Code*

NFPA 79, *Electrical Standard for Industrial Machinery*

UL 50, *Enclosures for Electrical Equipment, Non-Environmental Considerations*

UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*

UL 62, *Flexible Cords and Cables*

UL 94, *Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 248 Series, *Low-Voltage Fuses*

UL 310, *Electrical Quick-Connect Terminals*

UL 486A-486B, *Wire Connectors*

UL 486E, *Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors*

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

UL 514B, *Conduit, Tubing, and Cable Fittings*

UL 746A, *Polymeric Materials – Short Term Property Evaluations*

UL 746B, *Polymeric Materials – Long Term Property Evaluations*

UL 746C, *Polymeric Materials for Use in Electrical Equipment Evaluations*

UL 746D, *Polymeric Materials – Fabricated Parts*

UL 796, *Printed Wiring Boards*

UL 840, *Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment*

UL 845, *Motor Control Centers*

UL 869A, *Reference Standard for Service Equipment*

UL 1059, *Terminal Blocks*

UL 1097, *Double Insulation Systems for Use in Electrical Equipment*

UL 1310, *Class 2 Power Units*

UL 1446, *Systems of Insulating Materials – General*

UL 1557, *Electrically Isolated Semiconductor Devices*

UL 1577, *Optical Isolators*

UL 1581, *Electrical Wires, Cables, and Flexible Cords*

UL 1642, *Lithium Batteries*

UL 1973, *Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications*

UL 2054, *Household and Commercial Batteries*

UL 2111, *Overheating Protection for Motors*

UL 2237, *Outline of Investigation for Multi-Point Interconnection Power Cable Assemblies for Industrial Machinery*

UL 2238, *Cable Assemblies and Fittings for Industrial Control and Signal Distribution*

UL 5085-1, *Low Voltage Transformers – Part 1: General Requirements*

UL 5085-2, *Low Voltage Transformers – Part 2: General Purpose Transformers*

UL 5085-3, *Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers*

UL 60086-4, *Primary Batteries – Part 4: Safety of Lithium Batteries*

UL 60384-14, *Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains*

UL 60950-1, *Information Technology Equipment – Safety – Part 1: General Requirements*

USCG Title 46, *Electrical Engineering Regulations*

6 Installation and Operation Instructions

6.1 Literature intended to accompany a product, such as installation, rating, operation, and user-maintenance instructions or manuals shall be reviewed in the investigation of the product if the safe use of the product is dependent on the instructions. Since the literature is to be reviewed in the examination and test of the product, a draft copy of the literature may be used instead of a printed copy.

PART I – ALL EQUIPMENT

ENCLOSURE CONSTRUCTION

7 Frames and Enclosure

7.1 General

7.1.1 An enclosure of industrial control equipment shall be constructed and assembled so that it will have the strength and rigidity necessary to resist the abuses to which it is likely to be subjected, without total or partial collapse resulting in a risk of fire, electric shock, or injury to persons due to reduction of spacings, loosening or displacement of parts, or other serious defects.

7.1.2 Industrial controls with incomplete or partial enclosures are considered as open devices with respect to the performance requirements in this Standard.

7.1.3 An enclosure shall be constructed so as to reduce the risk of unintentional contact with enclosed electrical devices, and to provide internal devices with protection from specified external conditions.

7.2 Cast metal

7.2.1 A cast-metal enclosure shall be at least 1/8 inch (3.2 mm) thick at every point, more than 1/8 inch thick at reinforcing ribs and door edges, and at least 1/4 inch (6.4 mm) thick at tapped holes for conduit.

Exception: Other than at plain or threaded conduit holes, reinforcing ribs, and door edges, malleable iron and die-cast or permanent mold cast aluminum, brass, bronze, or zinc shall be:

> *a) At least 3/32 inch (2.4 mm) thick for an area greater than 24 square inches (155 cm^2) or having any dimension more than 6 inches (152 mm); and*
>
> *b) At least 1/16 inch (1.6 mm) thick for an area of 24 square inches or less having no dimension more than 6 inches. The area considered may be bounded by reinforcing ribs subdividing a larger area.*

7.2.2 The above thicknesses may be reduced if the enclosure complies with the Crushing Resistance Test and Resistance to Impact Test in accordance with UL 746C, except that the required ball impact force is 13.6 J (10 lb-ft) for enclosure surfaces greater than 40 in^2, and the Polymeric Enclosure Rigid Metallic Conduit Connection Tests per UL 50.

7.3 Sheet metal

7.3.1 The thickness of a sheet-metal enclosure shall not be less than that specified in Table 7.1 and Table 7.2, except that at points to which a wiring system is to be connected, uncoated 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: Enclosure thickness at points other than where a wiring system is to be connected may be less than 0.032 inch (0.81 mm) if the enclosure complies with the comparative deflection test (enclosure) and deflection test (doors and covers) in UL 50.

7.3.2 Table 7.1 and Table 7.2 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.

Table 7.1
Thickness of Sheet Metal for Enclosures – Carbon Steel or Stainless Steel

Without supporting frame[a]				With supporting frame or equivalent reinforcement[a]				Minimum acceptable thickness, Uncoated	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length			
Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(mm)
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020[d]	(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[d]	(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 7.3.3.

[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 may have supports in common and be made of a single sheet.

[c] Not limited applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet steel for an enclosure intended for outdoor use – raintight or rainproof – shall not be less than 0.032 inch thick.

Table 7.2
Thickness of Sheet Metal for Electrical Enclosures– Aluminum, Copper, or Brass

Without supporting frame[a]				With supporting frame or equivalent reinforcement[a]				Minimum acceptable thickness,	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length			
Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(mm)
3.0	(7.6)	Not limited		7.0	(17.8)	Not limited		0.023[d]	(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 7.3.3.

[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 may have supports in common and be made of a single sheet.

[c] Not limited applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet copper, brass, or aluminum for an enclosure intended for outdoor use – raintight or rainproof – shall not be less than 0.029 inch (0.74 mm) thick.

7.3.3 With reference to Table 7.1 and Table 7.2, 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 sufficient torsional rigidity to resist the bending moments that may be applied by the enclosure surface when it is deflected. A structure that is as rigid as one built with a frame of angles or channels is considered to have equivalent reinforcing. Constructions considered to be without supporting frame include:

a) A single sheet with single formed flanges – formed edges;

b) A single sheet that is corrugated or ribbed;

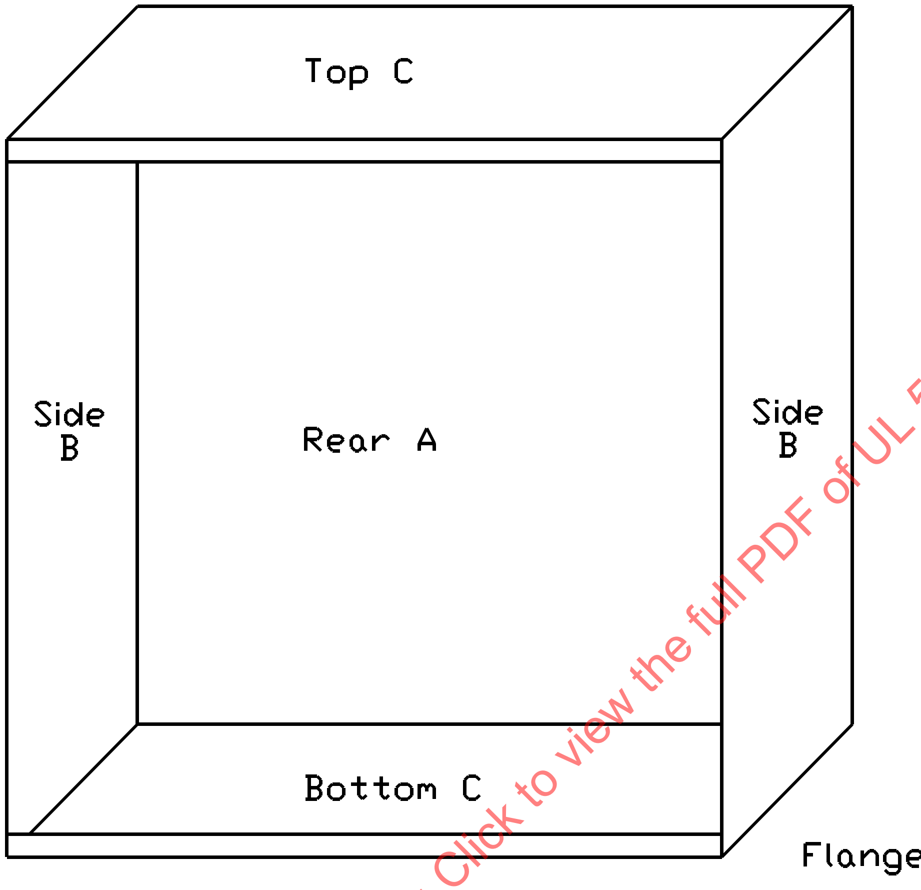
c) An enclosure surface loosely attached to a frame, for example, with spring clips; and

d) An enclosure surface having an unsupported edge.

See Figure 7.1 for evaluation of supported and unsupported enclosure surfaces. This figure further defines the means of selecting the required metal thickness from either the "with supporting frame" or "without supporting frame" columns in Table 7.1 and Table 7.2.

Figure 7.1

Determination of Required Metal Thickness from Table 7.1 and Table 7.2 for Supported and Unsupported Enclosure Surfaces



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NOTES:

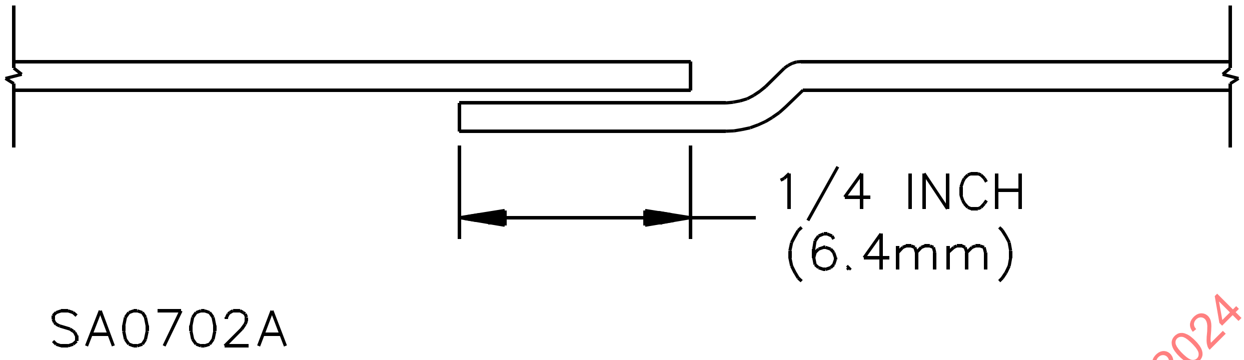
Each enclosure surface is evaluated individually based on the length and width dimensions. For each set of surface dimensions, A, B or C, the width is the smaller dimension regardless of its orientation to other surfaces. In Table 7.1 and Table 7.2, there are two sets of dimensions that correspond to 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 7.2, 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.

Figure 7.2

Rabbet



7.4 Doors and covers

7.4.1 A part of an enclosure, such as a door or a cover, shall be provided with a means – such as latches, locks, interlocks, or screws – for firmly securing it in place.

Exception: A snap-on cover that complies with the requirements in Section 10 need not have additional securing means.

7.4.2 An enclosure shall be provided with a door when it gives access to a fuse or any other overload protective device that requires renewal or when it is required to be opened in connection with the normal operation of the device.

Exception: A door is not required for an enclosure:

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

b) In which the only fuse enclosed is a control-circuit fuse, when the fuse and control-circuit load – other than a fixed control-circuit load, such as a pilot lamp – are within the same enclosure; or

c) In which a means is provided for resetting all overload-protective devices from outside the enclosure, or kits are available to provide a means for resetting all overload-protective devices from outside the enclosure and a marking is provided in accordance with Details, Section 76.

7.4.3 Other than as noted in 7.4.5, a door provided in accordance with the requirement in 7.4.2 shall be provided with a snap latch or a captive multiturn or partial-turn fastener. Such securing means shall be located or used in multiple so as to hold the door closed over its entire length. A captive fastener shall be operable by hand or by a simple hand tool such as a screwdriver.

7.4.4 A door more than 48 inches (1.2 m) long on the hinged side shall be provided with one of the following:

a) A multipoint latch operated by a single knob or handle;

b) Two or more snap latches or captive fasteners; or

c) One knob-operated latch and one snap latch or captive fastener.

7.4.5 An enclosure that is not required to comply with 7.4.2 is able to use a door with noncaptive fasteners.

7.4.6 A door giving access to a fuse or any portion of a circuit breaker other than the operating handle shall shut closely against a 1/4-inch (6.4-mm) rabbet as illustrated in Figure 7.2 or the equivalent.

7.4.7 A cover giving access to a fuse or any portion of a circuit breaker other than the operating handle shall have flanges for the full length of the four edges. Flanges on a cover shall fit closely with the outside walls of the enclosure, and shall comply with Figure 7.3 and Table 7.3. An acceptable combination of flange and rabbet may be used.

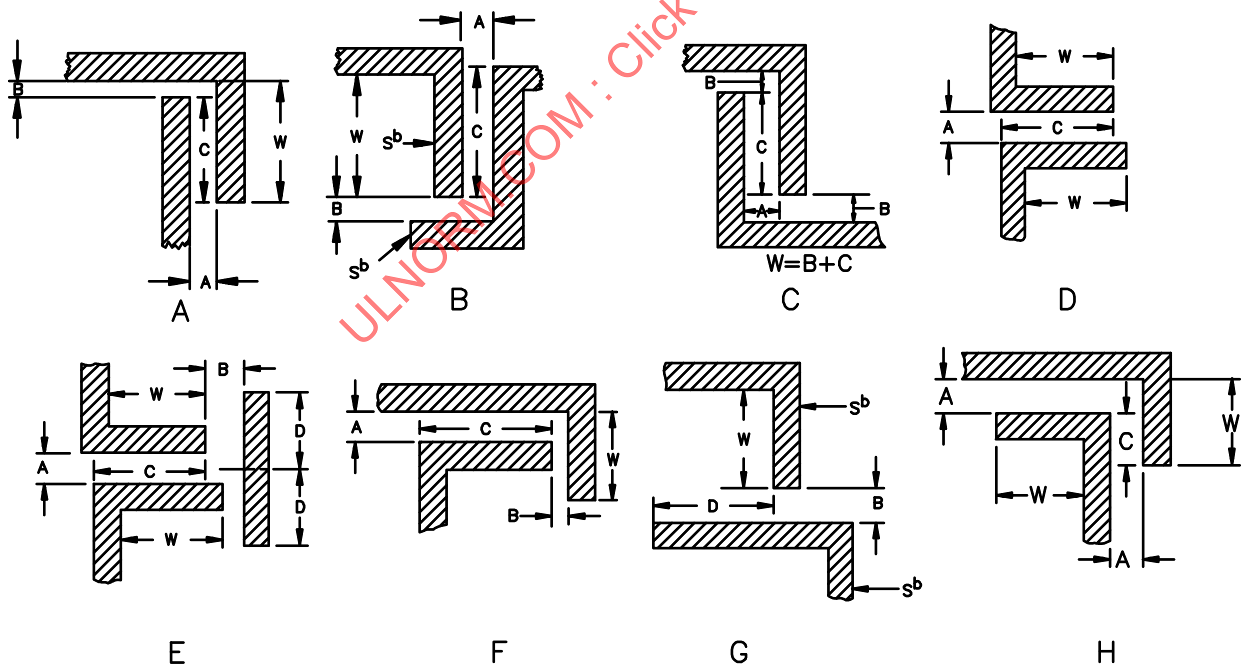
Exception No. 1: The flange width may be less than that specified if the construction complies with the Deflection Test (doors and covers) in UL 50.

Exception No. 2: The flanges on the cover are not required to fit closely on the outside wall if a gasket suitable for the application provides the intended tight fit. The gasket shall comply with the Gasket Tests in UL 50E.

Exception No. 3: For equipment incorporating an enclosure rated Type 1 only, the gap distance between the flanges on the cover and the outside wall are not required to comply with those specified in Table 7.3 when the equipment complies with the Short Circuit Test – General, Section 52 (and cotton is used as a fire indicator) and Accessibility of live parts, 7.17.

Figure 7.3

Flanged Cover Constructions[a]



S2766A

[a] See Table 7.3 for dimensions for sketches A – H.

[b] The surfaces "S" may be in line with one another – not as shown.

Table 7.3
Dimensions for Flanged Cover Constructions

Sketch – see Figure 7.3	Dimensions									
	W Minimum flange width[a]		A Maximum space between parts		B Maximum gap		C Minimum overlap		D Minimum barrier extension	
	Inches	(mm)	Inch	(mm)	Inch	(mm)	Inch	(mm)	Inch	(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)	1/8	(3.2)	1/4	(6.4)	7/16	(11.1)	–	–
G[b]	1/2	(12.7)	–	–	1/32	(0.8)	–	–	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 must be located on the side of the barrier extension D that is opposite the gap B.

7.4.8 To determine whether a flanged cover complies with the requirement in 7.4.7 regarding width of flange, the distance between the flat portion of the cover – clear of forming radii, beads, draws, and the like – and a straight edge placed anywhere across any two flanges at any points is to be measured.

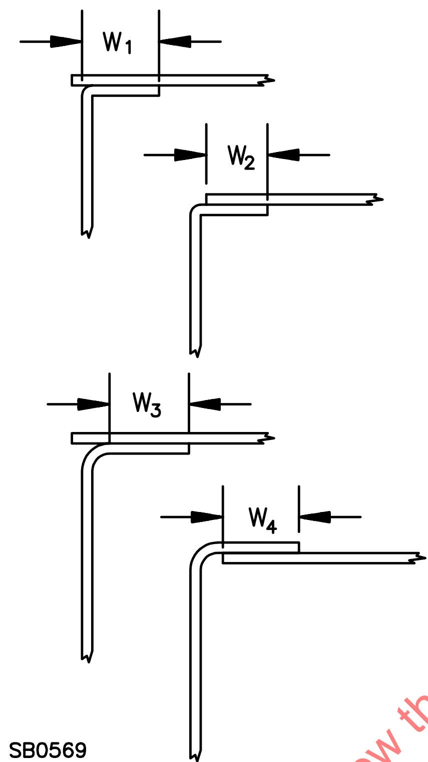
7.4.9 A construction involving a gasketed joint that provides the intended tight fit shall be investigated to determine whether it is acceptable for the application. See Section 7.15.14.

7.4.10 Figure 7.4 illustrates the method of determining the amount of overlap between a flat cover and a flanged box wall and the amount of overlap at a corner or box seam. If the radius of the flange bend is small, the flange width and overlap are considered to be W1 or W2, depending upon the actual construction, and shall be at least 1/2 inch (12.7 mm). If the radius of the flange bend is excessive or if the flat sheet is on the inside of the flange, the overlap, W3 or W4, is to be measured over only that portion where the two pieces of metal are actually in contact with each other, and shall be at least 1/2 inch.

7.4.11 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 normally 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, noted as W4 in Figure 7.4. In scribing the marks, the cover is to be held in a fixed position with sufficient firmness to prevent displacement of the cover by the scribing tool, but without bending or distorting any portion of the box, cover, or other part of the enclosure.

Figure 7.4

Overlap Between Flat Cover and Box Flange and at Corner or Box Seam



7.4.12 A flat strip used to provide a rabbet, or an angle strip fastened to the edges of a door giving access to a fuse or any portion of a circuit breaker, other than the operating handle, shall be at least 60 percent of the required thickness of the metal of the box proper, but not less than 0.042 inch (1.07 mm) if of uncoated steel, and not less than 0.058 inch (1.47 mm) thick if of nonferrous metal. It shall be secured at no fewer than two points. There shall not be more than 1-1/2 inches (38 mm) between an end of the strip and a point at which it is secured, and the distance between adjacent points at which the strip is secured shall not be more than 6 inches (152 mm).

7.4.13 The enclosure shall be constructed so that doors and panels that are hinged vertically and that provide access for installation, servicing or replacement of internal energized components shall be capable of being opened to a minimum of 90 degrees from the closed position when fully installed as intended. Doors and panels that provide access solely for operation or control are not included in this requirement. The 90 degree minimum is to be measured from the primary plane of the cover opening, to the corresponding plane of the door in the open position. Door mounted devices are allowed to reside within this 90 degree sweep.

7.5 Polymeric

7.5.1 A polymeric electrical enclosure shall comply with the applicable requirements in UL 746C, and also with the additional requirements specified in this Standard. See also 7.5.5 and 7.5.6.

Exception: With respect to requirements in UL 746C, devices marked for connection to a Class 2 source only in accordance with 73.31 and containing no other external connection to additional circuits, are not required to comply with the flame, impact, mold stress and crush tests.

7.5.2 A polymeric enclosure intended for connection to a rigid conduit system shall comply with the Polymeric Enclosure Rigid Metallic Conduit Connection Tests in UL 50.

Exception: Polymeric enclosures marked or provided with instructions as noted in 12.18 are not required to be subjected to the torque test described in Polymeric Enclosure Rigid Metallic Conduit Connection Tests in UL 50.

7.5.3 A polymeric part assembled to an electrical enclosure or a polymeric part of an open-type component intended to be installed through an opening in an enclosure shall be made of a material rated in accordance with UL 94, and shall comply with the following:

a) The polymeric part shall close an opening in the enclosure having an area of not more than 1.2 square inches (775 mm^2) and shall be:

1) A pilot light lens classed 5VA, 5VB, V-0, V-1, V-2, or HB;

2) Rated V-0, V-1, or V-2; or

3) Rated HB and comply with the flammability test requirements in UL 746C.

b) The polymeric part shall close an opening in the enclosure having an area of more than 1.2 square inches (775 mm^2) and having no dimension greater than 12 inches (304.8 mm), shall be rated V-0, V-1, V-2, or HB, and shall comply with the flammability and impact test requirements in UL 746C.

Exception: The polymeric part is not required to be subjected to the flammability test when it encloses only parts that do not pose a risk of fire, as in Section 30, and is protected from exposure to fire by an internal metal barrier or polymeric barrier that complies with the flammability test. A printed wiring board rated V-0 may serve as a polymeric barrier when the assembly complies with the flammability test.

c) The polymeric part shall close an opening in the enclosure having any dimension greater than 12 inches (304.8 mm), shall comply with the flammability and impact requirements in (b) above and also comply with requirements for the crush resistance test in UL 746C.

7.5.4 For an adhesive that secures a polymeric part closing an opening in an enclosure, the adhesive shall comply with the requirements for adhesives in UL 746C.

Exception: A polymeric part of a component is not required to comply with this requirement when:

a) It only encloses parts which do not pose a risk of fire or electric shock; or

b) The device complies with 7.17.1 for the accessibility of live parts with the polymeric part removed and any internal parts that do pose a risk of fire or electric shock are enclosed by barriers that comply with 7.5.1 or 7.5.3, and 9.2.

7.5.5 In addition to the requirements in 7.5.1 and 7.5.3 (b) and (c), polymeric materials used for Types 3, 3R, 3RX, 3S, 3SX, 3X, 4, and 4X enclosures or polymeric materials used for closures, fastenings, or hinges for these enclosures, or as a polymeric part of an open-type component for installation on these enclosures shall comply with the Ultraviolet Light Exposure test in UL 746C.

7.5.6 In addition to the requirements in 7.5.1 and 7.5.3 (b) and (c), polymeric materials used for Types 6 and 6P enclosures or polymeric materials used for closures, fastenings, or hinges for these enclosures, or as a polymeric part of an open-type component for installation on these enclosures shall comply with the Ultraviolet Light Exposure Test and the Water Exposure and Immersion Tests in UL 746C.

7.6 Bonding

7.6.1 An enclosure made of insulating material, either wholly or in part, shall have an acceptable bonding means to provide continuity of grounding between all conduit openings. The bonding means may be either completely assembled on the product or provided as separate parts for field installation. See 12.15 and 75.6.

Exception No. 1: 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. See 12.16.

Exception No. 2: A bonding means is not required to be provided with each enclosure if such means is available in the form of a kit from the manufacturer and the equipment complies with the marking requirements in 76.1.

7.6.2 The continuity of a conduit system shall be provided by metal-to-metal contact not relying on a polymeric material.

Exception: The continuity of the grounding system may rely on the integrity of the polymeric enclosure if samples have been subjected to the creep test requirements in UL 746C. Overcurrent Tests shall be conducted at 200 percent of the rated current of the branch circuit-protective device.

7.6.3 A separate bonding conductor whether in a plastic or metal enclosure shall be copper, a copper alloy, or other material acceptable for use as an electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. A separate bonding conductor shall:

a) Be protected from mechanical damage or be located within the confines of the outer enclosure or frame; and

b) Not be secured by a removable fastener used for any purpose other than bonding unless the bonding conductor is unlikely to be omitted after removal and replacement of the fastener.

7.6.4 The size of a separate component bonding conductor shall not be less than the applicable size specified in Table 7.4 or the size of the conductor supplying the component, whichever is smaller.

Exception: A bonding conductor may be smaller than the specified size if:

a) It does not open when carrying for the time specified in Table 7.5, a current equal to twice the branch-circuit overcurrent-device rating – see Table 7.4 – but at least 40 amperes; and

b) None of three samples of the bonding conductor opens during a limited-short-circuit test with a current as specified in Table 7.6 when in series with a fuse as described in 7.6.5.

Table 7.4
Size of Bonding Conductor

Maximum rating or setting of automatic overcurrent device in circuit ahead of equipment, amperes	Minimum acceptable size of bonding conductor[a]			
	Copper wire		Aluminum wire	
	AWG	(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	(107.0)
1200	3/0	(85.0)	250	(127.0)

[a] Or equivalent cross-sectional area.

Table 7.5
Duration of Current Flow for Bonding-Conductor Test

Overcurrent device rating amperes	Minimum duration of current flow minutes
30 or less	1
31 – 60	4
61 – 100	6

Table 7.6
Bonding Conductor Short-Circuit Test Capacity

Controller rating			Circuit capacity amperes
Horsepower	(kW Output)	Volts	
1/2	(0.373)	0 – 250	200
1/2	(0.373)	251 – 600	1,000
over 1/2 to 1	(0.374 – 0.746)	0 – 600	1,000
1 to 3	(0.747 – 2.24)	0 – 250	2,000
over 3 to 7-1/2	(2.25 – 5.59)	0 – 250	3,500
over 7-1/2 to 50	(5.60 – 7.46)	0 – 250	5,000
over 1 to 50	(7.47 – 37.3)	251 – 600	5,000

Table 7.6 Continued on Next Page

Table 7.6 Continued

Controller rating			Circuit capacity amperes
Horsepower	(kW Output)	Volts	
over 50 to 200	(37.4 – 149)	0 – 600	10,000
over 200	(over 150)	0 – 600	a

[a] See Table 53.3.

7.6.5 The circuit for the test required by the Exception to 7.6.4 is to have a power factor of 0.9 – 1.0 and is to be limited to the current specified in Table 7.6. The open-circuit voltage of the test circuit is to be 100 to 105 percent of the specified voltage. The circuit is to be connected through a nonrenewable fuse that will conduct twice its rated current for at least 12 seconds. The fuse rating is to be that of the branch-circuit overcurrent device to which the equipment will be connected but at least 20 amperes. One test is to be performed on each of three samples of the bonding conductor.

7.7 Resistance measurement

7.7.1 The resistance between two parts connected by a bonding conductor shall not be more than 0.1 ohm. The resistance is to be determined by a resistance measuring instrument, except that if unacceptable results are recorded, an alternating or direct current of at least 20 amperes from a power supply of not more than 12 volts is to be passed from the point of connection of the equipment grounding means to the metal part in the grounding circuit. The resulting drop in potential and the test current are to be measured between the two points. The resistance in ohms is to be determined by dividing the drop in potential in volts by the current in amperes.

7.8 Openings in enclosure

7.8.1 No covering is required across the bottom of Type 1, 2, 3R, or 3RX enclosures of a floor-mounted controller if the enclosure is within 6 inches (152 mm) of the floor or less and if uninsulated live parts within the device are at least 6 inches above the highest portion of the lower edge of the enclosure.

7.8.2 Openings in enclosures shall be filled by devices with suitable environmental ratings as specified in Table 7.7.

Table 7.7
Openings in Enclosure

Enclosure type	Openings shall be closed by equipment rated for enclosure types
2	2, 3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, 13
3	3, 3S, 3SX, 3X, 4, 4X, 6, 6P
3R	3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 6, 6P
3RX	3RX, 3SX, 3X, 4X
3S	3, 3S, 3SX, 3X, 4, 4X, 6, 6P
3SX	3SX, 3X, 4X
3X	3SX, 3X, 4X
4	4, 4X, 6, 6P
4X	4X

Table 7.7 Continued on Next Page

Table 7.7 Continued

Enclosure type	Openings shall be closed by equipment rated for enclosure types
5	3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 13
6	6, 6P
6P	6P
12, 12K	12, 12K, 13
13	13

7.9 Ventilating openings

7.9.1 A ventilation opening in an enclosure that contains power circuit switching devices, such as a disconnect switch, circuit breaker, motor controller or an overload relay shall be constructed and located to comply with 7.9.2 – 7.11.2. Ventilation openings in enclosures that do not contain power circuit switching devices noted above shall comply with 7.9.3 – 7.9.8 and 7.11.1 – 7.11.2.

7.9.2 A ventilation opening in an enclosure that contains power circuit switching devices as in 7.9.1 shall comply with the requirements in 7.9.3 – 7.9.8 and 7.11.1 – 7.11.2 and:

a) The construction shall comply with the requirements in 7.10.1 – 7.10.4; or

b) The opening is located at least 12 inches (305 mm) from power circuit switching components; or

c) The opening shall be so constructed and located that flame or molten metal is not emitted during the operation of power-circuit switching devices while subjected to overload and short circuit test conditions.

7.9.3 A ventilation opening in the top of a Type 1 enclosure shall be covered by a hood or protective shield spaced above the opening when there are uninsulated components below the opening, and shall be in accordance with 7.9.4.

7.9.4 Any ventilating opening in a Type 1, 2, 3R, or 3RX enclosure shall comply with 7.17.1(a).

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

7.9.6 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).

7.9.7 The diameter of the wires of a screen shall be at least 0.051 inch (1.30 mm) if the screen openings are 0.500 square inch (32.3 mm^2) or less in area, and shall be at least 0.081 inch (2.06 mm) for larger screen openings.

7.9.8 Perforated sheet steel and sheet steel employed for expanded-metal mesh shall be at least 0.042 inch (1.07 mm) thick uncoated steel for mesh openings or perforations 0.500 square inch (3.2 cm^2) or less in area, and shall be at least 0.080 inch (2.03 mm) thick uncoated steel for larger openings.

Exception: In a small device where the indentation of a guard or enclosure will 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 37.1, expanded-metal mesh of uncoated steel not less than 0.020 inch (0.51 mm) thick is able to be employed when:

a) The exposed mesh on any one side or surface of the device so protected has an area not more than 72 square inches (464 cm^2) and has no dimension greater than 12 inches (304.8 mm), or

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

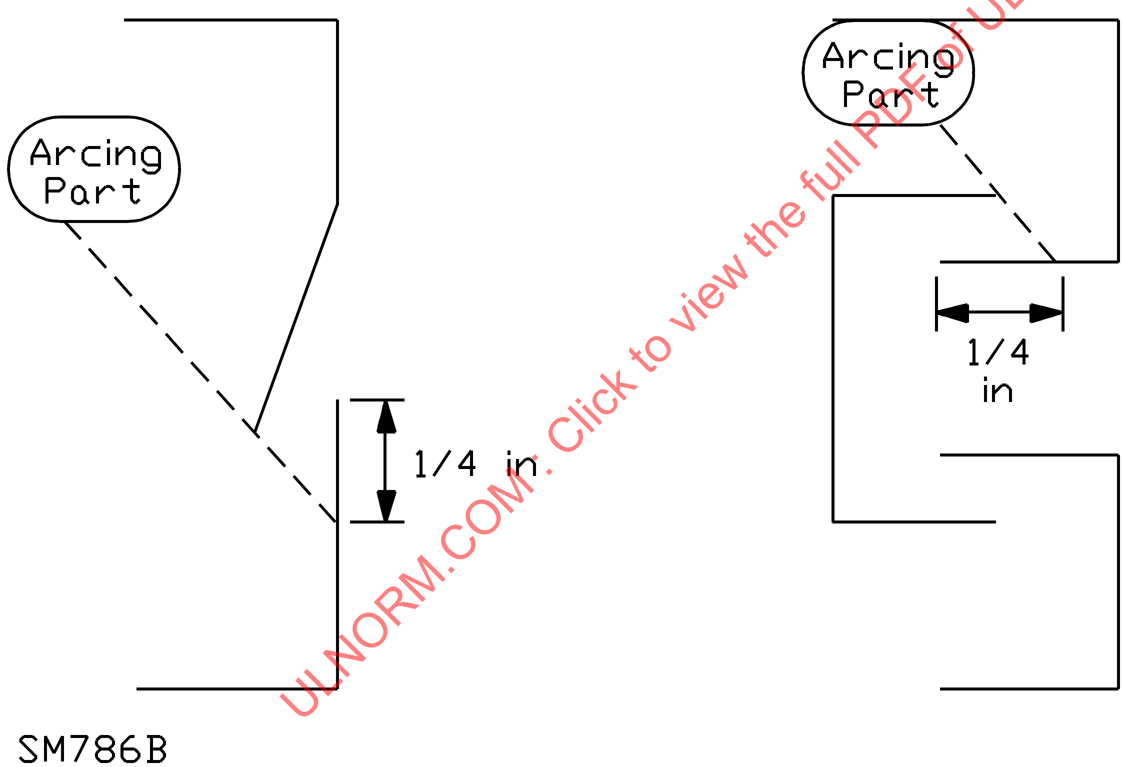
7.10 Barriers used with ventilation openings

7.10.1 A barrier interposed between ventilation openings and power circuit switching devices to prevent the emission of flames or molten metal from an enclosure shall comply with 7.10.2 – 7.10.4.

7.10.2 The barrier shall be of such dimensions and so located that any straight line drawn from any arcing part past the edge of the barrier intersects a point in the ventilating opening plane that is at least 0.25 inch (6.4 mm) outside of the edge of the ventilation opening. See Figure 7.5.

Figure 7.5

Barriers for Ventilation Openings



7.10.3 A sheet-metal barrier shall be at least 0.053 inch (1.35 mm) thick uncoated steel, or 0.075 inch (1.91 mm) thick aluminum.

Exception: A metal barrier may be of thinner metal provided its strength and rigidity are not less than that of a flat sheet of steel having the same dimensions as the barrier and of the specified thickness.

7.10.4 A nonmetallic barrier shall be at least 0.250 inch (6.35 mm) thick and shall be supported to provide mechanical strength and rigidity.

Exception: A nonmetallic material less than 0.250 inch thick shall be located so that it is not subjected to mechanical damage during installation, and supported to provide mechanical strength and rigidity.

7.11 Forced ventilation

7.11.1 When ventilation is fan forced – that is, ventilation is accomplished by one or more blowers within the enclosure that provide a positive intake and exhaust – the ventilation openings shall comply with the requirements in 7.11.2 in addition to the requirements in 7.9.2.

7.11.2 When operator controls are provided on the enclosure, the air outlet shall not direct air at the area occupied by the 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.

7.12 Observation windows

7.12.1 Glass covering an observation opening and forming a part of the enclosure shall be reliably secured in such a manner that it cannot be readily displaced in service and shall provide mechanical protection of the enclosed parts. Glass for an opening not more than 4 inches (102 mm) in any dimension shall not be less than 0.055 inch (1.40 mm) thick; and glass for an opening having no dimension greater than 12 inches (305 mm) shall not be less than 0.115 inch (2.92 mm) thick. Glass used to cover a larger opening shall comply with the Crush Resistance and Resistance to Impact tests in accordance with UL 746C, and shall otherwise be acceptable for the purpose.

7.13 Transformer or autotransformer

7.13.1 If a transformer or autotransformer is oil filled, means shall be provided for inspection and renewal of the oil.

7.14 Motor controller wire bending space

7.14.1 The space between the end of the soldering lug or pressure wire connector for the connection of field-installed wire and the wall of the enclosure toward which the wire will be directed upon leaving the lug or connector shall be at least that specified in Table 7.8.

Table 7.8
Wire Bending Space at the Terminals of Enclosed Motor Controllers

Size of wire[a]		Minimum bending space, terminal to wall, inches (mm)						
		Wires per terminal						
AWG or kcmil	(mm²)	1		2		3		4 or more
14 – 10	(2.1 – 5.3)	–		–		–		–
8 – 6	(8.4 – 13.3)	1-1/2	(38)	–		–		–
4 – 3	(21.2 – 26.7)	2	(51)	–		–		–
2	(33.6)	2-1/2	(64)	–		–		–
1	(42.4)	3	(76)	–		–		–
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)	–

Table 7.8 Continued on Next Page

Table 7.8 Continued

Size of wire[a] AWG or kcmil	(mm²)	Minimum bending space, terminal to wall, inches (mm) Wires per terminal 1		2		3		4 or more	
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)

[a] The wire size is to be based on 26.5.1(b).

7.14.2 The space specified in 7.14.1 is to be the length of a straight line extending from the end of the soldering lug or pressure wire connector where the wire would be connected toward and perpendicular to the enclosure wall toward which the wire would be initially directed.

7.14.3 If a wire is restricted by barriers or other means from being bent where it leaves the connector, the distance required by 7.14.1 and Table 7.8 is to be measured from the end of the barrier. A terminal lug or connector that is not prevented from turning as described in the exception to 18.2 is to be repositioned anywhere within the limits to obtain the shortest distance for measurement.

7.14.4 The wire size used to determine the wire bending space is based on 125 percent of the motor full-load current rating. See Table 47.2 or Table 47.3 for the full-load current rating of horsepower rated motors.

7.15 Specific enclosures

7.15.1 An enclosure shall comply with the construction requirements applicable to an enclosure of the type number or numbers with which it is marked. See 12.1.

7.15.2 An enclosure provided with multiple compartments is able to be evaluated to different enclosure type requirements when the compartments are completely separated by a wall or barrier and:

a) The assembly is intended for indoor use and the compartments are rated Type 1, 2, 4, 4X, 5, 6, 6P, 12, 12K, 13; or

b) The assembly is intended for outdoor use and the compartments are rated Type 3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 6, or 6P.

7.15.3 An environmental type connection, such as a watertight connection at a conduit entrance, shall be a conduit hub or the equivalent, such as a knockout or fitting, located so that when conduit is connected and the enclosure is mounted in the intended manner, the enclosure is found to be acceptable when subjected to the tests specified in the table for Enclosure Types in UL 50E.

7.15.4 TYPE 1 – A Type 1 enclosure shall comply with the requirement in 26.2.1.

7.15.5 TYPE 2 – A Type 2 enclosure shall have provision for drainage of water and shall have a threaded conduit hub or the equivalent for the connection of conduit at the top or sidewalls.

Exception No. 1: If the conduit connection opening is wholly below the lowest terminal lug or other live part intended for use within the enclosure, a threaded conduit hub or the equivalent need not be provided. See 12.14.

Exception No. 2: Provisions for a conduit hub or fitting need not be provided if information is provided in accordance with 12.11.

7.15.6 TYPE 3 or 3X – A Type 3 or 3X enclosure shall have:

a) A conduit hub or the equivalent for a watertight connection at conduit entrances – see 7.15.3;

b) A mounting means external to the equipment cavity; and

c) When a door is provided, the enclosure shall have provisions for locking the door or require the use of a tool to gain access to the equipment cavity.

Exception: Provision for a conduit hub or fitting is not required to be provided when information is provided in accordance with 12.11.

7.15.7 TYPE 3R or 3RX – A Type 3R or 3RX enclosure shall have:

a) A conduit hub or the equivalent for a watertight connection at conduit entrances – see 7.15.3;

b) Provision for drainage of water; and

c) When a door is provided, the enclosure shall have provisions for locking the door or require the use of a tool to gain access to the equipment cavity.

Exception No. 1: When the conduit connection opening is wholly below the lowest terminal lug or other live part intended for use within the enclosure, a threaded conduit hub or the equivalent is not required to be provided. See 12.14.

Exception No. 2: Provision for a conduit hub or fitting is not required to be provided when information is provided in accordance with 12.11.

7.15.8 TYPE 3S or 3SX – A Type 3S or 3SX enclosure shall have:

a) A conduit hub or the equivalent for a watertight connection at conduit entrances – see 7.15.3;

b) A mounting means external to the equipment cavity;

c) When a door is provided, the enclosure shall have provisions for locking the door or require the use of a tool to gain access to the equipment cavity; and

d) Operating mechanisms that will support the additional weight of ice and withstand removal of ice by a hand tool to gain access to the interior of the enclosure. Auxiliary means may be provided to break the ice and to permit operation of external mechanisms.

Exception: Provision for a conduit hub or fitting is not required to be provided when information is provided in accordance with 12.11.

7.15.9 TYPE 5 – A Type 5 enclosure shall have:

a) A conduit hub or the equivalent for a connection at conduit entrances – see 7.15.3; and

b) When a door is provided, the enclosure shall have provisions for locking the door or require the use of a tool to gain access to the equipment cavity.

Exception: Provisions for a conduit hub or fitting are not required when information is provided in accordance with 12.11.

7.15.10 TYPES 4, 4X, 6, AND 6P – A Type 4, 4X, 6, or 6P enclosure shall have a conduit hub or the equivalent mounted in place to provide a watertight connection at conduit entrances and shall have mounting means external to the equipment cavity – see 7.15.3.

Exception No. 1: The watertight conduit connection provision need not be mounted in place if information is provided in accordance with 12.13.

Exception No. 2: A hub or a fitting need not be provided or installed on a Type 4 or 4X enclosure if instructions are provided as specified in 12.17.

7.15.11 TYPE 12 – A Type 12 enclosure shall have no conduit knockout or conduit opening and no hole through the enclosure other than a hole for a Type 12 mechanism, or the equivalent. A gasket, if provided, shall be oil resistant.

Exception: A Type 12 enclosure may employ a conduit opening if the instructions required by 75.12 are included on the enclosure.

7.15.12 TYPE 12K – A Type 12K enclosure is as specified in 7.15.11, except it has knockouts located in the top or bottom walls, or both.

7.15.13 TYPE 13 – A Type 13 enclosure shall have oil-resistant gaskets and, if intended for wall or machine mounting, shall have a mounting means external to the equipment cavity. There shall be no conduit knockout or unsealed opening providing access to the equipment cavity. All conduit openings shall have provisions for oiltight connections.

7.15.14 A gasket of an elastomeric or thermoplastic material or a composition gasket utilizing an elastomeric material employed to comply with the requirements for a Type 2, 3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, or 13 enclosure shall comply with the Gasket Tests in UL 50E.

7.16 Components for use on specific enclosures

7.16.1 A component, such as a pilot light, a disconnect, a pushbutton, or similar component, intended for use with a type designated environmental enclosure, meets the requirements for use with a specific type enclosure when all of the following are met:

a) The component has been evaluated for its intended use installed on a representative enclosure.

b) All hardware, gaskets, or other parts needed to complete the installation are provided with the component.

Exception: Hardware, gaskets, or other parts are not required to be provided with the component when they are available from the component manufacturer in the form of a kit and the component is marked as specified in 76.1.

c) Installation instructions including such information as mounting hole location, opening configuration, and similar information, are provided either on the component, in the component package, or on a stuffer sheet.

d) The component, its carton, or accompanying instruction sheet is marked in accordance with the requirement in 73.9.

7.17 Accessibility of live parts

7.17.1 To reduce the likelihood of unintentional contact that may involve a risk of electric shock from an uninsulated live part, electrical energy - high current levels, or injury to persons from a moving part, an opening in an enclosure shall comply with either (a) or (b).

a) For an opening that has a minor dimension (see 7.17.4) less than 1 inch (25.4 mm), such a part or wire shall not be contacted by the probe illustrated in Figure 7.6.

Exception: As an alternative to 7.17.1(a), the probe illustrated in Figure 7.7 may be used to determine accessibility.

b) For an opening that has a minor dimension of 1 inch or more, such a part or wire shall be spaced from the opening as specified in Table 7.9.

Figure 7.6

Articulate Probe with Web Stop

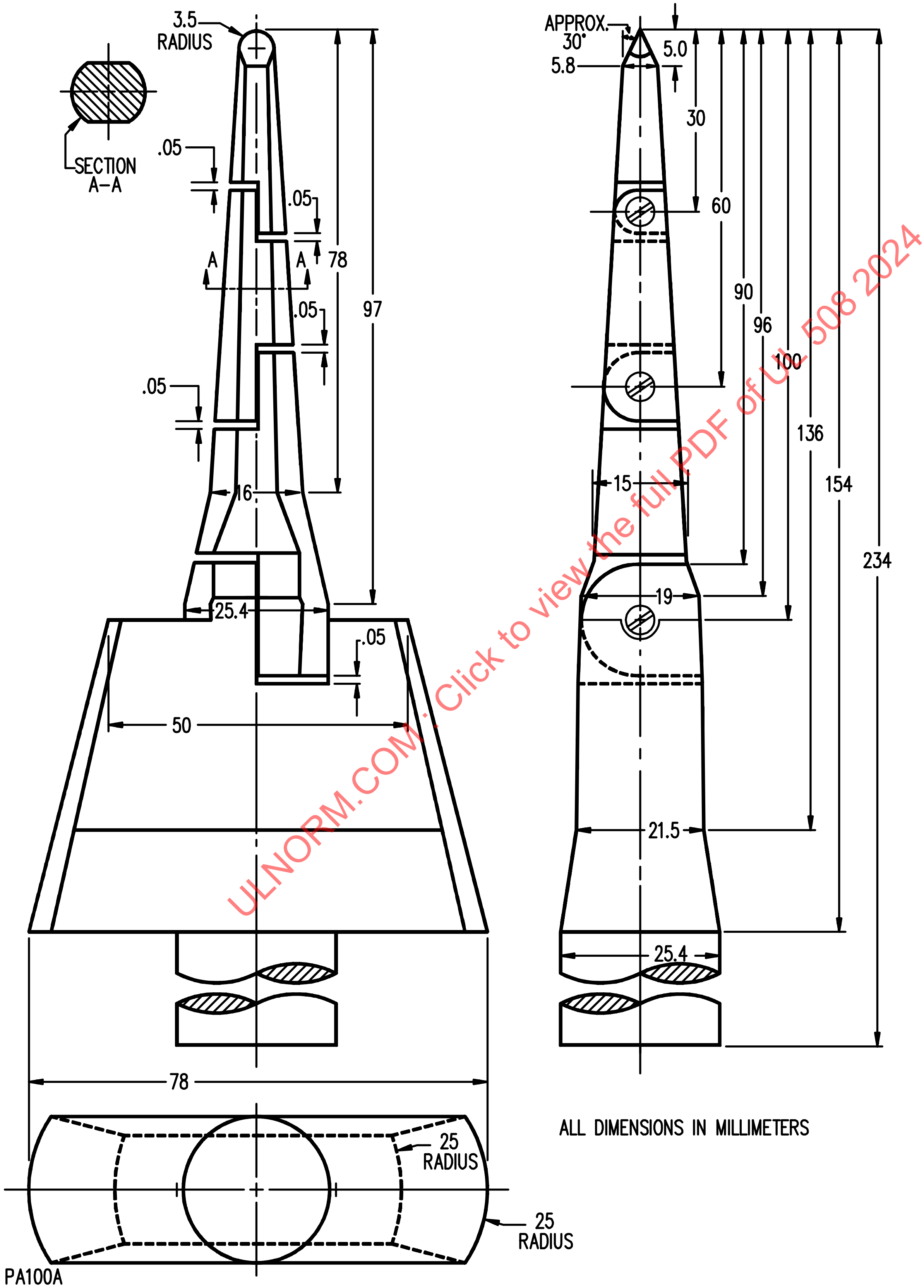


Figure 7.7

IEC Articulate Probe

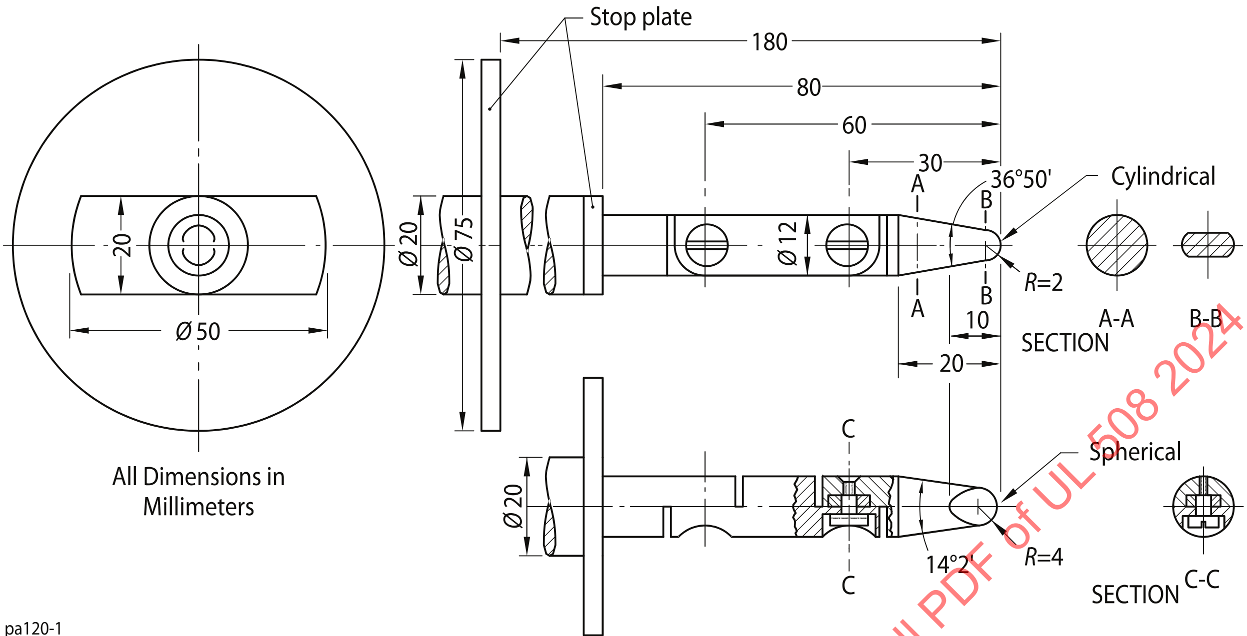


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Table 7.9
Minimum Acceptable Distance from an Opening to a Part That May Involve a Risk of Electric Shock, Electrical Energy-High Current Level, or Injury to Persons

Minor dimension of opening[a,b]		Minimum distance from opening to part[b]	
Inches	(mm)	Inches	(mm)
1	(25.4)	6-1/2	(165.0)
1-1/2	(38.1)	8-3/8	(212.7)
2	(50.8)	11-5/8	(295.3)
Over 2 but not more than 3	(Over 50.8 but not more than 76.2)	30	(762.3)

[a] See 7.17.4.

[b] Interpolation is to be used to determine a value between values specified in the table.

7.17.2 The probe specified in 7.17.1(a) shall be applied in any possible configuration; and, if necessary, the configuration shall be changed after insertion through the opening.

7.17.3 The probe specified in 7.17.1(a) shall be applied with a force not to exceed 2.2 pounds (10 N). The probe is to be used to determine the accessibility provided by an opening, and not as an instrument to determine the strength of a material.

7.17.4 With reference to 7.17.1, the minor dimension of an opening is the diameter of the largest cylindrical probe that can be inserted through the opening.

7.17.5 The probe specified in 7.17.1 is to be inserted as described in 7.17.2 into all openings, including those in the bottom of the unit. The unit is to be moved in whatever way necessary to make the entire bottom accessible for insertion of the probe.

Exception: For a floor-standing unit, the probe is to be inserted into all openings in the bottom that are accessible without tipping, turning over, or otherwise moving the unit from its intended installed position.

8 Protection Against Corrosion

8.1 General

8.1.1 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 upon which proper mechanical operation may depend.

Exception: This requirement does not apply to:

a) Bearings, thermal elements, sliding surfaces of a hinge, or shaft, and the like, where such protection is impracticable;

b) Small parts of iron or steel, such as washers, screws, bolts, and the like, that are not current carrying, if the corrosion of such parts would not be likely to result in a risk of fire, electric shock, or injury to persons; and

c) Parts made of stainless steel that are polished or treated, if necessary.

8.1.2 For a Type 1, 2, 5, 12, 12K, or 13 enclosure, both the inside and outside surfaces of an enclosure including means for fastening, shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means.

Exception: An enclosure and means for fastening that are of a metal that is inherently resistant to corrosion need not comply with this requirement.

8.2 Outdoor enclosures

8.2.1 A Type 3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 6, or 6P enclosure shall be protected against corrosion as specified under Protection Against Corrosion in UL 50E.

ENCLOSURE PERFORMANCE

9 General

9.1 The performance requirements of an enclosure are determined by the specific environmental type designation and other features such as gasketing or use of materials thinner than required by Table 7.1 or Table 7.2.

9.2 An enclosure shall be subjected to the tests specified in the table for Enclosure Types in UL 50E, applicable to an enclosure of the type number or numbers with which it is marked.

9.3 An enclosure having multiple compartments shall have each compartment subjected to the tests specified in the table for enclosure types in UL 50E, for its respective enclosure type designation. The internal barrier between compartments is not required to be directly subjected to these tests. Any joints and gasket materials between compartments shall be subjected to the environmental tests which are the most severe for either compartment.

9.4 A Type 12 enclosure having ventilation openings shall be subjected to the indoor dust test in accordance with UL 50E. When the enclosure is provided with a fan, the enclosure shall be subjected to all environmental tests required by 9.2, 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 compartment having a Type 12 rating.

9.5 An external operating means – such as those for a disconnect, a pilot device, or a resetting operation – mounted on or through an enclosure shall withstand the tests specified for the enclosure unless otherwise indicated in the specific test section.

9.6 Types 1, 2, 3R, and 3RX enclosures shall also comply with the requirements in 7.17.1.

9.7 A Type 4X enclosure intended for indoor use only and marked in accordance with 12.19:

a) Need not be subjected to the Icing Test in UL 50E; and

b) For a polymeric enclosure, need not have a material which is resistant to ultraviolet light weathering in accordance with UL 746C.

9.8 The conduit mentioned in 7.15.3 is to be tightened to the applicable torque value specified in Table 9.1. No sealing compound other than that normally provided by the end use manufacturer is to be used.

Exception No. 1: When conducting the Pressure Test in UL 50E, and the Submersion Test in UL 50E, a pipe thread sealing compound may be used when connecting conduit.

Exception No. 2: A lesser torque value may be used for polymeric enclosures if the device is marked as noted in 75.10.

Table 9.1
Tightening Torque

Trade size of circuit hub	Tightening torque	
inches	pound-inches	(N·m)
3/4 and smaller	800	(90.4)
1, 1-1/4, and 1-1/2	1000	(113)
2 and larger	1600	(181)

10 Securement of Snap-On Cover Test

10.1 A snap-on cover providing part of the overall enclosure that gives access to uninsulated live parts and does not have a separate tool-operated fastener shall have no apparent means for removal such as an extending tab, and is to comply with the following:

a) A cover that could be disengaged from the enclosure by a squeezing force applied with one hand shall not be released when a squeezing force of 14 pounds (62 N) or less is applied at any two locations not more than 5 inches (127 mm) apart. The distance is to be measured by a tape stretched tightly over that portion of the surface of the cover that would be encompassed by the palm of the hand.

b) A cover shall not disengage from the enclosure when a direct pull force of 14 pounds is applied by gripping the cover at any two convenient locations.

c) A cover shall not be disengaged from the enclosure by an impact force of 1 foot-pound (1.4 J) applied to the accessible faces of the cover – one blow per face. The impact is to be applied by a steel ball having a diameter of not less than 2 inches (51 mm).

10.2 The tests described in 10.1(a) and 10.1(b) are to be conducted in the as-received condition and after the cover has been removed and replaced ten times.

INSTRUCTIONS AND MARKINGS PERTAINING TO ENCLOSURES

11 Permanence of Marking

11.1 Any marking that is required to be permanent shall be molded, die-stamped, paint-stenciled, stamped or etched metal that is permanently secured, or indelibly stamped lettering on a pressure-sensitive label secured by adhesive. Ordinary usage, handling, storage, and the like, of a product are considered in the determination of the permanency of a marking.

12 Details

12.1 An enclosure shall be permanently marked with a type designation indicating the external conditions for which it is intended as defined in UL 50E. An enclosure that complies with the requirements for more than one type of enclosure may be marked with multiple designations. The marking shall be on either the inside or outside surface but shall be visible after installation upon inspection of the field wiring connections.

12.2 An enclosure having multiple compartments with different environmental ratings shall indicate on the nameplate, "Install in Type ___ Environment", or the equivalent where the marked type number is the type designation of the compartment affording the least protection from external conditions as specified in the table for enclosure types in UL 50E. Additional nameplate information regarding the level of protection provided for an individual compartment shall follow and be less prominent than the above marking.

12.3 A Type 1 enclosure may be additionally marked "indoor use only".

12.4 A Type 3, 3S, 3SX, 3X, 4, 4X, 6, or 6P enclosure may be marked "raintight".

12.5 A Type 3R or 3RX enclosure may be marked "rainproof".

12.6 A Type 4 or 4X enclosure may be marked "watertight".

12.7 A Type 3RX, 3SX, 3X, 4X or 6P enclosure may be marked "corrosion resistant".

12.8 A Type 2, 5, 12, 12K, or 13 enclosure is able to be marked "drip tight".

12.9 A Type 3, 3S, 3SX, 3X, 5, 12, 12K, or 13 enclosure is able to be marked "dust tight".

12.10 Conduit hubs provided for compliance with 7.15.3, 7.15.5, 7.15.6, 7.15.7, 7.15.8, or 7.15.10 shall comply with the requirements in UL 514B.

12.11 When conduit hubs are not provided for a Type 2, 3, 3R, 3RX, 3S, 3SX, 3X, or 5 enclosure, the enclosure, the instruction sheet provided with the enclosure, or the packaging carton shall be marked to indicate raintight or wet location hubs that comply with the requirements in UL 514B, are to be used.

12.12 A separable conduit hub and a closure fitting shall be marked with the manufacturer's name or trademark and the catalog number or equivalent. Such a hub or fitting may be shipped separately, and any gasket, hardware, and instructions necessary for installation shall be shipped with the fitting or packaged with the enclosure.

12.13 An enclosure marked Type 4, 4X, 6, or 6P shall be provided with instructions for use of the watertight connection if the connection is not mounted on the enclosure.

12.14 A Type 2, 3R, or 3RX enclosure that has knockouts for conduit in the sides or back of the enclosure and in which the equipment to be installed is not known shall be marked to indicate the area in which live parts are to be installed. See Exception No. 1 to 7.15.5 and Exception No. 1 to 7.15.7.

12.15 Installation instructions shall be provided with an enclosure intended for field assembly of the bonding means that identifies the parts for bonding and specifies the method of installation.

12.16 A pushbutton station or selector switch enclosure of insulating material that has no means for continuity of grounding between any conduit provision shall be marked that only one conduit is to be connected to the enclosure.

12.17 If a hub or fitting is not provided or installed on a Type 4 or 4X enclosure, instructions identifying the specific hub or fitting and installation instructions shall be provided with the enclosure.

12.18 A polymeric enclosure shall have instructions stating that the hub is to be connected to the conduit before the hub is connected to the enclosure if it:

a) Is intended for connection to a rigid conduit system;

b) Has not been subjected to the torque test described in Polymeric Enclosure Rigid Metallic Conduit Connection Tests in UL 50; and

c) Is not provided with a preassembled hub.

12.19 With reference to 9.7, a Type 4X enclosure intended for indoor use only shall be marked "4X Indoor Use Only" in letters at least 5/32 inch (4.0 mm) high.

DEVICE CONSTRUCTION

13 General

13.1 Industrial control equipment shall:

a) Be constructed so that it complies with the rules for installation and use of such equipment as given in NFPA 70-2002; and

b) Employ materials that are acceptable for the use.

14 Protection Against Corrosion

14.1 Iron and steel parts shall comply with the requirements in 8.1.1.

15 Provisions for Mounting

15.1 Provisions shall be made for securely mounting industrial control equipment to a supporting surface. A bolt, screw, or other part used to mount a component of the equipment shall not be used for securing the equipment to the supporting surface.

16 Insulating Material

16.1 A material that is used for the direct support of an uninsulated live part shall comply with the Relative Thermal Index (RTI), Hot Wire Ignition (HWI), High-Current-Arc Resistance to Ignition (HAI), and Comparative Tracking Index (CTI) values indicated in Table 16.1. A material is in direct support of an uninsulated live part when:

a) It is in direct physical contact with or in close proximity [less than 1/32 inch (0.8 mm)] to the uninsulated live part; and

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

Exception: A generic material provided in the thickness indicated in Table 16.2 complies with 16.1 without additional evaluation.

Table 16.1
Minimum Material Characteristics for the Direct Support of Uninsulated Live Parts

Flame Class	RTI Elec	Maximum Performance Level Category (PLC)		
		HWI[b,c]	HAI[d, e]	CTI[f,g,h]
HB	a	2	1	3
V-2, VTM-2	a	2	2	3
V-1, VTM-1	a	3	2	3
V-0, VTM-0	a	4	3	3

Relative Thermal Index (RTI)

[a] The electrical Relative Thermal Index (RTI) value of a material is to be determined in accordance with UL 746B, by test or by use of the generic RTI table. This material characteristic is dependent upon the minimum thickness at which the material is being used. The RTI shall not be exceeded during the Temperature Test, Section 45.

Hot Wire Ignition (HWI)

[b] The Hot Wire Ignition (HWI) value of a material is to be determined by test in accordance with UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HWI value, the material is evaluated as in footnote c.

[c] A material without an HWI Performance Level Category (PLC) value or with a HWI PLC value greater (worse) than the value required by Table 16.1 shall be subjected to the end-product Abnormal Overload Test or the Glow Wire End-Product Test specified in UL 746C.

High Current Arc Resistance to Ignition (HAI)

[d] The HAI value of a material is to be determined by test in accordance with UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HAI value, the material is evaluated as in footnote e.

[e] A material without an HAI PLC value or with an HAI PLC value greater (worse) than the value required by Table 16.1 shall be subjected to the end-product Arc Resistance Test specified in UL 746C.

Comparative Tracking Index (CTI)

[f] The Comparative Tracking Index (CTI) PLC value of a material is to be determined by test in accordance with UL 746A. This material characteristic is not dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a CTI value, the material is evaluated as having the same CTI value found for the greater thickness. The CTI value applies to insulating materials used in pollution degree 3 environments for voltages of 600V or less. For equipment where pollution degree 1 or 2 is maintained, an insulating material shall have a CTI PLC of 4 or less. For equipment rated 601-1500 volts, see footnote h.

[g] A material without a CTI PLC value or with a CTI PLC value greater (worse) than the value required by Table 16.1 shall have a proof tracking index of 175 when used in pollution degree 3 environment or a proof tracking index of 100 when used in pollution degree 1 or 2 environment as determined by the end-product Proof Tracking Test specified in UL 746C.

[h] For equipment rated 601 – 1500 volts, the insulating material shall not track beyond one inch in less than 60 minutes using the time to track method of the Inclined Plane Tracking Test specified in UL 746A. The voltage for the Inclined Plane Tracking Test shall be not less than the rated voltage of the equipment.

Table 16.2
Generic Materials for Direct Support of Uninsulated Live Parts

Generic material	Thickness, Inch	(mm)	RTI, °C
Diallyl Phthalate	0.028	(0.71)	105
Epoxy	0.028	(0.71)	105
Melamine	0.028	(0.71)	130
Melamine-Phenolic	0.028	(0.71)	130
Phenolic	0.028	(0.71)	150
Unfilled Nylon	0.028	(0.71)	105
Unfilled Polycarbonate	0.028	(0.71)	105
Urea Formaldehyde	0.028	(0.71)	100
Ceramic, Porcelain, and Slate	No limit		No limit
Beryllium Oxide	No limit		No limit
NOTE – Each material shall be used within its minimum thickness and its Relative Thermal Index (RTI) value shall not be exceeded during the Temperature Test, Section 45.			

16.2 Insulating material – such as a relay dust cover, transformer bobbin, printed wiring broad (PWB) insulating sheet, encapsulation, or the like – that is used as a barrier in lieu of the required over surface or through air spacings (or both) shall comply with the requirements in 38.1.

16.3 A printed wiring board shall comply with the requirements in UL 796, shall have a flammability rating of V-0, V-1, or V-2, and comply with the direct support requirements in 16.1.

16.4 An insulating material used for direct support as in 16.1, shall comply with Sections 8 – 10 of UL 746D, when:

a) More than 25 percent by weight of regrind thermoplastic is included;

b) Any amount of regrind thermoset material, such as phenolic, or melamine, is included;

c) The part is co-molded, using two different plastics in the same mold for a part; or

d) Made from any amount of recycled plastic.

17 Means for Switching

17.1 The position of a handle of a manual switching means shall be marked in accordance with 73.15.

17.2 If a circuit breaker or switch is mounted such that movement of the operating handle, either vertically or rotationally, between the on and off positions results in one position being above the other position, the upper position shall be the on position. The requirement does not apply to a circuit breaker or switch that is operated horizontally or that is operated rotationally and the on and off positions are at the same level, nor to a switching device having two on positions, such as a transfer switch or a double throw switch.

17.3 A single-throw knife switch shall be mounted so that gravity will not tend to close it.

17.4 A knife switch shall be connected so that the blade or blades are connected to the load circuit and are de-energized when the switch is open.

Exception: The blade or blades of a switch may be energized by a backfeed circuit when the switch is in an open position if the switch is marked in accordance with 75.11.

17.5 A direct-current motor-starting rheostat shall not complete the electrical circuit in the off or initial position

17.6 A motor-starting rheostat shall be constructed so that the contact arm or similar part cannot be left in any but the off position or the full running position.

17.7 A switch intended for mounting in an outlet box and with an identified "off" function, such as a marked "OFF" or "O" switch position, shall be constructed such that when the switch is in the "off" mode, all ungrounded conductors are completely opened by means of an air gap between the line and load terminals. For example, switches incorporating in-line components, such as neon indicators, that pass current through the load when the switch is open, shall not be marked "OFF" or "O".

18 Live Parts

18.1 A current-carrying part shall have mechanical strength and ampacity for the intended use and shall be of metal or other material that is acceptable for the application.

18.2 An uninsulated live part, including a terminal, shall be secured to its supporting surface by a method other than friction between surfaces so that it will be prevented from turning or shifting in position if such motion may result in reduction of spacings to less than those required elsewhere in this Standard. The security of a contact assembly shall maintain continued alignment of contacts.

Exception: A pressure terminal connector need not be prevented from turning providing no spacings less than those required result when the terminals are turned 30 degrees toward each other, or toward other uninsulated parts of opposite polarity, or toward grounded metal parts.

18.3 A live screwhead or nut on the underside of an insulating base shall be prevented from loosening and shall be acceptably insulated or spaced from the mounting surface. This may be accomplished by:

a) Countersinking such parts at least 1/8 inch (3.2 mm) and then covering them with a waterproof, insulating sealing compound that does not melt at a temperature of 15 °C (27 °F) higher than its normal operating temperature in the equipment, but at least 65 °C (149 °F); or

b) Securing such parts and insulating them from the mounting surface by a barrier, or the equivalent, or by through air or over surface spacings specified elsewhere in this Standard.

19 Protective Devices

19.1 General

19.1.1 For a single motor controller provided with branch-ciruit short-circuit and ground fault protection, a fuse-holder or circuit-breaker shall comply with the following:

a) The voltage rating of the fuseholder or circuit breaker shall be at least the voltage of any assigned horsepower rating;

b) The ampere rating or setting of a fuseholder or circuit breaker shall be at least 115 percent of the full-load current of any assigned horsepower rating; and

c) The ampere rating of an inverse-time circuit breaker shall be no more than:

1) Four times the largest full-load current of the assigned horsepower rating for a full-load current of 100 amperes or less; and

2) Three times the largest full-load current of the assigned horsepower rating for a full-load current greater than 100 amperes.

19.1.2 When the equipment includes one or more circuits supplying power to one or more lampholders or attachment-plug receptacles rated 15 amps or less, individual overcurrent protection rated not more than 20 amperes shall be provided as a part of the equipment.

Exception: No additional overcurrent protection is required in the equipment when it is intended to be connected in the field to a branch circuit rated not more than 20 amperes.

19.2 Protection of internal primary and secondary control circuit conductors

19.2.1 Conductors of control circuits that are connected to the load side of the motor branch-circuit short-circuit protective device – common control – shall be protected against overcurrent in accordance with Table 19.1 by protective devices located within the controller. Overcurrent protective devices shall be provided in each ungrounded conductor, located no more than 12 inches (305 mm) from the point where the conductor is connected to the source of power.

Table 19.1
Overcurrent Protection

Control-circuit wire size		Maximum protective device rating
AWG	(mm^2)	amperes
22	(0.32)	3
20	(0.52)	5
18	(0.82)	7
16	(1.3)	10
14	(2.1)	20
12	(3.3)	25

19.2.2 An additional protective device as in 19.2.1 is not required to be assembled as part of the controller when the rating or trip setting, in the case of an instantaneous-trip circuit breaker, of the motor branch-circuit short-circuit protective device is not more than the applicable value specified in Table 19.2. When the motor branch-circuit short-circuit protective device is not supplied with the controller, the controller is marked in accordance with 73.22. When the motor branch-circuit short-circuit protective device is an integral part of the controller and incorporates a fuseholder or an instantaneous-trip circuit breaker where the largest fuse or highest setting does not comply with Table 19.2, the controller is marked in accordance with 73.22.

Table 19.2
Branch-Circuit Short-Circuit Protection

Control-circuit wire size		Maximum rating of branch-circuit-protective device, amperes	
AWG	(mm^2)	Conductors within enclosure	Conductors outside enclosure
22	(0.32)	12	3
20	(0.52)	20	5
18	(0.82)	25	7
16	(1.3)	40	10
14	(2.1)	100	45
12	(3.3)	120	60

19.2.3 A controller that complies with 19.2.2 is able to have additional ratings that require protection for control circuit conductors to be added in the field when the manufacturer makes available an accessory kit with the protective device that complies with 19.2.1 intended for installation in the controller enclosure. The controller is marked in accordance with 73.21.

19.2.4 Direct leads measuring a maximum of 12 inches (305 mm) long or printed-wiring assemblies having no connection external to the motor controller, and having no more than casual contact with insulated or uninsulated parts of opposite polarity or with grounded parts need not be protected as required by 19.2.1.

19.2.5 A protective device specified in 19.2.1 shall be either a supplementary or a branch-circuit overcurrent-protective device. A fuse shall be factory installed in a supplementary fuseholder. A fuse is not required to be installed in a branch-circuit-type fuseholder. The controller shall be marked in accordance with 73.23 or 73.24 as applicable.

19.2.6 When the marked minimum short circuit current rating or marked maximum circuit capacity, required by 73.3, exceeds 10,000 amperes, only a branch-circuit overcurrent-protective device rated for the available fault current involved shall be used. When provided, fuses shall be Class CC, G, J, R, or T, and the fuseholder shall be appropriate for the fuse used. The controller shall be marked in accordance with 73.24.

19.3 Protection of control circuit transformer

19.3.1 A control circuit transformer shall be provided with overcurrent protection which complies with 19.2.5 and is one of the following types:

a) Individual overcurrent devices located in the primary circuit that are rated or set as specified in Table 19.3. Overcurrent protective devices shall be provided in each ungrounded conductor.

b) Secondary circuit protection rated or set at not more than 125 percent of the rated secondary current of the transformer and primary feeder circuit protection rated or set at not more than 250 percent of the rated primary current of the transformer.

Exception: When the rated secondary current of a transformer is 2 amperes or more, the current rating of the secondary overcurrent device shall be as indicated in line 2 or 3 of Table 19.3, as applicable.

c) Coordinated thermal overload protection arranged to interrupt the primary circuit when the primary circuit overcurrent device is rated for or set to open at a current of not more than:

1) For transformers having not more than 6 percent impedance – six times the rated current of the transformer.

2) For transformers having more than 6 but less than 10 percent impedance – four times the rated current of the transformer.

Exception: Overcurrent protection is not required when:

a) The transformer supplies a Class 1 power-limited, Class 2, or Class 3 remote-control circuit;

b) The transformer is rated less than 50 volt-amperes, is inherently protected, and is an integral part of the motor controller;

c) The primary feeder circuit overcurrent device provides the required protection; or

d) The protection is provided by other means that comply with the applicable requirements in NFPA 70-2002 and in this Standard.

Table 19.3
Maximum Acceptable Rating of Overcurrent Device

Rating primary current, amperes	Maximum rating of overcurrent protective device expressed as a percent of transformer primary current rating
Less than 2	500
2 to less than 9	167
9 or more	125[a]

[a] See 19.3.2.

19.3.2 When the rated primary current of the transformer is 9 amperes or more and 125 percent of this current does not correspond to a standard rating of fuse or nonadjustable circuit breaker, the next higher standard rating of protective device is able to be used. Standard ratings for fuses and inverse-time circuit breakers are specified in 53.1.2.2 and 53.1.3.2, respectively.

19.3.3 A control transformer and its primary and secondary conductors may be protected by overcurrent devices located in the primary circuit provided:

a) The transformer is single phase and has only a two-wire (single voltage) secondary;

b) The maximum value of an intended overcurrent device is determined in accordance with 19.3.1;

c) The maximum value of an intended overcurrent device as determined in 19.3.3(b) does not exceed the value of the overcurrent device obtained from Table 19.1 for the secondary conductor multiplied by the secondary-to-primary voltage ratio of the transformer; and

d) The overcurrent device complies with 19.2.5.

19.4 Low-voltage protection

19.4.1 A direct-current motor-starting rheostat shall be provided with a low-voltage protective device, operative on the reduction of voltage to less than one-third of its normal value, to cause and maintain the interruption of power to the main circuit.

19.5 Phase loss protection

19.5.1 A phase loss protective device shall operate upon the loss of power in one conductor of a polyphase circuit to cause and maintain the interruption of power in all of the circuit.

Exception: A phase loss protective device for an intermittently operated machine, such as a crane or an elevator, that has a definitely limited travel and a limited time for continuous running, may function only to prevent the restarting of the motor upon the loss of power in one conductor to the motor.

19.6 Phase-reversal protection

19.6.1 A phase-reversal protective device shall operate on the reversal of the phase rotation in a polyphase circuit to cause and maintain the interruption of power in all of the circuit.

20 Capacitors

20.1 A motor starting capacitor employing a liquid dielectric medium more combustible than askarel shall comply with the protected oil filled capacitor requirements in UL 810, including faulted overcurrent conditions based on the branch circuit in which it is used. See Short Circuit Test – General, Section 52. Also, these capacitors and any associated circuit solid-state components shall be evaluated in accordance with the Breakdown of Components Test, Section 60.

Exception: If the available fault current is limited by other components in the circuit such as a motor-start winding, the capacitor may be tested using a fault current less than the value specified in Table 53.3, but not less than the current established by dividing the rated circuit voltage by the impedance of the other components.

20.2 A non-motor starting capacitor employing a liquid dielectric medium more combustible than askarel, and any associated circuit solid-state components, need only be evaluated in accordance with the Breakdown of Components Test, Section 60.

21 Fuseholders

21.1 A fuseholder shall be of either the cartridge or plug fuse type.

21.2 A cartridge fuseholder shall be constructed for use with a branch-circuit fuse.

Exception: If a supplementary fuse is used as specified in 19.2.5, the fuseholder shall be constructed for use with the supplementary fuse.

21.3 A plug fuse shall not be used in equipment rated more than 125 or 125/250 volts.

22 Internal Wiring

22.1 General

22.1.1 The wiring and connections between parts of the equipment shall be protected from mechanical damage during installation.

22.1.2 The insulation on all internal wires of the equipment shall be rated for the voltage and the temperature conditions of use. It shall also be considered with respect to other conditions of service to which it is likely to be subjected. Wire insulation shall be at least 1/32 inch (0.8 mm) thick if it is subjected to movement, flexing, or handling during its intended use, or during maintenance.

Exception: Internal wires used for grounding or bonding need not be insulated.

22.2 Routing of internal wiring

22.2.1 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 may bear to reduce the risk of abrasion of the insulation.

22.2.2 Wires shall be routed away from sharp edges, screw threads, burrs, fins, moving parts, drawers, and the like, that can abrade the wire insulation.

22.3 Clamps and guides

22.3.1 Clamps and guides, 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 cannot 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.

22.4 Flexing of internal wiring

22.4.1 Wiring that is subject to flexing during servicing such as that from a stationary part to a part mounted on a hinged door shall be provided with additional insulation at any point where it is flexed, unless the wiring is flexible cord.

Exception: Additional insulation is not required if the test described in Wire Flexing, Section 63 is completed without evidence of damage to the wiring.

22.5 Additional insulation

22.5.1 Additional insulation, if used, shall be insulating sleeving, tubing, or a wrapping of not less than two layers of insulating tape. The insulation shall be made of materials rated for the temperature and voltage involved.

22.6 Splices and connections

22.6.1 All splices and connections shall be mechanically secure and shall provide electrical continuity.

22.6.2 Electrical connections shall be soldered, welded, crimped, or otherwise securely connected. A soldered joint shall be mechanically secure before soldering.

Exception: Printed wiring board joints need not be mechanically secure before soldering.

22.6.3 A soldered lead is mechanically secure when it is:

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.

22.6.4 If stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire cannot contact other uninsulated live parts not always of the same polarity as the wire, and de-energized metal parts. This can be accomplished by any acceptable means including use of machine- or tool-applied pressure terminal connectors, soldering lugs, or crimped eyelets, or soldering all strands of the wire together.

22.7 Splice insulation

22.7.1 A splice shall be provided with insulation equivalent to that of the wires involved.

22.7.2 In determining if splice insulation consisting of coated-fabric, thermoplastic, or other types of tubing is acceptable, consideration is to be given to electrical and mechanical properties including dielectric voltage-withstand ability, heat resistance, and moisture resistance. See 22.5.1. Thermoplastic tape shall not be wrapped over a sharp edge or connection.

23 External Interconnections

23.1 Open equipment

23.1.1 The means provided for the interconnection of open equipment within a control enclosure such as interconnecting cable, cord, or harness, shall be evaluated as internal wiring in accordance with the requirements for Internal Wiring, Section 22. The means provided for the interconnection of open equipment to remote equipment outside of the control enclosure, such as by means of permanently installed field wiring, shall comply with the requirements for Supply Connections, Section 26.

23.2 Enclosed equipment

23.2.1 The means provided for the interconnection of enclosed equipment shall comply with the requirements of 23.3.1 – 23.3.4, except that equipment with field wiring provisions to facilitate interconnection by means of permanently installed field wiring shall comply with the requirements of Supply Connections, Section 26.

23.3 Interconnecting cords and cables

23.3.1 Cable assemblies and flexible cords provided for interconnection between sections of equipment or between units of a system shall be of a type that is acceptable for the service or use involved and shall be provided with bushings and strain relief.

23.3.2 Misalignment of male and female connectors, insertion of a multipin male connector in a female connector other than the one intended to receive it, and other manipulations of parts that are accessible to the operator shall not result in mechanical damage or a risk of fire, electric shock, or injury to persons.

23.3.3 If 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.

23.3.4 An interlock circuit in the cable to de-energize the exposed contacts whenever an end of the cable is disconnected is an acceptable method of complying with the requirement in 23.3.3.

24 Transformers

24.1 A transformer employed in industrial control equipment shall comply with UL 5085-1 and UL 5085-2, unless the load is part of the equipment. Where the transformer is part of the equipment, the transformer shall comply with the construction requirements as noted elsewhere, the Temperature Test, Section 45, and the Dielectric Voltage-Withstand Test, Section 51, in this Standard.

Exception: Pulse and current transformers constructed in a manner other than allowed by the applicable UL transformer standard are considered to be in compliance with this requirement if they can withstand, without breakdown, a dielectric voltage withstand potential in accordance with Section 51, applied between the primary and the secondary windings. An example of transformer constructions for which this exception would apply are those that may rely upon magnet wire coating to provide isolation instead of inter-winding tape.

25 Blower Motors

25.1 Each blower motor shall be capable of delivering its maximum normal load without introducing risk of fire, electric shock, or injury to persons. The motor winding shall resist the absorption of moisture. See Coil Windings, Section 28.

25.2 Each blower motor shall incorporate one of the following forms of locked rotor protection:

a) Thermal protection complying with the applicable requirements in UL 2111;

b) Impedance protection complying with the applicable requirements in UL 2111; or

c) Other protection that is shown by test to be equivalent to the protection specified in 25.2(a).

26 Supply Connections

26.1 General

26.1.1 Supply connections are considered to be those electrical connections that are made in the field when the equipment is installed.

26.2 Permanently connected equipment

26.2.1 Industrial control equipment intended for permanent connection to the power supply shall have provision for connection of one of the applicable wiring systems in accordance with NFPA 70-2002.

Exception: An enclosure is not required to have provision for the connection of a wiring system, such as a conduit hub, a knockout or a fitting, if it is intended to be drilled or punched in the field to accommodate a wiring system and is provided with appropriate installation instructions.

26.3 Tapped holes for conduit

26.3.1 A tapped hole in a cast metal enclosure for the attachment of threaded rigid conduit shall be provided with:

a) An integral bushing having a smooth, rounded inlet hole with a diameter approximately the same as the internal diameter of a standard bushing to provide protection for the conductors equivalent to that provided by such a bushing, or shall be located so that a standard bushing may be attached to the end of the conduit; and

b) At least three full threads when tapped all the way through the wall of an enclosure, or with at least 3-1/2 full threads when used with an integral bushing.

26.4 Knockouts

26.4.1 A knockout in a sheet-metal enclosure shall be reliably secured but capable of being removed without undue deformation of the enclosure.

26.4.2 A knockout shall be provided with a flat surrounding surface for proper seating of a conduit bushing, and shall be located so that installation of a bushing at any knockout likely to be used during installation will not result in spacings between uninsulated live parts and the bushing that are less than the minimum values specified in this Standard.

26.5 Size of wiring terminals and leads

26.5.1 Except as noted in 26.6.5, industrial control equipment shall be provided with wiring terminals or leads for connection of conductors having an ampacity or wire size not less than 14 AWG for power- or lighting-circuit conductors or the largest of the following, whichever is larger, for each field wiring terminal:

a) The ampere rating of the circuit.

b) One-hundred twenty-five percent of the full-load motor current specified in Table 47.2 or Table 47.3 for the horsepower rating, or, in the case of power conversion equipment, in which the input current is different from motor full-load current, 125 percent of maximum rated input current.

c) One-hundred twenty-five percent of the resistive ampere rating of the devices intended to control fixed electric space-heating equipment loads.

d) For equipment controlling a direct-current motor intended to be operated from a rectified single-phase power supply;

1) One-hundred ninety percent of full load current when a half wave rectifier is used.

2) One-hundred fifty percent of full load current when a full wave rectifier is used.

Exception: Item (d) does not apply when the product is marked in accordance with 75.9.

e) 14 AWG (2.1 mm^2) for control, signal, or sensor circuits unless the terminals are intended and marked (on product or installation instructions) for the connection of smaller conductor size or sizes.

f) Minimum 14 AWG (2.1 mm^2) for power circuits.

26.5.2 Equipment having a current rating or a horsepower rating with a full-load motor current as specified in Table 47.2 or Table 47.3 is connected with wire of a size determined in accordance with Table 45.3. Unless marked for use only with wire rated 75 °C (167 °F), the size is to be based upon wire rated for a 60 °C (140 °F) temperature for equipment rated 100 amperes or less; and upon wire rated for 75 °C for equipment rated greater than 100 amperes. The type of insulation is not specified.

26.5.3 When a wiring terminal will receive the next larger size conductor than that required in 26.5.1, the terminal shall comply with secureness and pullout requirements with that size conductor, unless the equipment is marked to restrict its use to only the smaller size conductor as in 74.10.

26.6 Evaluation of pressure wire connectors

26.6.1 A field-wiring pressure wire connector provided with or specified for use with industrial control equipment shall comply with one of the following, as applicable:

a) The performance requirements in UL 486A-486B; or

b) The performance requirements in UL 486E.

26.6.2 The tightening torque for a field-wiring terminal shall be as specified by the industrial control equipment manufacturer and shall be marked as specified in 74.12. The specified tightening torque shall not be less than 90 percent of the value employed in the temperature test or static heating test as specified in the requirements in UL 486A-486B or UL 486E, for that wire size corresponding to the ampere rating of the industrial control equipment.

Exception No. 1: When the tightening torque is less than 90 percent of the value specified, the connector shall be investigated in accordance with UL 486A-486B or UL 486E, with the lesser assigned torque value.

Exception No. 2: A field-wiring terminal intended only for the connection of a control circuit conductor is not required to be marked with a value of tightening torque when tested in accordance with the applicable requirements in UL 486A-486B or UL 486E, with a value of tightening torque of 7 pound-inches (0.8 N·m).

26.6.3 A field wiring terminal intended for field wiring of conductors smaller than 14 AWG (2.1 mm^2) as specified by the installation instructions or wiring diagram furnished with the device, the terminal shall comply with the requirements in 26.6.1 and 26.6.2:

a) For such conductors; and

b) For 18 AWG (0.8 mm^2) when the specified conductors are smaller than 18 AWG.

26.6.4 A pressure wire terminal shall comply with the Verification of the Performance of Terminal Assemblies Test in UL 1059.

26.6.5 A pressure terminal connector, including one that is compression tool applied, for field connection to line or load is not required to be provided for equipment with field wiring larger than 10 AWG (5.3 mm^2) when the construction complies with the following conditions:

a) Component terminal connectors are available from the equipment manufacturer and one or more are specified for field installation on the equipment.

b) A fastening device, such as a stud, nut, bolt, spring or flat washer, or similar fastening device, that is required for installation provided as part of the component terminal assembly, or mounted on or separately packaged with the equipment.

c) The installation of the terminal assembly does not involve the loosening or disassembly of a part other than a cover or other part giving access to the terminal location. The means for securing the terminal connectors shall be accessible for tightening before and after installation of the conductor.

d) If the pressure connector provided in a component terminal assembly requires the use of other than an ordinary tool for securing the conductor, instructions referencing use of the tool shall be included with the component assembly or with the equipment.

e) Installation of a pressure terminal connector in the intended manner shall result in a product that complies with the requirements in this Standard.

f) The equipment is marked in accordance with 74.11.

26.7 Evaluation of quick connect terminals

26.7.1 A quick connect terminal shall be used with 22 – 10 AWG conductors. A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch wide quick-connect terminal shall comply with UL 310. Other sizes of quick-connect terminals shall be investigated with respect to such areas as crimp pullout, engagement-disengagement forces of the connector and tab, and temperature rises in accordance with UL 310.

Note: A quick connect terminal may consist of either a connector (Female QC) or a production tab (Male QC).

26.7.2 A quick connect tab shall comply with the Tab Pull Test of UL 1059, and the construction requirements in accordance with UL 310.

26.8 Evaluation of wire binding screws

26.8.1 A terminal to which 10 AWG (5.3 mm^2) or smaller wiring connections are to be made shall consist of a clamp or binding screw with a terminal plate having upturned lugs or the equivalent to hold the wire in position.

26.8.2 A wire-binding screw to which field-wiring connections are made shall have a major thread diameter of 0.154 inches (3.91 mm) minimum.

Exception: A wire-binding screw with a major thread diameter of 0.128 inches (3.25 mm) minimum is able to be used for a terminal intended only for connection of a 14 AWG (2.1 mm^2) conductor.

26.8.3 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. There shall be at least two full threads in the plate.

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

26.8.4 A terminal plate formed from stock having the required thickness specified in 26.8.3 is able to have the metal extruded at the tapped hole for the binding screw to provide two full threads.

26.8.5 A wire-binding screw shall thread into metal.

26.9 Evaluation of field wiring leads

26.9.1 A lead that is intended to be spliced in the field to a circuit conductor shall not be smaller than 18 AWG (0.8 mm^2) and the insulation, when rubber or thermoplastic, shall not be less than 1/32 inch (0.8 mm) thick.

26.9.2 The free length of a field wiring lead shall be not less than 6 inches (152 mm) long.

Exception: The free length of a field wiring lead shall not be less than 4 inches (100 mm) long when intended for installation in an outlet box.

26.9.3 A field wiring lead shall comply with the Strain Relief Test in Section 61.

26.10 Evaluation of spring type terminations

26.10.1 Spring type terminations shall comply with the requirements in Part III – Spring Force Connections in UL 1059.

26.11 Cord-connected equipment

26.11.1 Equipment that complies with 26.11.2 and is to be cord-connected to the power supply shall be provided with hard-service or junior hard-service flexible cord, such as Type S, SJ, or the equivalent, that is rated for the temperature and voltage involved.

Exception: Such equipment is not required to be provided with a hard service or junior hard service type cord if the cord is 14 AWG or smaller and complies with requirements for proximity switches in Power-

Supply Cord Tests, Section 157, Cable Gland Connector Tests, Section 158, Strain Relief Test, Section 159 and:

a) The application or design of the equipment is such that it does not allow the use of a hard service or junior hard service cord, and the previously evaluated cord will not be subjected to abuses seen in general use cord application; or

b) The cord is used in circuits which comply with Class 2 or Limited Voltage/Current Isolated Secondary Circuits, Section 33.

26.11.2 Equipment is able to be cord-connected when the equipment is:

a) Portable;

b) Free standing or stationary (not permanently connected to building wiring);

c) A pendant;

d) Proximity Switches as described in Part XVIII;

e) Restricted for use in industrial machinery applications as defined in NFPA 79, and marked in accordance with 73.37;

f) Open type; or

g) As described in 26.11.11.

26.11.3 The cord ampacity, as specified in Table 26.1, shall not be less than the ampacity required for the equipment in 26.5.1.

Table 26.1
Ampacity of Flexible Cord

Conductor size AWG	Number of conductors	
	2	3[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.

26.11.4 When provided, a standard attachment plug or multi-pin connector shall be rated for the voltage involved and have an ampere rating not less than the required cord ampacity as in 26.11.3.

26.11.5 Cord-connected equipment provided with a standard attachment plug whose ampere rating exceeds the ampacity of the power supply cord shall be provided with an integral overcurrent protective device rated not more than the ampacity of the conductors. Cord-connected equipment provided with a multi-pin connector or without any attachment plug or connector shall be:

a) Provided with integral overcurrent protection rated not more than the ampacity of the conductors; or

b) Marked as in 73.34 to indicate the ratings of the overcurrent protection required to be installed in the field.

26.11.6 Strain relief shall be provided on power supply or signal multicable cords.

26.11.7 At the point at which the cord passes through the enclosure wall, protection shall be provided to prevent cord abrasion.

26.11.8 If a knot serves as strain relief in an attached flexible cord, any surface that the knot may contact shall be free from projections, sharp edges, burrs, fins and the like, that may cause abrasion of the insulation on the conductors.

26.11.9 Means shall be provided to prevent the supply cord from being pushed into the enclosure through the cord-entry hole when such displacement results in:

a) Subjecting the supply cord or lead to mechanical damage;

b) Exposing the supply cord or lead to a temperature higher than that for which it is rated;

c) Reducing spacings (such as to a metal strain-relief clamp) below the minimum required values; or

d) Damaging internal connections or components.

To determine compliance, the supply cord shall be tested in accordance with Section 62, Push-Back Relief Test.

26.11.10 A power-supply or signaling connecting cord, used on equipment having a:

a) Type 3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 6, or 6P enclosure shall be acceptable for outdoor use;

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

c) Type 12, 12K, or 13 enclosure shall be oil resistant (such as SO, SJO, or STO).

26.11.11 For a device that is intended to provide a signaling function, an attachment plug is not required.

26.11.12 Multi-pin cord fittings and cord sets of equipment restricted to use in industrial machinery applications as defined in NFPA 79, and intended for use in power and motor branch circuits shall comply with the requirements in UL 2237.

26.11.13 Multi-pin cord fittings and cord sets of equipment restricted to use in industrial machinery applications as defined in NFPA 79, and intended for use in control circuits shall comply with the requirements in UL 2238.

27 Cord-Connected Programming and Diagnostic Units

27.1 Auxiliary units such as portable programmers intended to be used only on a temporary basis, to diagnose or program industrial controls shall comply with UL 60950-1. These units may be considered as a subsystem of the industrial electronic control equipment.

28 Coil Windings

28.1 A coil winding shall resist the absorption of moisture. This may be accomplished by impregnating, dipping in or brushing with varnish, or by other acceptable means.

Exception: A coil made with film-coated wire need not have additional treatment to resist moisture absorption.

29 Risk of Electric Shock

29.1 A risk of electric shock is considered to exist within a circuit unless that circuit meets one of the following criteria:

a) The circuit is supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V ac or 42.4 V peak; or

b) The circuit is supplied by an isolating source such that the current available through a 1500 ohm resistor connected across any potential in the circuit (including to ground) does not exceed 5 mA.

29.2 The secondary circuits that do not involve a risk of electric shock are:

a) A Class 2 circuit;

b) A Limited Voltage/Current circuit;

c) A Limited Voltage circuit;

d) A Limited Energy circuit that involves open circuit potential less than or equal to 30 V ac or 42.4 V peak;

e) A Limiting Impedance circuit that complies with 29.1; and

f) A Limited Power Source.

30 Risk of Fire

30.1 A risk of fire is considered to exist within a circuit unless that circuit meets one of the following criteria:

a) The circuit is supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V ac or 42.4 V peak and the current available is limited to a value not exceeding 8 amperes measured after 1 minute of operation; or

b) The circuit is supplied by an isolating source such that the power available to the circuit is limited to a value less than 15 watts.

30.2 The secondary circuits that do not involve a risk of fire are:

a) A Class 2 circuit;

b) A Limited Voltage/Current circuit;

c) A Limiting Impedance circuit; and

d) A Limited Power Source.

31 Lithium Cells and Batteries

31.1 This section applies to rechargeable lithium (typically lithium ion) and non-rechargeable lithium (typically lithium metal) batteries supplying power to any primary or secondary circuit. A circuit supplied by a lithium cell or battery shall comply with the primary circuit requirements in this Standard or with the requirements for Secondary Circuits, Section 32.

31.2 Equipment provided with replaceable lithium single cell batteries and battery packs shall be marked in accordance with 75.14.

31.3 An individual, non-rechargeable lithium single cell battery shall comply with UL 1642 or UL 60086-4.

Note – An individual lithium single cell battery includes coin type batteries and other commercially available batteries such as "AA", "AAA", "C", "D" format lithium batteries.

31.4 A battery pack or battery system, that is a single cell or multiple cells with control or protection circuitry for the battery, shall comply with UL 2054, for batteries at or below 60 Vdc and 1 kWh.

31.5 A battery pack/system above 60 Vdc or 1 kW-h or one that is not wholly enclosed within the end product shall comply with UL 1973.

31.6 A battery pack/system with its own enclosure is not required to be placed inside the end-product enclosure.

32 Non-Lithium Battery Circuits

32.1 General

32.1.1 A non-lithium battery circuit is a primary or secondary circuit that obtains power from rechargeable or non-rechargeable, non-lithium batteries.

32.1.2 A non-lithium battery circuit shall comply with the following:

a) The primary non-rechargeable (see 32.2) or secondary rechargeable/non-rechargeable (see 32.3) requirements; and

b) The primary circuit requirements in this Standard or with the requirements for Isolated Secondary Circuits, Section 33.

32.2 Primary non-rechargeable

32.2.1 A primary non-rechargeable non-lithium battery circuit shall involve a battery that has an output in compliance with the requirements for a Class 2 (see 33.2) or Limited Voltage/Current secondary circuit (see 33.3).

32.3 Secondary rechargeable/non-rechargeable

32.3.1 A secondary rechargeable/non-rechargeable non-lithium battery circuit shall involve a battery that has an output in compliance with the requirements for a Class 2 (see 33.2) or Limited Voltage/Current (33.3) secondary circuit.

32.3.2 Charging circuitry for these battery circuits shall be derived from an isolating source that complies with the Class 2 (see 33.2), the Limited Voltage/Current (see 33.3), the Limited Voltage (see 33.4), the Isolated Power Supply (see 33.5), or the Limited Energy (see 33.6) circuit requirements in Section 33.

33 Isolated Secondary Circuits

33.1 General

33.1.1 An isolated secondary circuit is a control circuit that is isolated at all points from the primary branch circuit. This isolation shall be provided by means such as a transformer, optical isolator, limiting impedance, or electro-mechanical relay.

33.1.2 In addition to the requirements for Separation of Circuits, Section 35, a secondary circuit shall comply with the requirements for a primary circuit or with the isolated secondary circuit requirements in 33.1 and the applicable requirements for one of the following types of secondary circuits:

a) A Class 2 circuit (see 33.2);

b) A Limited Voltage/Current circuit (see 33.3);

c) A Limited Voltage circuit (see 33.4);

d) An Isolated Power Supply circuit (see 33.5);

e) A Limited Energy circuit (see 33.6);

f) A Limiting Impedance circuit (see 33.7); or

g) A Limited Power Source (see 33.8).

33.1.3 The construction and performance requirements for various secondary circuits described in 33.1.2 shall be as in Table 33.1.

Table 33.1
Differences Between the Level of Evaluation Required Within Each Type of Secondary Circuit

Section		Type of secondary circuit:								
		Class 2 and limited power source	Limited voltage / current	Limited voltage	Limited energy		Limiting impedance			Isolated power supply
29	Risk of electric shock	–	–	–	–	x	–	–	x	x
30	Risk of fire	–	–	x	x	x	–	–	–	x
Electrical Characteristics of Isolated Secondary Source (ISC):										
33	Maximum voltage,ac	x[b]	30	30	30	100	–	30	–	150
	Maximum voltage, peak	x[b]	42.4	42.4	42.4	–	–	42.4	–	–
	Max. secondary current, A	x[b]	8	–	–	–	0.005[a]	–	–	–
	Max. secondary power, VA	x[b]	100	–	200	200	15 W	15 W	15 W	10,000
Component Requirements within Isolated Secondary Circuit (ISC):										
31	Lithium batteries	x	x	x	x	x	x	x	x	x
16	Printed wiring boards	–	–	x[c]	x[c]	x[c]	–	–	–	x[c]
22	Internal wiring	–	–	x	x	x	–	–	–	x
25	Blower motors	–	–	–	–	x	–	–	–	x
26	Field wiring terminals	x	x	x	x	x	x	x	x	x
	All other ISC components	x[d]	x[d]	x[d]	x[d]	x[d]	x[d]	x[d]	x[d]	x[d]
Spacing Requirements for Isolated Secondary Circuit (ISC):										
37	Within ISC	–	–	–	–	–	–	–	–	–
	Between ISC and ground	–	–	–	–	x	–	–	x	x[e]
	Between ISC and enclosure or accessible parts	–	–	–	–	x	–	–	x	x[e]

Table 33.1 Continued on Next Page

Table 33.1 Continued

Section		Type of secondary circuit:								
		Class 2 and limited power source	Limited voltage / current	Limited voltage	Limited energy		Limiting impedance			Isolated power supply
	Between ISC and other isolated circuits	x[g]	x[g]	x[g]	x[g]	x[g]	x[g]	x[g]	x[g]	x[g]
Enclosure Requirements for Isolated Secondary Circuit (ISC):										
7	ISC must be enclosed	–	–	x	x	x	–	–	x	x
Performance Requirements[f] **Isolating Source (Such as: Transformer, Power Supply, Limiting Impedance, Battery):**										
45	Temperature	x[d]	x	x	x	x	x	x	x	x
51	Dielectric	x	x	x	x	x	x	x	x	x
65	Secondary circuit	x[b]	x	x	x	x	x	x	x	x
60	Breakdown of components	x[b]	x	x	x	x	x	x	x	x
58	Transient voltage surge suppression	–	–	–	–	–	–	–	–	x
Isolation Components (Such as: Optical Isolator, relay, power switching semiconductor)										
45	Temperature	x[d]	x	x	x	x	x	x	x	x
51	Dielectric	x	x	x	x	x	x	x	x	x

NOTE: An "x" indicates the requirement applies or the condition exists. A "–" indicates the requirement does not apply, or the condition does not exist.

[a] See 29.1(b).

[b] For Class 2 sources see UL 1310 or UL 5085-1 and UL 5085-3 for maximum electrical characteristics and performance requirements. For Limited Power Sources see UL 60950-1 for maximum electrical characteristics, construction and performance requirements.

[c] Printed wiring boards shall comply with 16.3 and shall be rated V-2, V-1 or V-0.

[d] No evaluation of secondary components required except the effect of heat generating components in the isolated secondary circuit on adjacent components such as printed wiring boards and wiring shall be evaluated during the temperature test.

[e] Spacings comply with 33.5.1(c).

[f] Tests specified in this table evaluate isolating components for use with secondary circuits and does not indicate all tests applicable to the isolating components.

[g] See 33.1.4.

33.1.4 Spacings and isolation between two or more isolated secondary circuits of the same or different types as identified in 33.1.2 are not required when:

a) Testing and/or analysis shows that, due to the breakdown of a single spacing or single component fault, the resulting circuit complies with the requirements applicable to a single isolated secondary circuit; and

b) The equipment complies with the applicable requirements of this Standard when incorporating the isolated secondary circuit that results from the failure of a single spacing or single component fault.

33.2 Class 2 circuit requirements

33.2.1 A Class 2 circuit shall be supplied by an isolating source that complies with the requirements in UL 1310, or the requirements in UL 5085-1 and UL 5085-3.

Exception: A circuit intended to be supplied from an isolating source that complies with 33.2 in the field shall be marked as in 73.31.

33.3 Limited voltage/current circuit requirements

33.3.1 A limited voltage/current circuit shall be supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V ac or 42.4 V peak and the current available is limited to a value not exceeding 8 amperes measured after 1 minute of operation.

33.3.2 The secondary winding of an isolating type transformer or power supply tested in accordance with 65.2 is able to be used to comply with this requirement. For a device (circuit) that is intended to be supplied by an isolating source that complies with this requirement and that is intended to be supplied as an accessory in the field, the device shall be marked as in 76.1 – 76.3.

33.3.3 A secondary fuse or other such secondary circuit protective device used with an isolating source to limit the available current in accordance with 33.3.1, shall be rated at not more than the values specified in Table 33.2. When a secondary fuse that complies with UL 248 series of standards is used, the test specified in 65.2 is not required. Other types of protective devices and protective devices with a rating higher than in Table 33.2 shall be evaluated as in 65.2.

Exception No. 1: When the protective device, that complies with Table 33.2, and isolating source are intended to be supplied in the field, the device is marked as in 73.32.

Exception No. 2: When the protective device and isolating source, that have been found to comply with 65.2, are intended to be supplied in the field, the device is marked as in 76.1 – 76.3.

Table 33.2
Rating for Fuse or Circuit Protective Device

Open circuit volts, ac rms (dc peak)	Amperes
0 – 20 (0 – 28.3)	5.0
Over 20 – 30 (28.3 – 42.4)	100/V[a]
[a] V is defined as the maximum open circuit voltage.	

33.3.4 The secondary circuit protective device referenced in 33.3.3 is able to be provided in the primary circuit. When provided in the primary circuit, there are no restrictions on the current rating of the protective device as long as it limits the available secondary current in accordance with Table 33.2.

33.3.5 When a protective device is used as specified in 33.3.3 or 33.3.4, this protective device shall comply with the requirements of this Standard and shall be provided with an adjacent replacement marking or replacement instructions that includes the required voltage and current rating. The printed wiring board, wiring, and spacings prior to the point at which the voltage and current are limited shall comply with the primary circuit requirements of this Standard.

33.3.6 A fixed impedance (such as a component or grouping of components in the same circuit) or a regulating network (such as used in a switching type power supply) is able to limit the voltage and/or the available current in accordance with 33.3.1. Such a fixed impedance or regulating network shall be able to function under single component fault conditions.

33.4 Limited voltage circuit requirements

33.4.1 A Limited Voltage circuit shall be supplied by an isolating source that complies with the following:

a) The maximum open circuit voltage potential available to the circuit shall not be more than 30 V ac or 42.4 V peak without any limitation on the available current or volt-ampere capacity;

b) All external secondary-circuit interconnecting cables and all secondary-circuit wiring between units shall be protected against burnout and damage to the insulation resulting from any overload or short-circuit condition that is able to occur during use of the equipment. Overcurrent protection shall be provided in the secondary circuit and comply with Table 19.1 or the isolated secondary circuit shall comply with the secondary circuit test, Section 65.5. Overcurrent protection provided in the primary circuit of the isolating source is able to serve as protection for the secondary circuit when it complies with 19.3.3 or the secondary circuits test, Section 65.5; and

c) These circuits are intended for use in a pollution degree 2 environment.

Exception No. 1: When the protective device, that complies with Table 19.1, and isolating source are intended to be supplied in the field, the device is marked as in 73.32.

Exception No. 2: When the protective device and isolating source, that have been found to comply with 65.5, are intended to be supplied in the field, the device is marked as in 76.1 – 76.3.

33.5 Isolated power supply circuit requirements

33.5.1 An isolated power supply circuit shall comply with the following:

a) The secondary circuit is supplied from the secondary of an isolating source that complies with 65.4.
b) The construction or circuitry shall suppress internally and externally generated surges in the secondary circuit to at least 300 volts peak. See Transient Voltage Surge Suppression Test, Section 58.

c) Spacings shall not be less than 1/8 inch (3.2 mm) through air and over surface, between live parts of the secondary circuit and operator-accessible metal, or grounded dead metal including the enclosure.

Exception No. 1: These spacings shall not be less than 1/16 inch in secondary circuits rated 50 volts or less.

Exception No. 2: When spacings are less than specified above, the construction shall withstand, without breakdown or arc-over the application of an ac potential of twice the rated voltage plus 1000 V (or a dc potential of 1.4 times the sum of twice the rated voltage plus 1000 V) for 60 seconds between the secondary and accessible or grounded noncurrent carrying metal parts. During the test any component normally connected to ground is to be disconnected.

33.6 Limited energy circuit requirements

33.6.1 A limited energy circuit shall be supplied by an isolating source such that the maximum volt-ampere capacity available to the circuit is 200 volt-amperes or less at a maximum open circuit voltage potential of 100 V ac. The isolating source shall comply with the test described in 65.3. For a device (circuit) that is intended to be supplied by an isolating source that complies with this requirement and that is intended to be supplied as an accessory in the field, the device shall be marked as in 76.1 – 76.3.

33.6.2 A primary or secondary circuit fuse or other such circuit protective device is able to be used to limit the maximum available volt-ampere capacity in accordance with 33.6.1. There are no restrictions on the current rating of this protective device as long as it limits the available secondary volt-ampere limit in accordance with 33.6.1. The protective device shall comply with the requirements of this Standard and shall be marked as in 73.23.

33.7 Limiting impedance circuit requirements

33.7.1 A limiting impedance circuit relied upon to reduce the risk of fire as defined in Section 30 shall be supplied by an impedance that complies with the following:

a) The calculated power dissipation of the impedance, as the result of a direct short applied across the circuit limited by the impedance, does not exceed the power rating of the impedance and the power dissipation is less than 15 watts; or

b) The impedance shall:

1) Be rated such that the calculated power dissipation of the impedance, as the result of a direct short applied across the circuit limited by the impedance, exceeds the power rating of the impedance and is still less than 15 watts; and

2) Not open or short when subjected to the effects of a direct short applied across the circuit limited by the impedance as described in 65.6.1.

c) The circuit shall be evaluated as in 65.6.2 to determine the points where less than 15 watts are available and then subjected to the test described in 65.6.1.

33.7.2 The 15-watt power limitation of the impedance shall not be exceeded under single component fault conditions. A limiting impedance relied upon to reduce the risk of electric shock as in 29.1(b) shall comply with 29.1(b) under single component fault conditions.

Exception No. 1: When the circuit limited by the 15-watt impedance is enclosed, the effect of single component fault conditions is not evaluated.

Exception No. 2: A single resistor serving as a limiting impedance is considered to comply with this requirement without further investigation.

Exception No. 3: A single capacitor serving as a limiting impedance is considered to comply with this requirement without further investigation when the capacitor complies with requirements in UL 1414.

33.7.3 A limiting impedance, relied upon to reduce the risk of electric shock as defined in Section 29, shall comply with 33.7.2 and 33.7.5 and one of the following:

a) The limiting impedance is connected to the high potential side of or as a voltage divider across a grounded single phase supply voltage rated not more than 150V and serves to limit the voltage within the isolated secondary circuit to be less than 30V rms or 42.4V peak within the isolated secondary circuit and also with respect to ground as determined by circuit analysis;

b) The limiting impedance is connected to each of two ungrounded supply voltage lines from a 120/240V supply or two or three ungrounded supply voltage lines from a three phase supply and serves to limit the voltage within the isolated secondary circuit to be less than 30V rms or 42.4V peak within the isolated secondary circuit and also with respect to ground as determined by circuit analysis for any primary voltage system supplying the equipment; or

c) The limiting impedance complies with the test in 65.6.1.2.

33.7.4 A limiting impedance circuit that complies with 33.7.1 and does not comply with 33.7.3 shall:

a) Be insulated from or have spacings to grounded metal or accessible parts; and

b) Not have external connections from the limiting impedance circuit that leave the equipment enclosure; or

c) Be marked with a cautionary marking indicating the maximum voltage to ground that is able to be present on the low voltage output from the equipment; or

d) Comply with the test in 65.6.1.2 when performed between each of the field wiring terminals of outputs from the limiting impedance circuit to ground.

33.7.5 A circuit element relied upon to limit the voltage, current, or both to the values specified in Section 29 shall not experience an electrical stress factor:

a) Greater than 0.5 during all conditions of normal operation; or

b) Greater than 1.0 after single component failure with respect to rated voltage, current and dissipated wattage.

The electrical stress factor is defined as ratio of applied electrical characteristic to rated electrical characteristic (applied current to rated ampacity).

33.8 Limited power source circuit requirements

33.8.1 A Limited Power Source shall be supplied by an isolating source that complies with the requirements in UL 60950-1.

Exception: A circuit intended to be supplied from a Limited Power Source that complies with 33.8 in the field shall be marked as in 73.38.

34 Limited Voltage Primary Circuit

34.1 Equipment supplied from a Limited Voltage source rated less than 30 Vrms or 42.4 V peak for control of motors or other loads shall comply with the requirements for a primary circuit, Sections 13 – 28 and 35 – 77, and applicable requirements from Parts II – XVIII.

35 Separation of Circuits

35.1 A factory-installed conductor shall be separated by a barrier or segregated as specified in 35.2 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.

35.2 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.

35.3 A conductor shall be provided with strain relief in accordance with 26.11.6 – 26.11.9 if stresses on the conductor might cause the conductor to move such that compliance with 35.1 is not maintained.

35.4 The equipment shall be constructed so that a field-installed conductor of any circuit is segregated as specified in 35.6 or separated by a barrier (see 35.5) from:

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

1) Both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3; and

2) The conductors of both circuits will 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.

35.5 With respect to 35.4, if the intended uses of the device are such that in some applications a barrier is required while in some other applications no barrier is required, a removable barrier or one having openings for the passage of conductors may be employed. Instructions for the use of such a barrier are to be a permanent part of the device.

35.6 Field-installed conductors may be segregated from each other and from uninsulated live parts or factory-installed conductors of the industrial control equipment 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.

36 Isolation Devices

36.1 An optical isolator that is relied upon to provide isolation between primary and secondary circuits or between other circuits as required by this Standard shall comply with UL 1577, and shall be able to withstand for 1 minute, without breakdown, an ac dielectric voltage withstand potential equal to 1000 V plus twice rated voltage between the input and output circuits.

Exception No. 1: An optical isolator need not be subjected to the requirements in UL 1577 if the internal insulation is of such a material and at such a thickness that it complies with 38.1.

Exception No. 2: An optical isolator that is constructed in accordance with the requirements in UL 1577, but at a dielectric potential less than 1000 V plus twice rated voltage ac is considered to comply with 36.1 if the internal insulation is at such thickness that it also complies with 38.1(c)(1).

36.2 A power switching semiconductor device that is relied upon to provide isolation to ground shall comply with UL 1557. The dielectric voltage withstand tests required by UL 1557 shall be conducted at a dielectric potential of 1000 V plus twice rated voltage for 1 minute.

Exception No. 1: A power switching semiconductor need not be subjected to the requirements of UL 1557 if the internal insulation is of such material and at such a thickness that it complies with 38.1.

Exception No. 2: A power switching semiconductor that is constructed in accordance with UL 1557 but at a dielectric potential less than 1000 V plus twice rated voltage ac is considered to comply with 36.2 if the internal insulation is at such thickness that it also complies with 38.1(c)(1).

37 Spacings

37.1 Other than as noted in 37.3, 37.6, 37.13, 37.14, and 37.15 and Clearance and Creepage Distances, Section 40, the electrical spacings in industrial control equipment rated 600V or less shall be at least those specified in Table 37.1. Equipment rated 600V or less and intended for installation in a feeder circuit, on the line side of branch circuit protective devices, shall comply with the spacing requirements in Table 37.2 or as in Section 133, General.

Exception: For open type equipment or components rated 600V or less and intended for installation in a feeder circuit (e.g. a feeder bus bar system of accessory components providing a common line connection for multiple branch circuits), the internal spacings (no bare live parts are accessible) shall comply with the spacings specified in Table 37.1.

Table 37.1
Minimum Acceptable Spacings

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

NOTES –

1. A slot, groove, or the like, 0.013 inch (0.33 mm) wide or less in the contour of insulating material is to be disregarded.

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

[a] See 37.8.

[b] See 37.9.

[c] 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 if short-circuiting or grounding of such terminals may result from projecting strands of wire. For circuits involving no potential greater than 50 volts rms ac or dc, spacings at field wiring terminals may be 1/8 inch through air and 1/4 inch over surface.

[d] For the purpose of this requirement, a metal piece or component attached or mounted to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce the spacings between uninsulated live parts or between uninsulated live parts and metal parts.

[e] Spacings apply as indicated, except as specified in 37.6 and the spacings between the low-potential circuit are in accordance with the requirements that are applicable to the high-potential circuit.

[f] 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).

[g] 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).

[h] 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 and result in a shock hazard.

Table 37.2
Equipment Intended for Installation in a feeder Circuit

Voltage between parts involved, rms ac or dc	Minimum spacings in inches (mm)							
	Between uninsulated parts of opposite polarity on line side				Between uninsulated parts on line side and any grounded dead metal			
	Over surface		Though air		Over surface		Through air	
0 – 125	3/4	(19.1)	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)
126 – 250	1-1/4	(31.8)	3/4	(19.1)	1/2	(12.7)	1/2	(12.7)
251 – 600	2	(50.8)	1	(25.4)	1	(25.4)	1	(25.4)

37.2 Other than as noted in Section 40, Clearance and Creepage Distances, the electrical spacings in industrial control equipment rated 601 – 1500V shall not be less than the applicable value specified in Table 37.3.

Table 37.3
Minimum Acceptable Spacings

Potential involved, in volts	Location	Minimum spacings, inches (mm)	
		601 – 1000 V rms ac or dc	1001 – 1500 V rms ac or dc
Between any uninsulated live part and an uninsulated live part of opposite polarity, an uninsulated grounded part other than the enclosure, or an exposed metal part	Through air	0.55 (14.0)	0.70 (17.8)
	Through oil	0.45 (11.4)	0.60 (15.2)
	Over surface air	0.85 (21.6)	1.20 (30.5)
	Over surface oil	0.62 (15.7)	0.70 (17.8)
Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable	Through air or oil	0.80 (20.3)	1.20 (30.5)
	Over surface	1.00 (25.4)	1.65 (41.9)

37.3 The spacing in industrial control equipment in which transient voltages are known and controlled by a transient suppressive device shall not be less than those specified in Table 37.4 except that spacings at a field-wiring terminal shall be in accordance with Table 37.1.

Table 37.4
Minimum Acceptable Spacings for Products With Known and Controlled Transient Voltages

Short-circuit power[a]	Peak working voltage	Minimum spacing, Inch (mm)			
		Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part		Between any uninsulated live part and the walls of a metal enclosure including fittings for conduit or armored cable[b]	
		Through air or oil	Over surface	Through air	Over surface
More than 10 kVA, for use where transient voltages are known and controlled	0 – 50	0.030 (0.76)	0.030 (0.76)	0.500[c] (12.70)	0.250 (6.35)
	51 – 225	0.075 (1.91)	0.100 (2.54)	0.500 (12.70)	0.500 (12.70)
	226 – 450	0.150 (3.81)	0.200 (5.08)	0.500 (12.70)	0.500 (12.70)
	451 – 900	0.300 (7.62)	0.400 (10.16)	0.500 (12.70)	0.500 (12.70

Table 37.4 Continued on Next Page

Table 37.4 Continued

Short-circuit power[a]	Peak working voltage	Minimum spacing, Inch (mm)			
		Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part		Between any uninsulated live part and the walls of a metal enclosure including fittings for conduit or armored cable[b]	
		Through air or oil	Over surface	Through air	Over surface
More than 500 VA but not more than 10 kVA	0 – 50	0.030 (0.76)	0.030 (0.76)	0.500[c] (12.70)	0.250 (6.35)
	51 – 225	0.060 (1.52)	0.060 (1.52)	0.500 (12.70)	0.500 (12.70)
	226 – 450	0.100 (2.54)	0.100 (2.54)	0.500 (12.70)	0.500 (12.70)
	451 – 900	0.200 (5.08)	0.200 (5.08)	0.500 (12.70)	0.500 (12.70)
500 VA or less	0 – 36	0.012 (0.30)	0.012 (0.30)	0.500[c] (12.70)	0.250 (6.35)
	37 – 72	0.016 (0.40)	0.016 (0.40)	0.500[c] (12.70)	0.250 (6.35)
	73 – 100	0.030 (0.76)	0.030 (0.76)	0.500[c] (12.70)	0.250 (6.35)
	101 – 225	0.045 (1.14)	0.045 (1.14)	0.500 (12.70)	0.500 (12.70)
	226 – 450	0.060 (1.52)	0.060 (1.52)	0.500 (12.70)	0.500 (12.70)
	451 – 900	0.100 (2.54)	0.100 (2.54)	0.500 (12.70)	0.500 (12.70)

[a] Maximum short-circuit power is the product of the open-circuit voltage and the short circuit current available at the supply terminals when protective devices are bypassed.

[b] A metal piece attached to the enclosure is considered to be part of the enclosure if deformation of the enclosure is likely to reduce spacings between the metal piece and uninsulated live parts. Spacings specified for parts other than enclosure walls are acceptable to metal walls of a subassembly mounted inside another enclosure if spacings in the subassembly are rigidly maintained.

[c] Where deflection of an enclosure wall cannot reduce the through-air spacing to the enclosure wall, the spacing through air may be 0.250 inch.

37.4 The transient suppressive device specified in 37.3 shall prevent peak transient voltages from exceeding 300 percent of the instantaneous peak working voltage or 300 volts, whichever is greater. See Transient-Voltage-Surge Suppression Test, Section 58.

37.5 With reference to the requirements in 37.3, industrial control equipment shall have provision for the maintenance of clean, dry electrical surfaces, such as a coating on a printed wiring board, or other equivalent means.

37.6 The primary circuit spacings in industrial control equipment intended for use in a pollution degree 2 environment shall be at least those specified in Table 37.5 and Table 37.6.

Table 37.5
Spacings Other Than at Field-Wiring Terminals for Pollution Degree 2 Environments

Potential involved in volts[c]		Minimum spacings[a], inch (mm)			
rms	Peak or dc	Over surface		Through air	
0 – 50	0 – 70.7	3/64	(1.2)	3/64	(1.2)
51 – 125	72.1 – 176.8	1/16	(1.6)	1/16	(1.6)
126 – 250	178.2 – 353.6	3/32	(2.4)	3/32	(2.4)
251 – 600	355.0 – 848.5	1/2	(12.7)[b]	3/8	(9.5)[b]

Table 37.5 Continued on Next Page

Table 37.5 Continued

Potential involved in volts[c]		Minimum spacings[a], inch (mm)	
rms	Peak or dc	Over surface	Through air

[a] On printed-wiring boards, their connectors, and board-mounted electrical components, wired on the load side of the line filters or similar voltage peak reduction networks and components, a minimum spacing of 0.0230 inch (0.584 mm) plus 0.0002 inch (0.005 mm) per volt peak shall be maintained over surface and through air between uninsulated live parts and any other uninsulated live or dead conductive parts not of the same polarity. See 37.16.

[b] Film-coated wire is considered to be an uninsulated live part. However, a spacing of not less than 3/32 inch (2.4 mm) over surface and through air is acceptable between a dead metal part and film-coated wire that is rigidly supported and held in place on a coil.

Table 37.6
Spacings at field-Wiring Terminals for Pollution Degree 2 Environments

Potential involved, in volts, rms ac or dc	Minimum spacings[a], inch (mm)					
	Between field-wiring terminals		Between field-wiring terminals and other uninsulated parts not always of the same polarity			
	Through air or over surface		Over surface		Through air	
0 – 50	1/8	(3.2)	1/8	(3.2)	1/8	(3.2)
51 – 250	1/4	(6.4)	1/4	(6.4)	1/4	(6.4)
251 – 600	1/2	(12.7)	1/2	(12.7)	3/8	(9.5)

[a] These spacings apply to the sum of the spacings involved wherever an isolated dead metal part is interposed.

37.7 The spacing at a field-wiring terminal is to be measured with wire connected to the terminal as in service. The connected wire for a programmable controller is to be the size that would normally be required for the equipment rating. The connected wire for all devices other than a programmable controller is to be the next larger size than would normally be required for the equipment rating if the terminal will accommodate it or if the equipment is not marked to restrict its use.

37.8 The spacings specified in column B of Table 37.1 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 provided 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.

37.9 The spacings specified in column C of Table 37.1 apply only to equipment rated at 300 volts or less, and 1 horsepower (746 W output) or less or 2000 volt-amperes or less per pole and to a device that has a current rating per pole of 15 amperes or less at 51 – 150 volts, 10 amperes at 151 – 300 volts, or both.

37.10 A motor controller rated more than 1 horsepower (746 W output) at 151 – 300 volts that complies with the spacings specified in column A of Table 37.1 for such rating may have an additional rating of 1 horsepower or less at 301 – 600 volts. See also 37.9 for multipole products.

37.11 A motor controller rated more than 1 horsepower (746 W output) at 51 – 150 volts that complies with the spacings specified in column A of Table 37.1 for such rating may have an additional rating of 1 horsepower or less at 51 – 300 volts. See also 37.10 for multipole products.

37.12 In an open-type controller, the spacings between live parts and metal parts that may be grounded, such as the heads of mounting screws that pass through an insulating panel, shall be judged as if they were grounded parts within an enclosure. The spacing between uninsulated live parts and the surface on which the device may be mounted is to be judged as if the mounting surface were part of an enclosure.

37.13 For other than providing isolation between different circuits, in a safety circuit, or as defined in 33.1.2, spacings between traces of different potential on a printed wiring board are not required to comply with the spacing requirements of this Standard when:

a) The printed wiring board has a flammability rating of V-0;

b) The printed wiring board base material has a minimum Comparative Tracking Index (CTI) of 100 volts; and

c) The equipment complies with the Printed Wiring Board Abnormal Operation Test, Section 64.

37.14 For a pilot light, the spacings shall be:

a) At least 3/64 inch (1.2 mm) between uninsulated live parts of opposite polarity at or within a lampholder – an inherent lampholder spacing – rated 250 volts or less and at least 1/8 inch (3.2 mm) for a lampholder rated more than 250 volts;

b) At least those specified in Table 37.1 between uninsulated live parts of opposite polarity – other than at or within the lampholder – based on the normal operating voltage existing between such parts; and

c) At least those specified in Table 37.1 between uninsulated live parts and grounded parts, exposed dead metal parts, or the enclosure based on the line voltage of the pilot-light circuit.

37.15 In a series circuit, the spacings between resistor terminals, transformer taps, and the like are to be based on the normal operating voltage existing between such parts.

37.16 To assist in determining the adequacy of opposite polarity spacings on printed wiring boards, a voltage map layout may be used. This layout would identify potential differences on the printed wiring board.

37.17 In a pushbutton, selector switch, limit switch, or the like, opposite polarity is not considered to exist on any one pole, including double-throw arrangements; but opposite polarity is considered to exist between poles and between live parts on adjacent units unless the parts in question are connected to the same line terminal or conductor and the device is marked as indicated in 74.13 or 132.4.

37.18 The spacings at fuses and fuseholders are to be measured with the fuses having maximum standard dimensions in place, and shall be at least the spacings specified in column A of Table 37.1.

37.19 Insulation provided in lieu of spacings between a magnetic coil cross over lead and the turns of the winding to which it is connected, the adjacent winding, the core and other uninsulated live parts or grounded dead metal parts, may differ from that required by 38.1. Crossover-lead insulation and insulation under coil terminals secured to the coil winding need not comply with the requirements in 38.1, if for thicknesses less than 0.013 inch (0.33 mm), or where only through air space is provided, there is no indication of breakdown in the system as a result of the tests described in 51.2.1 – 51.2.5.

37.20 A ceramic, vitreous-enamel, or similar coating is not acceptable as insulation in place of spacings unless, upon investigation, the coating is found to be acceptable for the purpose.

37.21 If contact arms, blades, or the like, in a motor controller remain connected to the motor load terminals when in the off position, the spacing from such parts to the enclosure or to exposed dead metal parts that are isolated (insulated) shall be at least 1/8 inch (3.2 mm) more than the spacings required for stationary uninsulated live parts.

37.22 Film-coated wire is considered to be an uninsulated live part in determining compliance with the spacing requirements in this Standard.

37.23 For an enclosure without conduit openings or knockouts, spacings not less than the minimum specified in this section shall be provided between uninsulated live parts and a conduit bushing installed at any location likely to be used during installation. A permanent marking on the enclosure, a template, or a full-scale drawing furnished with the equipment may be used to identify such locations.

37.24 For the spacing between an uninsulated live part and a bushing installed in a knockout, it is to be assumed that a bushing having the dimensions specified in Table 37.7 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

Table 37.7
Dimensions of Bushings

Trade size of conduit inches	Bushing dimensions, inches (mm)			
	Maximum overall diameter		Height	
1/2	0.97	(24.6)	3/8	(9.5)
3/4	1.14	(29.0)	27/64	(10.7)
1	1.42	(36.1)	33/64	(13.1)
1-1/4	2.28	(57.9)	9/16	(14.3)
1-1/2	2.60	(66.0)	19/32	(15.1)
2	3.18	(80.7)	5/8	(15.9)
2-1/2	3.56	(90.5)	3/4	(19.1)
3	4.25	(108)	13/16	(20.6)
3-1/2	4.80	(122)	15/16	(23.8)
4	5.40	(137)	1	(25.4)
5	6.67	(170)	1-3/16	(30.2)
6	7.93	(202)	1-1/4	(31.8)

38 Insulating Barriers

38.1 When a barrier is used to comply with spacing requirements, the insulating material used shall comply with at least one of the following criteria:

a) Be a generic direct support material provided in the thickness indicated in Table 16.2;

b) Be a generic barrier material provided in the thickness indicated in Table 38.1 when the insulating barrier does not physically support or maintain the relative position of the uninsulated parts involved; or

c) Comply with the direct support requirements in Table 16.1 at a thickness that meets at least one of the following:

1) Not less than 0.028 inch (0.71 mm) thick;

2) Not less than 0.013 inch (0.33 mm) thick plus one-half required clearance spacings when the barrier is provided in lieu of required clearance distance only; or

3) Capable of withstanding the 5000 V ac Dielectric Strength Test in accordance with the internal barrier requirements in UL 746C.

Exception: When the barrier is provided in lieu of clearance distance only, is not within 1/32 inch (0.8 mm) of uninsulated live parts, and does not physically support or maintain the relative position of uninsulated parts involved, the insulating material is only required to comply with the RTI and HAI values in Table 16.1.

Table 38.1
Generic Materials Suitable as a Barrier

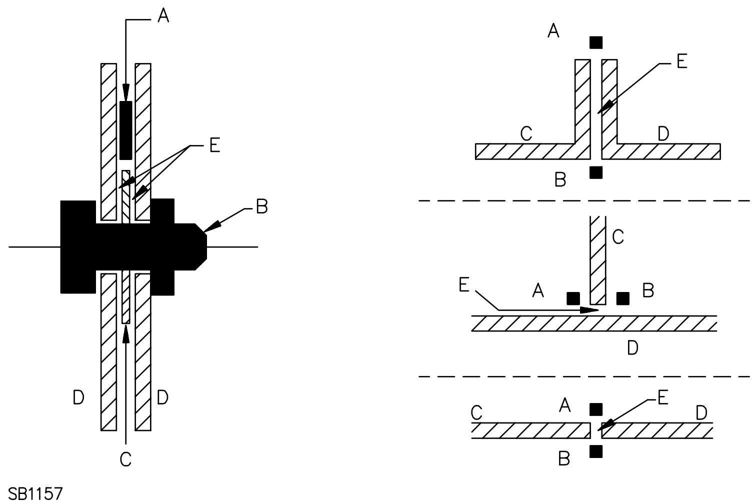
Generic material	Minimum thickness		RTI, °C
	Inch	(mm)	
Aramid Paper	0.010	(0.25)	105
Cambric	0.028	(0.71)	105
Electrical Grade Paper	0.028	(0.71)	105
Epoxy	0.028	(0.71)	105
Mica	0.006	(0.15)	105
Mylar (PETP)	0.007	(0.18)	105
RTV	0.028	(0.71)	105
Silicone	0.028	(0.71)	105
Treated Cloth	0.028	(0.71)	105
Vulcanized Fiber	0.028	(0.71)	105
NOTE – Each material shall have at least the minimum thickness specified and its Relative Thermal Index (RTI) value shall not be exceeded during the Temperature Test.			

39 Clamped Insulating Joints in Lieu of Spacings

39.1 In the case of a clamped insulating joint, spacings are to be measured through cracks unless a clamped joint has passed the test described in 51.3.2. A clamped joint is a joint between two pieces of insulation that are under pressure as shown in Figure 39.1. Adhesives, cements, and the like, if used to effect a seal in place of a tightly mated joint, shall comply with UL 746C.

Figure 39.1

Clamped Joint



Parts A, B – Live parts of opposite polarity, or a live part and grounded metal part with spacing through the crack between C and D less than required in Table 37.1 or Table 37.5.

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

Part E – The clamped joint.

40 Clearance and Creepage Distances

40.1 As an alternative approach to the spacing requirements specified in Spacings, Section 37, and other than as noted in 40.2 and 40.3, clearances and creepage distances may be evaluated in accordance with the requirements in UL 840, as described in 40.4.

40.2 Clearances between an uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable, shall be as noted in Table 37.1 or Table 37.3 as appropriate. The clearances shall be determined by physical measurement.

40.3 The clearance and creepage distance at field wiring terminals shall be in accordance with the requirements in Spacings, Section 37.

Exception: If the design of the field wiring terminals is such that it will preclude the possibility of reduced spacing due to stray strands or improper wiring installation, clearances and creepage distances at the field wiring terminal may be evaluated in accordance with UL 840.

40.4 In conducting evaluations in accordance with the requirements in UL 840, the following guidelines shall be used:

a) For evaluating clearances:

1) Equipment which operates in the direct line of the source of power to the load equipment shall be evaluated for Overvoltage Category III. Other equipment covered under this Standard shall be Overvoltage Category II;

2) The Phase-to-Ground Rated System Voltage used in the determination of Clearances shall be the equipment rated supply voltage rounded to the next higher value (in the table for determining clearances for equipment) for all points on the supply side of an isolating

transformer or the entire product when no isolating transformer is provided. The measured clearance distance used in the evaluation of isolated secondary circuitry is able to be interpolated when the secondary voltage occurs between voltages in the supply voltage column;

3) To determine equivalence with current through air spacings requirements an impulse test potential having a value as determined in UL 840 is to be applied.

b) For evaluation of creepages:

1) Any printed wiring board which complies with the requirements in UL 796, provides a Comparative Tracking Index (CTI) of 100, and when it complies with the requirements for Direct Support in UL 796, then it provides a CTI of 175;

2) Unless specified elsewhere in this Standard, equipment shall be evaluated for pollution degree 3;

3) Printed wiring boards are evaluated as pollution degree 2 when adjacent conductive material is covered by any coating, such as a solder mask, which provides an uninterrupted covering over at least one side and the complete distance up to the other side of conductive material;

4) Printed wiring boards shall be evaluated as pollution degree 1 under one of the following conditions:

i) A coating which complies with the requirements for Conformal Coatings in UL 746C; or

ii) At a specific printed wiring board location by application of at least a 1/32 inch (0.79 mm) thick layer of silicone rubber or through potting, without air bubbles, in epoxy or potting material.

41 Protection of Service Personnel

41.1 Any uninsulated live part involving a potential of more than 30 volts rms (42.4 volts peak) mounted to the inside of a door shall be guarded, recessed, or enclosed to provide protection against unintentional contact when the door is open. A mechanical obstacle, such as a barrier, cover or guard, relied upon to comply with this requirement is able to be removed without the use of tools. See 68, Protection Against Contact with Live Parts of Door Mounted Components Test.

Exception: Uninsulated live parts de-energized by the interlocking mechanism in 41.3 comply with this requirement.

41.2 Industrial control equipment incorporating a fuse holder and the location of fuses, the normal function of which requires renewal, shall be so constructed that the fuses are readily accessible when the switch contacts are open so that a person is not required to touch any live part when replacing a fuse. The electrical arrangement of a single-throw switch shall be such that when it is connected as intended and the contacts are open, the fuse terminals are not energized.

Exception: A control-circuit fuse arrangement is not required to comply with this requirement when the fuse and control-circuit load – other than a fixed control-circuit load, such as a pilot lamp – are within the same enclosure.

41.3 Enclosed equipment with a door and containing a reset button, routine adjustment, or operating handle of a switch or circuit breaker shall be constructed so the button, adjustment or operating handle is readily accessible so that a person is not required to touch any live part in order to perform the operation or adjustment. When a barrier is relied upon to comply with this requirement, the barrier shall require the use of a key or tools for removal.

Exception: Uninsulated live parts de-energized by the interlocking mechanism in 41.3 comply with this requirement.

41.4 For a combination motor controller, a door shall be interlocked with the disconnecting means such that:

a) The door is not able to be opened unless the disconnecting means is in the open (OFF) position; and

b) The door is required to be latched before the disconnecting means is able to be switched to the closed (ON) position.

Exception: The door is not required to comply with this requirement when the interlocking means is intentionally defeated by means described in 41.5.

41.5 The interlocking means required by 41.3 is able to have a defeat mechanism that requires the use of tools to open the door and that is self-restoring when the door is closed.

42 Grounding

42.1 General

42.1.1 The following enclosed industrial control equipment shall have provision for grounding all noncurrent carrying metal parts that are exposed or that are likely to be contacted by persons during normal operation or adjustment of the equipment and that are likely to become energized:

a) All fixed equipment; and

b) Portable equipment intended for use on circuits involving a potential of more than 150 volts to ground.

42.1.2 Acceptable means for grounding shall be as follows:

a) Motor controllers shall be provided with a means of attachment of a terminal or the equivalent for connecting an equipment grounding conductor. The terminal shall be sized to receive a grounding conductor as specified in Table 42.1 and is not required to be larger than the supply conductors;

b) Pendant, cord-connected equipment shall be provided with a terminal for connecting one conductor of a multiple-conductor cord to the enclosure;

c) Portable equipment shall be provided with a power-supply cord with a grounding conductor. The grounding conductor shall be connected to the grounding blade of a grounding attachment plug and shall be connected to the frame or enclosure of the equipment. The surface of the insulation on the grounding conductor shall be green with or without one or more yellow stripes;

d) A proximity switch, limit switch, and similar end-of-the-line devices shall be provided with a means for mounting all exposed dead metal parts to a metal frame, or shall be provided with a terminal mounted to exposed dead metal, or the equivalent, to receive an equipment grounding conductor; or

e) Other industrial control equipment requiring grounding shall be provided with a ground bus. A grounding terminal shall also be provided.

The grounding means may be in the form of a kit. See 74.11.

Table 42.1
Size of Bonding, Equipment Grounding, Grounding Electrode Conductors

Maximum ampere rating[a]	Size of equipment grounding or bonding conductor, minimum (AWG or kcmil)		Size of grounding electrode conductor, minimum (AWG or kcmil)		Size of main bonding jumper, minimum (AWG or kcmil)	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
15	14[b]	12[b]	8	6	8	6
20	12[b]	10[b]	8	6	8	6
30	10[b]	8[b]	8	6	8	6
40	10[b]	8[b]	8	6	8	6
60	10[b]	8[b]	8	6	8	6
90	8	6	8	6	8	6
100	8	6	6	4	6	4
150	6	4	6	4	6	4
200	6	4	4	2	4	2
300	4	2	2	0	2	0
400	3	1	0[c]	3/0[c]	0[c]	3/0[c]
500	2	1/0	0	3/0	0	3/0
600	1	2/0	2/0	4/0	2/0	4/0
800	0	3/0	2/0	4/0	2/0	4/0
1000	2/0	4/0	3/0	250	3/0	250
1200	3/0	250	3/0	250	250[d]	250
1600	4/0	350	3/0	250	300[d]	400[d]
2000	250	400	3/0	250	400[d]	500[d]
2500	350	600	3/0	250	500[d]	700[d]
3000	400	600	3/0	250	600[d]	750[d]
4000	500	800	3/0	250	750[d]	1000[d]
5000	700	1200	3/0	250	900	1250
6000	800	1200	3/0	250	1250	1500

[a] Maximum ampere rating of equipment or circuit overcurrent device ahead of equipment-grounding means.

[b] Values are applicable to equipment-grounding conductors only.

[c] When the ampere rating is 400 and the wire terminal connectors for the main service conductors are rated for two 3/0 AWG copper or two 250 kcmil aluminum conductors and does not accept a 600 kcmil conductor, these values are able to be reduced to 2 AWG copper or 0 AWG aluminum.

[d] The cross section is able to be reduced to 12.5 percent of the total cross section of the largest main service conductor of the same material (copper or aluminum) for any phase on equipment rated 1200 amperes and over. This applies when the wire terminal connectors provided limit the cross section of the service conductors.

42.1.3 A wire binding screw intended for the connection of a field-installed equipment grounding conductor shall have a green colored head. See 26.8.2 – 26.8.5 for requirements.

42.1.4 For wiring device type equipment, the wire binding screw shall have a hexagonal head. The head may or may not be slotted.

42.1.5 A pressure wire connector intended for connection of a field-installed equipment grounding conductor shall be green-colored or plainly identified, such as being marked "G," "GR," "GRD," "GND," "GRND," "Ground," "Grounding," or the like. The symbol ⏚ (IEC Publication 417, Symbol 5019) may be used.

42.1.6 If the wiring diagram of a magnetic motor controller indicates that one side of the control circuit is or may be grounded, the control circuit shall be arranged so that an unintentional ground in the remote-control device will not cause the motor to start.

42.1.7 A switch intended for mounting in an outlet box shall be so constructed that a metallic cover plate will be bonded to ground when installed in the intended manner.

42.2 Internal insulated bonding, grounding, and grounded circuit conductors

42.2.1 Insulated grounding and bonding conductors shall be identified by the color green with or without one or more yellow stripes. No other leads shall be so identified in the field wiring area.

42.2.2 Insulated conductors that extend outside an enclosure and are connected to the grounded side of a transformer secondary as in 42.3 shall be identified by the color white or grey or by three continuous white stripes on other than green insulation and no other conductor shall be so identified.

42.3 Transformer secondary grounding

42.3.1 A secondary circuit of a power or control transformer shall be grounded under any of the following conditions when field wiring is intended to be connected to the circuit which extends beyond the enclosure in which the transformer is mounted.

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

b) When the secondary 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.

42.3.2 A transformer secondary that is required to be grounded in accordance with 42.3.1, shall have a main bonding jumper factory connected to the transformer secondary and to the grounding electrode conductor terminal (or to the enclosure when a grounding electrode conductor terminal is not provided). The size of the main bonding jumper shall be sized in accordance with Table 42.1, based on the transformer secondary rating. A grounding electrode conductor terminal sized to retain the required grounding electrode conductor in accordance with Table 42.1, based on the transformer secondary rating, shall be provided in the enclosure containing the transformer and a marking as specified in 73.30 shall be provided.

Exception: When the transformer is rated not more than 1000 volt-amperes and supplies only remote control and signaling circuits, the grounding electrode conductor terminal is not required and the main 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.

42.4 Switches intended for mounting in a flush-device box and suitable for lighting control

42.4.1 An industrial switch intended for mounting in a flush-device box shall be so constructed that a metallic flush cover plate will be bonded to ground when installed in the intended manner.

42.4.2 Circuitry shall be arranged such that an equipment-grounding/bonding connection or conductor does not carry current.

Exception: A current not exceeding 0.5 mA conducted through an equipment-grounding conductor or connection, when measured in accordance with Section 67, is not prohibited if the leakage current is limited by any two independent means listed below in (a) to (d) and the device is marked in accordance with 73.40. Each independent means shall be capable of limiting the available leakage current to not more than 0.5 mA:

a) Metal film, carbon film, wire wound, and metal glazed resistors;

b) Metallized polyester film capacitors used in isolated secondary circuits according to the requirements of Section 33;

c) Fixed capacitors of Class Y, or two fixed capacitors of Class X in series in accordance with UL 60384-14 used in circuits other than isolated secondary circuits according to the requirements of Section 33; and

d) Other components, if investigated and found acceptable for the application.

Note – The two independent means may be two components from the same option, e.g. two separate resistors.

42.4.3 An industrial switch terminal that is intended to accommodate an installation using either grounded (neutral) conductor or grounding conductor shall also comply with the Terminal Assembly Test described in Section 70 and be marked in accordance with 73.40.

Exception: An industrial switch that is provided with both individual grounded conductor (neutral) and grounding conductor terminals need not be subject to testing nor so marked, if the grounding terminal carries no current under normal operation.

43 Accessories

43.1 Equipment having provision for the use of an accessory to be attached in the field shall comply with the requirements in this Standard, and shall comply with the requirements for the equipment for which it is intended. See Details, Section 76 for instructions and markings.

43.2 As part of the investigation, an accessory is to be tested and trial-installed. The installation shall be feasible, and the instructions shall be detailed and correct. The installation shall be capable of being accomplished using tools that are readily available unless a special tool is provided with the accessory.

DEVICE PERFORMANCE

44 General

44.1 The performance of industrial control equipment shall be investigated by subjecting a representative sample or samples in commercial form to the tests described in Sections 45 – 68. Those tests that are required to be conducted in a sequence are indicated in Table 44.1.

Table 44.1
Sequence of Tests

Standard reference section	Test	Sample number[a, b]	
		1	2
		Sequence	Sequence
45	Temperature	1	
46	Overvoltage and Undervoltage	2	
47	Overload		1
48	Endurance		2
51	Dielectric Voltage-Withstand	3	3

[a] All or any combination of sequences may be conducted on a single sample if agreeable to those concerned. One sequence need not be completed as a prerequisite to the starting of another.

[b] Devices intended for use with AC Electrical Discharge Lamps, self-ballasted LED or CFL, or LED driver, and similar loads with capacitive load characteristics may require additional test sequence for endurance, Section 48, and dielectric, Section 51, using new untested samples and loads specified for electronic ballasts. See Table 48.1 and Section 69.

44.2 Temperature or current sensitive devices or systems that cause termination of a test shall be additionally evaluated to determine their suitability for the application.

44.3 Unless indicated otherwise in the specific test section, the tests are to be conducted at rated frequency at the applicable voltage specified in Table 44.2.

Table 44.2
Values of Voltage for Tests

Test	Voltage rating of equipment[a]						Standard section number
	110 – 120	220– 240	254 – 277	380 – 415	440 – 480	560 – 600	
Temperature	120	240	277	415	480	600	45
Overvoltage, a-c or d-c	132	264	305	457	528	660	46
Undervoltage, a-c	102	204	235	353	408	510	46
Undervoltage, d-c	96	192	222	332	384	480	46
Overload	120	240	277	415	480	600	47
Endurance	120	240	277	415	480	600	48

[a] If the rating of the equipment does not fall within any of the indicated voltage ranges, it is to be tested at its rated voltage except for the overvoltage and undervoltage tests. See 45.5.

44.4 Unless indicated otherwise in the specific test section, the tests are to be conducted at any ambient temperature within the range of 10 – 40 °C (50 – 104 °F). The ambient temperature is to be determined using either thermometers or thermocouples placed in the vicinity of the equipment being tested.

44.5 An industrial control device with an incomplete or partial enclosure is considered to be an open device with respect to the performance requirements in this Standard.

44.6 An open type device shall be mounted in an enclosure considered representative of the intended use. The maximum enclosure dimensions are to be determined by one of the following methods:

a) 150 percent of the dimensions of the device – that is, length, width, and height;

b) Dimensions needed to meet the wire-bending space specified in Table 7.8;

c) The intended enclosure, such as a standard outlet box; or

d) The intended enclosure, which may be larger than indicated in 44.6 (a) – 44.6(c) provided the size is marked on the device or a separate stuffer sheet.

Exception: Relays rated as specified in 37.8(a) need not be so tested.

44.7 A reversing controller, a selector switch, a meter switch, 2-circuit or 3-circuit equipment, or other type of device in which there are two or more on and off positions is to be connected for tests so that opposite polarity representative of normal use exists between or across open contacts or parts. See 74.1.

Exception: Equipment on which same polarity is indicated by marking is to be connected as indicated in the marking.

44.8 During the tests, equipment shall be mounted and wired so as to represent the intended use. Except as indicated in Terminal Torque Test, all field wiring terminal blocks or wire connectors shall be tightened to the value of torque marked on the product.

45 Temperature Test

45.1 Industrial control equipment tested under the conditions described in 45.2 – 45.24 shall:

a) Not attain a temperature at any point so high as to constitute a risk of fire or adversely affect any materials employed in the equipment;

b) Not exceed the temperature limit for any individual component within the equipment; and

c) Not exceed the temperature rise above the test ambient at specific points greater than those specified in Table 45.1 and Table 45.2.

45.2 All values for temperature rises specified in Table 45.1 and Table 45.2 apply to equipment intended for use in a maximum consistent ambient temperature of 40 °C (104 °F).

45.3 For industrial control equipment rated above 40 °C (104 °F), the allowable temperature rise for this elevated ambient is to be calculated in accordance with the following formula:

$$T_R = T_T - [T_M - 40\ °C\ (104\ °F)]$$

in which:

T_R is the Allowable Temperature Rise;

T_T is the Maximum Temperature Rise allowed by Table 45.1 or Table 45.2; and

T_M is the Elevated Ambient Temperature Marked on the equipment. See 72.2.

45.4 For industrial control equipment rated below 40 °C (104 °F), the allowable temperature rise for this reduced ambient is to be calculated in accordance with the following formula:

$$T_R = T_T + [40\ °C\ (104\ °F) - T_M]$$

in which:

T_R is the Allowable Temperature Rise;

T_T is the Maximum Temperature Rise allowed by Table 45.1 or Table 45.2; and

T_M is the Reduced Ambient Temperature Marked on the equipment. See 72.2.

Table 45.1
Maximum Temperature Rises

Materials and components	°C	(°F)
1. Knife-switch blades and contact jaws	30	(54)
2. Fuse clip when tested with a dummy fuse that represents a fuse intended to provide branch circuit protection	30	(54)
3. Fuse clip when tested with a fuse intended to provide branch circuit protection[m]	85	(153)
4. Rubber- or thermoplastic-insulated conductors	a	a
5. Field-wiring terminals[c,h,i]		
Equipment marked 60 °C or 60/75 °C supply wires	50	(90)
Equipment marked 75 °C supply wires	65	(117)
6. Buses and connecting straps or bars[d]	j	j
7. Contacts		
Solid and built-up silver, silver alloy, and silver faced	e	e
All other metals	65	(117)
8. Insulation systems		
Class 105 insulation system[f]		
Thermocouple method	65	(117)
Resistance method	85	(153)
Class 105(A) insulation systems on single-layer series coil with exposed surfaces either uninsulated or enameled, thermocouple method	90	(162)
Class 120(E) insulation system[f,p]		
Thermocouple method	75	(135)
Resistance method	95	(171)
Class 130(B) insulation systems[f,p]		
Thermocouple method	85	(153)
Resistance method	105	(189)
Class 155(F) insulation systems[f,p]		
Thermocouple method	95	(171)
Resistance method	115	(207)
Class 180(H) insulation systems[f,p]		
Thermocouple method	115	(207)
Resistance method	135	(243)
Class 200(N) insulation system[f,p]		
Thermocouple method	135	(243)
Resistance method	155	(279)
Class 220(R) insulation systems[f,p]		
Thermocouple method	155	(279)
Resistance method	175	(315)

Table 45.1 Continued on Next Page

Table 45.1 Continued

Materials and components	°C	(°F)
9. Insulating materials[b]	n	n
10. In the issuing air, 1 inch (25.4 mm) above the enclosure	175	(315)
11. On the embedding material of a resistor, a rheostat, and a wall-mounted dimmer with an embedded resistive element	300	(540)
12. ON the embedding material of a rheostatic dimmer having embedded resistive conductors, and arranged for mounting on a switchboard, or in a noncombustible frame	350	(630)
13. On bare resistor material, thermocouple method	375	(675)
14. Capacitor	g	g
15. Power switching semiconductors	k	k
16. Printed-wiring boards	l	l
17. Any component or material not specifically identified in 1 – 16	o	o

[a] For insulated conductors the maximum temperature rise shall not exceed the maximum operating temperature specified for the wire in question minus an assumed ambient (room) temperature of 40 °C (104 °F).

[b] For compounds which have been investigated for particular temperature ratings, the maximum temperature rise shall not exceed the temperature rating minus an assumed ambient of 40 °C (104 °F).

[c] The temperature on a wiring terminal or lug is measured at the point most likely to be contacted by the insulation of a conductor installed as in actual service.

[d] The limit does not apply to connections to a source of heat, such as a resistor and a current element of an overload relay.

[e] Temperature limited by the temperature limitations on the material for adjacent parts. See 45.15. There shall be no structural deterioration of the contact assembly, loosening of parts, cracking or flaking of materials, loss of temper of spring, annealing of parts, or other visible damage.

[f] See 45.16 – 45.22.

[g] For a capacitor, the maximum temperature rise is the marked temperature limit of the capacitor minus an assumed ambient temperature of 40 °C (104 °F).

[h] When the rise is 50 °C (90 °F) or less and an aluminum bodied connector is used or aluminum wire is intended, the connector shall be marked AL7CU or AL9CU; when the terminal temperature rise exceeds 50 °C and does not exceed 65 °C, the connector shall be marked AL9CU.

[i] See 74.9.

[j] The limit applies only to bus bars and connecting straps used for distribution of power to industrial control devices. The limit does not apply to short pieces of copper located within industrial control devices and used for the support of stationary contact assemblies or factory or field wiring terminations. The maximum temperature rises for this type of construction are determined by the temperature limitations on the support material, adjacent part material, or 100 °C (180 °F) temperature rise on the copper material, whichever is lower. There shall be no structural deterioration of the assembly, loosening of parts, cracking or flaking of material, loss of temper of spring, annealing of parts, or other visible damage.

[k] The maximum temperature rise on the case is the maximum case temperature for the applied power dissipation recommended by the semiconductor manufacturer minus an assumed ambient of 40 °C (104 °F).

[l] The maximum temperature rise of the printed-wiring board is the operating temperature of the board minus an assumed ambient of 40 °C (104 °F).

[m] See 73.26.

[n] See Table 16.2 and Table 38.1.

[o] The maximum temperature rise of any component shall not exceed the temperature limit of the component minus an assumed ambient temperature of 40 °C (104 °F).

[p] The insulation system shall meet the requirements of UL 1446.

Table 45.2
Maximum enclosure Surface Temperature Rises

Surface	°C	(°F)
1. Inaccessible parts of the enclosure (for example, the back of wall mounting enclosure) or accessible surfaces not subject to casual contact (for example, without parts intended to be touched) [a,b]	50	(90)
2. Accessible parts of the enclosure subject to casual contact (for example, enclosure surfaces containing parts intended to be touched)		
Nonmetallic[b]	40	(72)
Metal[b]	30	(54)
3. Parts intended to be touched (for example, operating knobs or handles of power switches and similar parts)		
Nonmetallic	25	(45)
Metal	15	(27)

[a] When the temperature rise on the side of an enclosure that is intended for mounting against building materials exceeds 50 °C (90 °F) per Table 45.2, when operated under normal conditions, the construction shall be such that only the points of support are in contact with a plane mounting surface with the remainder of the equipment spaced at least 1/4 inch (6.4 mm) from the mounting surface such that the temperature rise of the supporting surface does not exceed 50 °C.
[b] The temperature rise of an accessible surface of an enclosure is able to be exceeded when provided with the marking indicated in 75.13.

45.5 The coil test voltages are to be as specified in Table 44.2. However, if a manufacturer supplies transformer or magnet coils for various voltage ratings within each specified range in Table 44.2 (for example, 110, 115, or 120 volts), and if a coil is supplied for the maximum voltage rating of each range, tests may be conducted on representative coils within each range based on percentages specified in 46.1 of the marked voltage ratings of the coils selected for testing. If a coil is not provided for the maximum voltage rating for each range, tests are to be conducted on all coils at the test voltages indicated in Table 44.2.

45.6 To determine whether industrial control equipment complies with the temperature test requirements, it is to be operated:

a) Under normal conditions;

b) While carrying its rated current continuously (see 45.8 – 45.10);

c) At the voltage specified in Table 44.2 or as in 45.5 for coils;

Exception: Instead of the voltages specified, a low voltage source of supply is able to be used for temperature tests on parts other than voltage rated coils.

d) While mounted as intended in use (see 45.11 and 45.13);

e) At an ambient temperature as in 45.14; and

f) Until temperatures are constant (see 45.22).

At the conclusion of the test, the temperature rise of each material or component shall not exceed the maximum temperature rises as specified in 45.1, 45.3, and 45.4. The temperature rise of a material or component is the difference between its stabilized test temperature and the test ambient. Protective devices or circuitry shall not trip during the test. For equipment provided with a thermostat or other thermal protective device and tested as in 45.14(a), the temperature of the thermal device shall be measured, corrected for the difference in ambient temperature, and the resulting temperature compared to the trip temperature to determine whether the device would have been tripped as a result of the test.

45.7 Temperatures are to be measured with all parts operating simultaneously, as the heating of one part may affect the heating of another part.

45.8 The rated current for horsepower-rated equipment is to be as specified in Table 47.2, Table 47.3, Table 72.2, or Table 72.3.

45.9 For equipment provided with an overload relay, unless the equipment is marked as specified in 73.36 to restrict the maximum current rating, the temperature test shall be conducted using the maximum full-load current shown in a current element table, or if no table is provided (e.g., an electronic overload relay), at the maximum setting of the overload relay. When the equipment is marked as specified in 73.36 to restrict the maximum current rating, the temperature test shall be conducted at the current rating marked on the equipment. For equipment having a current-element table showing only tripping current, the test current is to be 87 percent of the specified maximum tripping current.

45.10 For an auxiliary switch mounted directly to a contactor or starter, the test current is to correspond to the maximum break current consistent with the switch rating.

45.11 Industrial control equipment is to be tested with 4 feet (1.2 m) of wire attached to each field-wiring terminal. For example 8 feet (2.4 m) of conductor is required when the conductor is connected between two field-wiring terminals. The wire is to be of the smallest size having an ampacity of at least 125 percent of:

a) The maximum full-load motor-current in accordance with Table 47.2 or Table 47.3, as appropriate, and at least 100 percent for other loads;

b) The maximum full-load motor current for the component (as listed in Table 45.1) with the highest current-rated element for equipment employing an overload device with interchangeable current elements; or

c) The maximum full-load motor current for the overload relay for equipment employing an overload relay with non-interchangeable current elements.

The wire size is to be in accordance with Table 45.3 based on the wire temperature rating marked on the equipment. The type of insulation is not specified. The temperature test may be conducted with conductors having other than black insulation, but referee temperature measurements are to be conducted with black-insulated conductors. If the terminal will not receive the size of wire required for testing in accordance with 45.9 for equipment having an overload relay, or if the device is marked in accordance with 26.5.3 to limit the size of wire, the maximum allowable wire size is to be used.

Exception: When there is only provision for the connection of bus bars to industrial control equipment rated at 450 amperes or more, 1/4 inch (6.4 mm) thick copper bus bars of the width specified in Table 45.4 and at least 4 feet in length are to be used. The temperature test may be conducted with other than black-painted bus bars, but if referee temperature measurements are required, black-painted bus bars are to be used. The spacing between multiple bus bars is to be 1/4 inch with no intentional wider spacing except as necessary at the individual terminals of the equipment.

Table 45.3
Ampacities of Insulated Conductors

Wire size		60 °C (140 °F)		75 °C (167 °F)	
AWG	(mm^2)	Copper	Aluminum	Copper	Aluminum
24	(0.2)	2	–	–	–
22	(0.3)	3	–	–	–
20	(0.5)	5	–	–	–
18	(0.8)	7	–	–	–
16	(1.3)	10	–	–	–
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
kcmil					
250	(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
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 Table 45.3 for that conductor multiplied by the number of conductors that the terminal will accommodate.

2. These values of ampacity apply only if not more than three conductors will be field-installed in the conduit. If four or more conductors, other than a neutral that carries the unbalanced current, will be installed in a conduit (as may occur 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.

Table 45.4
Width of Copper Bus Bars

Product rating	Bus bars per terminal	Width of bus bars	
Amperes		Inches	(mm)
450 – 600	1	2	(51)
601 – 1000	1	3	(76)
1001 – 1200	1	4	(102)
1201 – 1600	2	3	(76)
1601 – 2000	2	4	(102)
2001 – 2500	2	5	(127)
	4	2-1/2	(64)
2501 – 3000	3	5	(127)
	4	4	(102)

45.12 When referee measurements of ambient temperatures are required, several thermometers or thermocouples are to be placed at different points around the equipment. The thermometers or thermocouples are to be located in the ingoing path of the cooling medium, and are to be protected from drafts and abnormal heat radiation. The ambient temperature is to be the mean of the readings of the temperatures taken at equal intervals of time during the final quarter of the duration of the test.

45.13 Enclosed industrial control equipment is to be tested in the enclosure provided by the manufacturer. Open type industrial control equipment is to be tested in an enclosure as specified in 44.6.

Exception: Open type industrial control equipment is not required to be tested in an enclosure when marked with a surrounding air temperature rating.

45.14 The temperature test is to be conducted with the equipment placed in:

a) An ambient in accordance with 44.4; or

b) A non-air circulating or air circulating test chamber with the ambient temperature of the test chamber adjusted to the rated ambient. When an air circulating test chamber is used for testing, baffles shall be provided within the test chamber to prevent drafts from cooling the product under test.

45.15 The acceptability of insulating materials other than those specified in Table 45.1 is to be determined with respect to properties such as flammability, arc-resistance, and the like, based on an operating temperature equal to the measured temperature rise plus 40 °C (104 °F) or other marked ambient temperature rating.

45.16 The thermocouple method for temperature measurement as specified in Table 45.1 consists of the determination of temperature by use of a potentiometer type instrument and thermocouples that are applied to the hottest accessible parts. The thermocouples are to be made of wires not larger than 24 AWG (0.21 mm^2). The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform with the requirements for:

a) Special tolerance thermocouples specified in the Special Tolerances thermocouples as listed in the Tolerances on Initial Values of EMF versus Temperature tables in ASTM E230/E230M;

b) The table of Special Limits as outlined in ASTM E230; or

c) IEC 60584-2 or JIS C 1602. Tolerance Class 1,2 or 3; type and Class tolerance shall be selected according to the following:

1) The maximum tolerance value does not exceed ±1.5 °C of reading for thermocouples identified in IEC 60584-2 or JIS C 1602.

2) Alternately, where higher temperature ranges of the selected thermocouple are measured, a tolerance value of 0.4% of reading may be applied to thermocouple tolerances as specified in IEC 60584-2 or JIS C 1602.

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

45.18 The resistance method for temperature measurement as specified in Table 45.1 consists of the calculation of the temperature rise of a winding using the equation:

$$\Delta t = \frac{r_2}{r_1}(k + t_1) - (k + t_2)$$

in which:

Δt is the temperature rise of the winding in °C

r_2 is the resistance of the coil at the end of the test in ohms.

r_1 is the resistance of the coil at the beginning of the test in ohms.

t_1 is the room temperature in °C at the beginning of the test.

t_2 is the room temperature in °C at the end of the test.

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors are to be determined.

45.19 Because it is generally necessary to de-energize the winding before measuring r_2, the needed value of r_2 at shutdown may be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown. A curve of the resistance values and the time may be plotted and extrapolated to give the value of r_2 at shutdown.

45.20 The preferred method of measuring the temperature of a coil is the resistance method; but temperature measurements by either the thermocouple or resistance method are acceptable; except that the thermocouple method is not to be employed at any point where supplementary insulation is employed.

45.21 With reference to 45.20, when thermocouples are used for measuring the temperatures of a coil, at least two thermocouples are to be used. The thermocouples are to be placed on the surface of the magnet wire which is the upper surface based on the orientation during testing. An additional thermocouple is to be placed on a surface subjected to heating by another source, such as another transformer or a hot resistor.

45.22 A temperature rise is considered to be constant when three successive readings that are taken at intervals of not less than 15 minutes indicate no change between any two of three consecutive readings of more than ±1 °C in the temperature rise.

45.23 Infrared thermal analysis may be used to determine maximum temperature locations for placement of thermocouples for the temperature test.

45.24 A device having mechanical contacts may have the contacts cleaned by any non-abrasive, non-corrosive method or may be cycled under load several times prior to initiating the temperature test.

46 Overvoltage and Undervoltage Test

46.1 An assembly using one or more electromagnetic switching components shall withstand 110 percent of the rated voltage without damage to the operating coil that prevents full closure of the switched contacts and shall operate at 80 percent of its rated voltage when for use on direct current or 85 percent of its rated voltage when for use on alternating current.

46.2 If equipment, such as a combination motor controller, is provided with a control-circuit transformer, the voltage for conducting the undervoltage test is to be applied on the primary side of the transformer at 90 percent of the rated transformer primary voltage.

46.3 The electromagnet is first to be energized under the conditions of the temperature test until constant coil temperatures are observed. The control circuit voltage is then to be reduced to the undervoltage test voltage explained in 46.1. The control circuit is then to be opened and closed several times to determine if full closure of the armature results.

46.4 The control circuit voltage is to be increased to the overvoltage test value stated in 46.1 until constant temperatures are observed using the thermocouple method. The voltage is then to be rapidly reduced to the temperature test voltage and the control circuit is to be immediately opened and closed several times to determine if full closure of the armature results.

46.5 An electromagnet intended for intermittent duty is to be tested to determine whether it complies with the requirements in 46.1 – 46.4 for the time rating specified. If resistance is inserted into the electromagnet circuit after closing of the contactor, this resistance is to be included in the circuit when the coil is energized under temperature test conditions.

47 Overload Test

47.1 During the overload test described in this section, there shall be no electrical or mechanical breakdown of the equipment, no undue burning or pitting of the contacts and no welding of the contacts. The fuse specified in 47.13 shall not open.

47.2 Line and load terminals of industrial control equipment having clearances in accordance with Clearance B (Controlled Overvoltage), Section 8, in the requirements of UL 840, are to be monitored for overvoltages during operation at rated operational voltage under load and no-load conditions. Generated voltages shall not be greater than the lowest impulse withstand voltage rating specified in Table 8.1 of UL 840. This monitoring is to be done during the overload test by an oscillographic study.

47.3 The wire used for this test is to have an ampacity of at least 125 percent of the maximum full-load motor-current in accordance with Table 47.2 or Table 47.3, as appropriate, or at least 100 percent for other loads.

47.4 The overload test or tests are to cover the conditions of maximum interrupted values of voltage, power, and current.

47.5 Tests on equipment having an alternating-current rating are to be conducted using a circuit having a frequency of 60 hertz.

Exception: A test circuit frequency in the range of 25 – 60 hertz may be considered to be representative.

47.6 Equipment is to close and open a test circuit having the current and power factor as described in Table 47.1. If a controller is rated in horsepower instead of current, the horsepower rating is to be converted to a full load current value using the information in Table 47.2 and Table 47.3 in order to apply Table 47.1.

Table 47.1
Overload Test Circuit

Intended device application	Current, amperes	Power factor
Across-the-Line AC Motor Starting, single phase	6 times device full-load current	0.40 – 0.50
Across-the-Line AC Motor Starting, 2- and 3-phase	See Table 47.4 for Test Current	0.40 – 0.50
Across-the-Line DC Motor Starting	10 times device full-load current	dc[a]
DC General Use	1.5 times device rated value	dc[a]
AC General Use	1.5 times device rated value	0.75 – 0.80
DC Resistance	1.5 times device rated value	dc[a]
AC Resistance	1.5 times device rated value	1.0
AC Resistance Air Heating	1.5 times device rated value	1.0
DC Resistance Air Heating	1.5 times device rated value	dc[a]
AC Incandescent Lamps (Tungsten)	1.5 times device rated value	0.75 – 0.80
DC Incandescent Lamps (Tungsten)	1.5 times device rated value	dc
AC Electrical Discharge Lamps (Standard Ballast)	3.0 times device rated value	0.40 – 0.50
Elevator Control, AC hp	b	b
Elevator Control, DC hp	b	b
Capacitive Switching (kVar)	1.5 times device rated value	c

NOTE – The test cycles are to be as described in 47.12.

[a] Load is a noninductive resistive load.

[b] Overload conditioning shall be identical to the overload conditioning required for across the line motor starting.

[c] The load is to consist of commercially available capacitors. The available test current at the test terminals shall not be less than 3000 A or the marked short circuit rating of the capacitors, whichever is greater. The available current capacity is able to be determined by analytical evaluation.

Table 47.2
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
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 47.3
Full-Load Motor-Running Currents in Amperes Corresponding to Various D-C 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	–	17.0	10.8	8.5	–	3.6
3	–	25.0	16.0	12.2	–	5.2
5	–	40.0	27.0	20.0	–	8.3
7-1/2	–	58.0	–	29.0	–	12.2
10	–	76.0	–	38.0	–	16.0
15	–	110.0	–	55.0	27.0	24.0
20	–	148.0	–	72.0	34.0	31.0
25	–	184.0	–	89.0	43.0	38.0
30	–	220.0	–	106.0	51.0	46.0
40	–	292.0	–	140.0	67.0	61.0
50	–	360.0	–	173.0	83.0	75.0
60	–	–	–	206.0	99.0	90.0
75	–	–	–	255.0	123.0	111.0
100	–	–	–	341.0	164.0	148.0
125	–	–	–	425.0	205.0	185.0
150	–	–	–	506.0	246.0	222.0
200	–	–	–	675.0	330.0	294.0

[a] The full-load current for a 1/4-horsepower, 32-volt d-c motor is 8.6 amperes.

Table 47.4
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

Table 47.4 Continued on Next Page

Table 47.4 Continued

HP	110 – 120 V	200 V	208 V	220 – 240 V	380 V – 415 V	440 – 480 V	550 – 600 V
	Motor designations	Motor designations	Motor designations	Motor designations	Motor designations	Motor designations	Motor designations
	B, C, D	B, C, D	B, C, D	B, C, D	B, C, D	B, C, D	B, C, D
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

47.7 Air core type reactors are to be used to obtain the reactive power factor specified in Table 47.1. Reactors may be connected in parallel. No reactor is to be connected in parallel with a resistor.

Exception No. 1: An air-core reactor in any phase may be connected in parallel with a resistor (R_{SH}) if the resistor power consumption is approximately 1 percent of the total power consumption in that phase calculated in accordance with the following formula:

$$R_{SH} = [100(1 / PF - PF)] E / I$$

in which:

PF is the power factor;

E is the closed-circuit phase voltage; and

I is the phase current.

Exception No. 2: Iron-core reactors may be used provided that the sine-wave shape for the test load current at maximum is such that the ratio of peak-to-rms values is equal to 1.414 ±5 percent (essentially *sinusoidal), or has a Total Harmonic Distortion (THD) of 5% maximum to verify the absence of magnetic saturation of the core. This requirement applies to both make and break load currents.*

47.8 Except as specified in 47.9, the closed test circuit voltage is to be 100 to 110 percent of the overload test voltage specified in Table 44.2.

47.9 For a motor controller rated more than 25 horsepower (18.6 kW output) or a magnetically operated switch rated more than 100 amperes, the open-circuit voltage is to be as much above the voltage specified in Table 44.2 as the closed-circuit voltage is below that value, unless such adjustment results in the open-circuit voltage being more than 110 percent of the specified voltage. In that case, the test is to be conducted using whatever closed-circuit voltage is obtained when the open-circuit voltage is 110 percent of the specified voltage. However, the capacity of the supply circuit need not be greater than that of a circuit that is considered to be acceptable for the short circuit test as described in Short Circuit Test – General, Section 52.

47.10 Tests on a reversing controller provided with a factory-installed mechanical, electrical, or electronic interlock, or any combination thereof, are to be conducted with all such interlocks in operation. If an interlock system is provided as an option, that system is to be defeated during the test.

47.11 The equipment is to open and close the test circuit 50 times. A reversing controller is to be subjected to ten additional cycles of operation with both coils energized simultaneously after the 50 cycles of operation.

47.12 For all equipment except a reversing controller, the test cycle time is to be 1 second on and 9 seconds off. For a reversing controller, the test cycle time is to be 1 second forward, 1 second reverse, and 8 seconds off.

Exception No. 1: If the device operation will not permit these cycle times, times as close as possible to these are to be used.

Exception No. 2: If it is determined that for a duration less than one second, the device conducts the test current without interrupting the circuit or being adversely affected by heat and the device contacts are properly seated before the break is initiated as confirmed by oscilloscopic or oscillographic measurements, the on time may be reduced to that duration.

Exception No. 3: The off time for equipment conducting a test current of 500 – 1499 amperes is to be no more than 120 seconds, and for devices conducting a test current more than 1499 amperes, the off time is to be no more than 240 seconds.

47.13 During the test, the enclosure is to be connected through a 30-ampere cartridge fuse that does not have a time delay to the electrical test circuit pole considered least likely to strike to ground.

47.14 A device having two or more poles is to be tested with opposite polarity as noted in 74.13 between two adjacent poles.

Exception: If the device is marked same polarity, opposite polarity need not exist between adjacent poles.

47.15 During tests on multipole devices for use in opposite-polarity applications, all unused poles are to be connected electrically to the enclosure.

47.16 Unless a device is provided with a wiring diagram or equivalent marking indicating the number of poles to be used to control the load, the device is to be tested using one pole to control single-phase or direct-current loads and using two poles to control polyphase loads.

47.17 Figure 47.1 shows typical connection diagrams.

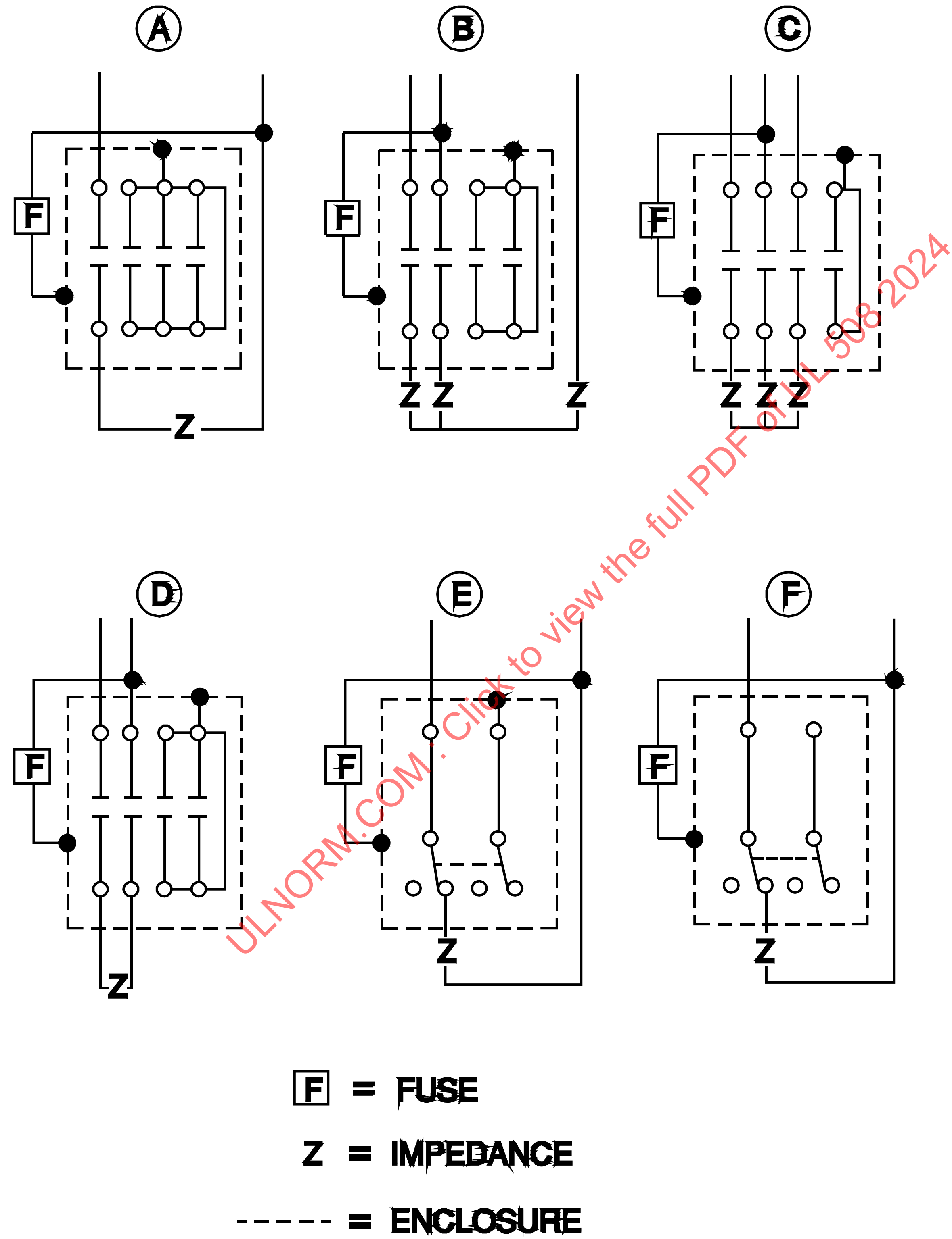
a) Diagrams A and B show connections for a device for single- and 3-phase loads, respectively, that are unmarked regarding load connection.

b) Diagram C and D show connections for a device for 3-phase and single-phase loads, respectively, that are marked "Break All Lines" or the equivalent.

c) Diagram E shows connections for a double-pole, double-throw relay that is unmarked for polarity connection. Diagram F shows connections for a double-pole, double-throw relay marked for same polarity. For a double-throw device, either the normally open or normally closed position may be tested, provided, for each position the contacts, the travel distance, and the contact force are the same. This also applies to a single-pole, double-throw relay.

Figure 47.1

Overload Test Connection Diagrams



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48 Endurance Test

48.1 During the endurance test described in this section, there shall be no electrical or mechanical breakdown of the device, welding, undue burning or pitting of the contacts. The fuse specified in 47.13 shall not open. After the test, the device shall comply with the requirements of the Dielectric Voltage-Withstand Test, Section 51.

48.2 The conditions for the endurance test shall be the same as the conditions for the overload test as specified in Section 47, except as described in this section.

48.3 The equipment is to close and open a test circuit having the applicable current and power factor specified in Table 48.1. The number of test cycles and the test cycle times are to be as specified in Table 48.1. The closed circuit test voltage is to be 100 to 110 percent of the endurance test voltage specified in Table 44.2.

Table 48.1
Endurance Test

Intended device application	Test current amperes	Power factor	Number of cycles	Test cycle times seconds	
				On	Off
Across-the-Line AC Motor Starting[a]	Twice Full-Load Current	0.40 – 0.50	1000[b]	f	f
Across-the-Line DC Motor Starting	Twice Full-Load Current	dc[h]	1000[b]	f	f
DC General Use	Rated Current	dc[h]	6000	1[d]	9[d]
AC General Use	Rated Current	0.75 – 0.80[c]	6000	1[d]	9[d]
DC Resistance	Rated Current	dc[h]	6000	1[d]	9[d]
AC Resistance	Rated Current	1.0	6000	1[d]	9[d]
DC Resistance Air Heating[i]	Rated Current	dc[h]	100,000	1[d]	9[d]
AC Resistance Air Heating[i]	Rated Current	1.0	100,000	1[d]	9[d]
AC Incandescent Lamps (Tungsten)	Rated Current. See 48.4 – 48.7.	1.0	6000[g]	1[e]	59[e]
DC Incandescent Lamps (Tungsten)	Rated Current. See 48.4 – 48.7.	dc	6000[g]	1[e]	59[e]
AC Electrical Discharge Lamps (Standard Ballast)	Twice Rated Current	0.40 – 0.50	6000	1	9
AC Electrical Discharge Lamps (Electronic Fluorescent Ballast), self-ballasted LEDs and CFLs, and LED Drivers, and similar loads with capacitive load characteristics	k	k	6000	1	9
Elevator Control, AC hp	Twice Full-Load Current	0.40 – 0.50	500,000	1	9
Elevator Control, DC hp	Twice Full-Load Current	dc[h]	500,000	1	9
Capacitive Switching (kVar)	Rated Current	j	6000	1[d]	9[d]

[a] For an alternating current combination controller, the manual switch is to be tested for 6000 cycles at the rate of 6 cycles per minute at 0.75 – 0.80 power factor, and at rated full-load current.

Table 48.1 Continued on Next Page

Table 48.1 Continued

Intended device application	Test current amperes	Power factor	Number of cycles	Test cycle times seconds	
				On	Off

[b] These devices are to be subjected to at least 6000 mechanical cycles at any convenient rate.

[c] If the device is marked "resistance only" in accordance with 73.10, the test may be conducted using a noninductive resistance load. This "resistance only" rating is different than a resistance heating rating or a resistance air heating rating.

[d] The cycle times are to be shown or as described in 47.12.

[e] A control may be operated faster than 1 cycle per minute if synthetic loads are used or if a sufficient number of banks of lamps controlled by a commutator are employed so that each bank will cool for at least 59 seconds between successive applications.

[f] Other than as noted in note a, the test cycle is to be as indicated in Table 48.2.

[g] For a magnetic relay intended to turn a television receiver on and off, and marked in accordance with 73.25, the number of test cycles is to be 25,000.

[h] Load is a noninductive resistive load.

[i] Applicable only to a device that controls the power to a resistance heating element used for comfort heating, and is controlled by an automatic reset safety control required by the end product standard.

[j] The load is to consist of commercially available capacitors. The available test current at the test terminals shall not be less than 3000 A or the marked short circuit rating of the capacitors, whichever is greater. The available current capacity is able to be determined by analytical evaluation.

[k] Devices rated 120, 277 VAC, or 347 VAC intended to control electronic fluorescent ballast, self-ballasted LED or CFL, LED driver, and similar loads with capacitive load characteristics up to 16 amps of steady state current shall be endurance tested using the load in accordance with Section 69. Alternately, they may be tested on the specific model electronic ballast(s), self-ballasted LEDs or CFLs, LED drivers, or other similar loads with capacitive load characteristics they are intended to control and marked according to 73.11.

Table 48.2
Test Cycle for Motor Controllers

Type of controller	Test current amperes	Time on[a] second	Maximum time off seconds
Non-reversing	Less than 200	1/2	1/2
	200 – 499	1	1
	500 – 1499	1	120
	1500 or more	1	240
Reversing	Less than 200	1/2 forward 1/2 reverse	1
	200 – 499	1 forward 1 reverse	2
	500 – 1499	1 forward 1 reverse	120
	1500 or more	1 forward 1 reverse	240

[a] Or as noted in Exception Nos. 1 and 2 to 47.12.

48.4 If tungsten-filament lamps are used as the load, the load is to be made up of the smallest possible number of 500-watt lamps, or of larger lamps if agreeable to those concerned; except that one or two lamps smaller than the 500-watt size may be used if necessary to make up the required load.

48.5 With regard to 48.4, the circuit is to be such that the peak value of the inrush current will be reached in 1/240 of a second after the circuit is closed.

48.6 A synthetic load may be used in place of tungsten-filament lamps if it is equivalent to a tungsten-filament lamp load on the test circuit in question, and the inrush current is at least ten times the normal current.

48.7 A synthetic load used in place of tungsten-filament lamps may consist of noninductive resistors if they are connected and controlled so that a portion of the resistance is shunted during the closing of the switch under test. A synthetic load may also consist of a noninductive resistor or resistors that are connected in parallel with a capacitor.

49 Endurance Test for Relays for Television Applications

49.1 A relay having contacts connected in the supply circuit to turn a television receiver on and off and controlling a peak inrush current (rms times 1.414) that exceeds the contact rating of the relay shall perform acceptably without breakdown when subjected to 25,000 cycles of operation making and breaking the test loads specified for incandescent lamp control (tungsten) in Table 48.1 at the test potential specified for the endurance test in Table 44.2.

49.2 The conditions for the endurance test shall be the same as those specified for the overload test in 47.1 – 47.16.

49.3 A relay tested in accordance with 49.1 and 49.2 shall be marked as specified in 73.25.

50 Calibration Test

50.1 These requirements apply to an overload relay, or industrial control equipment incorporating an overload relay.

50.2 When tested at an ambient temperature of 40 °C (104 °F), an overload relay shall operate:

a) Ultimately when carrying 100 percent of the current element rated tripping current;

b) Within 8 minutes when carrying 200 percent of the current element rated tripping current; and

c) Within:

1) 20 seconds when carrying 600 percent of the current element rated tripping current; or

2) The time specified in Table 50.1 if marked in accordance with 73.41.

Table 50.1
Marking Designation for Tripping Time at 600 Percent of the Current Element Rating

Class designation[a]	Tripping time seconds
Class 10	10
Class 20[b]	20
Class 30	30

[a] Class designations in excess of 30 seconds may be used, with the tripping time in seconds equal to the numerical class marking.

[b] Class 20 need not be marked.

50.3 The test sequence for an overload relay with respect to 50.2 is to be the test in 50.2(c), followed by the test in 50.2(b), followed by the test in 50.2(a), all conducted on the same overload relay. If a relay employs interchangeable type current elements, the tests are to be conducted on the same current elements. The overload relay and the current elements are to be cooled to ambient temperature between tests.

50.4 An overload relay mounted in a starter or other enclosure is to be tested with the enclosure in the 40 °C (104 °F) ambient.

Exception: Solid state overload relays are not required to be tested in a 40 °C (104 °F) ambient.

50.5 An adjustable overload relay is to be set at the 100 percent mark on the calibration scale and subjected to the tests specified in 50.2. The relay is also to be tested carrying a current of 200 percent of the current element rating, at the high and low points of the operating range – such as 120 and 80 percent of the element rating – to determine that the times of operation will be consistently longer and shorter, respectively, than the operating time at the 100 percent setting.

50.6 If an adjustable relay covers several tripping current ratings, the relay shall comply with the requirements in 50.2 for each separate rating.

50.7 In lieu of tests at 40 °C (104 °F) ambient, an ambient-compensated overload relay or a starter provided with an ambient-compensated overload relay is to be subjected to those tests in 50.2 in an ambient temperature of 25 °C (77 °F) and also in an ambient temperature of 50 °C (122 °F) or the maximum ambient temperature rating of the device, whichever is higher.

50.8 The overload relay or a starter provided with an overload relay is to be tested with 4 feet (1.2 m) of wire attached to each field-wiring terminal. For example 8 feet (2.4 m) of conductor is required when the conductor is connected between two field-wiring terminals. The wire is to have the ampacity of at least 125 percent of the maximum full-load motor-current rating of the current element. The wire size is to be determined in accordance with Table 45.3 based on the wire temperature rating marked on the equipment. The type of insulation is not specified. If the terminal will not receive that size of wire, or if the device is marked in accordance with 26.5.3 to limit the size of wires, the maximum allowable wire size is to be used.

50.9 The overload relay or relays in a starter intended for polyphase use are to be calibrated with only two current elements in the circuit during 600 and 200 percent calibration tests to cover single-phasing and with three current elements in the circuit during 100 percent tests.

Exception: An electronic overload relay that offers loss of phase protection is not required to be calibrated at 600 percent and 200 percent in the single phase mode. For this type of function, the tests at 600 percent and 200 percent are to be conducted in the three phase mode.

50.10 The overload relay in a starter employing one current element for single-phase use is to be calibrated with one current element in the circuit during all tests. The overload relay or relays in a starter employing two current elements for single-phase use are to be calibrated with two current elements in the circuit during all tests.

50.11 A separate overload relay – one not furnished as part of a starter – having two or more current elements is to be calibrated with one element in the circuit during all tests unless provided with marking to indicate other connection.

51 Dielectric Voltage-Withstand Test

51.1 General

51.1.1 While at its maximum normal operating temperature, industrial control equipment shall withstand for 1 minute without breakdown the application of a 60 hertz essentially sinusoidal potential or a direct-current potential:

a) Between uninsulated live parts and the enclosure with the contacts open and closed;

b) Between terminals of opposite polarity with the contacts closed; and

c) Between uninsulated live parts of different circuits.

51.1.2 With respect to 51.1.1, the test potential shall be the following values for testing an alternating-current rated device using an alternating-current supply, or 1.414 times the following values for testing an alternating-current rated device using a direct-current supply, or the following values for testing a direct-current rated device using a direct-current supply, or 0.707 times the following values for testing a direct-current rated device using an alternating-current supply:

a) 500 volts – For industrial control equipment rated not more than 50 volts;

b) 1000 volts plus twice the rated voltage of the equipment – For industrial control equipment rated 51 – 600 volts

c) 1000 volts – For industrial control equipment rated 51 – 250 volts and intended for use in a pollution degree 2 location; or

d) 2000 volts plus 2.25 times maximum rated voltage – For Industrial control equipment rated 601 – 1500 volts.

51.1.3 A transformer, a coil, an electronic part, or a similar device normally connected between lines of opposite polarity is to be disconnected from one side of the line during the test described in 51.1.1(b).

51.1.4 If the equipment has a meter or meters, they are to be disconnected from the circuit for the dielectric voltage-withstand test described in 51.1.1 and 51.1.2. The meter or meters are to be tested separately for dielectric voltage withstand, with an applied potential of 1000 volts in the case of an ammeter, and 1000 volts plus twice rated voltage in the case of any other instrument having a potential circuit.

51.1.5 To determine whether industrial control equipment complies with the requirements in 51.1.1 and 51.1.4, it is to be tested by means of a 500 volt-ampere or larger capacity transformer, the output voltage of which is essentially sinusoidal and can be varied. The applied potential is to be increased from zero to the required value at a substantially uniform rate and as rapidly as is consistent with its value being correctly indicated by a voltmeter.

Exception: A 500 volt-ampere or larger capacity transformer need not be used if the transformer is provided with a voltmeter that directly measures the applied output potential.

51.2 Coils

51.2.1 A coil assembly that complies with the construction requirements in 37.19 shall be subjected to the tests described in 51.2.2 – 51.2.5. There shall be no breakdown of the coil assembly during these tests.

51.2.2 Three separate samples of the assembly of coil and frame shall be subjected to this test after constant temperatures have been reached as the result of operation under the conditions specified in 45.5 – 45.11. While heated from the normal temperature test, the coil terminals are to be connected to an alternating current source of twice the normal rated voltage at any frequency up to 400 hertz.

51.2.3 The required test voltage specified in 51.2.2 is to be obtained by starting at one-quarter or less of the full rated value and increasing to twice full rated value in not more than 15 seconds. After being held for 7200 electrical cycles or for 60 seconds, whichever is less, the voltage is to be reduced within 5 seconds to one-quarter or less of the maximum rated value and the circuit is to be opened.

51.2.4 While heated following operation at 110 percent of its rated voltage, each of the three samples are to be subjected to the test described in 51.2.2 and 51.2.3, except that the test voltage is to be 130 percent of the temperature test voltage.

51.2.5 If the temperature that a coil winding reaches in the tests described in 51.2.2 and 51.2.4, is known, an oven that can be set at the required temperature may be used to condition the sample to that temperature before conducting the test.

51.3 Secondary circuits

51.3.1 A secondary circuit intended for use in a pollution degree 2 location shall also comply with the requirements in 51.1.1 – 51.2.5.

Exception: A secondary circuit that has a maximum voltage of 30 volts rms or 42.4 volts peak is not required to have a dielectric voltage-withstand test applied between the secondary voltage and ground.

51.3.2 With respect to 39.1, a clamped joint between two insulators is to be tested using two samples.

a) The first sample is to have the clamped joint opened up to produce a space 1/8 inch (3.2 mm) wide. This may be accomplished by loosening the clamping means or by drilling a 1/8 inch diameter hole at the joint between the insulators at a point of minimum spacing between the metal parts on the opposite sides of the joint. The drilled hole shall not decrease spacings between the opposite polarity parts as measured through the crack between the insulators. The 60 hertz dielectric breakdown voltage through this hole is then determined by applying a gradually increasing voltage (500 volts per second) until breakdown occurs.

b) The second sample with the clamped joint intact is to be subjected to a gradually increasing 60 hertz voltage until 110 percent of the breakdown voltage of 51.3.2(a) has been reached. If the breakdown voltage of 51.3.2(a) was less than 4600 volts rms, the voltage applied to the second sample is to be further increased to 5000 volts rms and held for 1 second. The clamped joint is acceptable if there is no dielectric breakdown of the second sample.

52 Short Circuit Test – General

52.1 General

52.1.1 The requirements in this section shall be used in conjunction with Section 53, Standard Fault Current Circuits, Section 54, High Available Fault Current Circuits (Optional), Section 55, Group Installation (Optional), Section 56, Standard and High Fault Acceptance Criteria, and Section 57, Calibration of Test Circuits.

52.1.2 The requirements for device performance of Section 44, General, are to be applied.

52.1.3 A short circuit test is to be conducted on:

a) A motor control device that is rated more than 1 hp (746 W) at voltages greater than 300 V or more than 2 hp (1492 W) at all voltages;

b) A starter;

c) An overload relay;

d) Industrial control equipment incorporating an overload relay;

e) Combination motor controllers; and

f) Bus bar systems.

Exception: Short circuit tests on a motor control device rated more than 1 horsepower (746 W) at voltages greater than 300 V or more than 2 horsepower (1492 W output) at all voltages and marked for use only with specific overload relays are able to be performed with the motor control device installed as part of a starter. A marking shall be provided as specified in 73.33.

52.1.4 Motor control devices, overload relays, and starters are subjected to separate short circuit test while protected by fuses and by an inverse-time circuit breaker. Combination motor controllers are subjected to the short circuit test with the short circuit protective devices provided in the equipment.

Exception No. 1: When equipment is marked to limit protection to fuses only as specified in the Exception to 73.3, the equipment is subjected to the test while protected by fuses.

Exception No. 2: Testing with inverse-time circuit breakers is not required when it is shown that the let-through energy (I^2t) and peak let-through current (I_p) of the inverse-time circuit breakers is less than that of the fuse with which the product has been tested.

Exception No. 3: A test performed on a device for 3 electrical cycles without a short circuit protective device in series, covers the use of fuses and circuit breakers when the clearing time of such branch circuit protective devices is less than 3 cycles.

52.1.5 After each operation, the contacts of the motor control devices, or the entire motor control device, may be replaced and new current elements may be installed in the overload relay. The same sample may be used provided that no additional impedance is introduced. If an overload relay employs noninterchangeable current elements, the entire overload relay may be replaced.

52.1.6 If the marked rating of the equipment includes both alternating and direct current, or if the marked rating does not exclude one or the other, the acceptability of the equipment for both ratings is to be determined. The ac rating is to be verified in accordance with 57.2. The dc rating is to be verified in accordance with 57.3.

52.1.7 A feeder bus bar system of accessory components providing a common line connection for multiple branch circuits shall comply with the short circuit test in UL 845. When the bus bar is intended to be supported solely by terminal connections to specific components, the withstand test of the bus bar structure alone is not required. Short circuit testing of the assembly (bus bar and components) is conducted per the requirements in this section. The products are marked in accordance with Section 76.

52.1.8 A branch circuit bus bar system of accessory components providing a common line side connection for multiple motor circuits within a branch circuit, a group installation, shall comply with the group installation short circuit test. The load side devices shall be selected having an ampere rating equal to the ampere rating of the bus bar or the highest ratings specified by the manufacturer. The products are marked in accordance with Section 76.

52.1.9 In choosing representative samples of bus bars, the following factors are to be evaluated:

a) Bracing structure, when different, for each rating;

b) Material and cross-sectional configuration of each bus-bar structure;

c) Weakest bus-bar structure that could result in bus-bar distortion;

d) Strongest bus-bar structure that will transmit the maximum forces to the bracing; and

e) Various incoming bus and terminal configurations provided.

52.2 Enclosure

52.2.1 For open-type equipment, a metal enclosure shall be used and shall comply with the requirements of 44.6 (a) – (d) and Table 7.1 and Table 7.2 (for the thickness of the enclosure) and 52.2.2 – 52.2.5.

52.2.2 Openings may be provided in any enclosure if the combined area of all openings does not exceed 10 percent of the total external enclosure area and if no opening is directly opposite a vent in a circuit breaker case, if provided with a circuit breaker.

52.2.3 An enclosure having the smallest dimensions and the least provision for pressure relief is to be selected.

52.2.4 The enclosure cover is to be held closed only by the intended latch mechanism and securement means.

52.2.5 An enclosure for testing of open-type equipment provided with a door shall be secured by one latch point when less than 48 inches (1.2 m) long, or shall comply with the requirement of 7.4.4 when over 48 inches (1.2 m) long.

Exception: Additional latching points are able to be used when information is provided to the user in the form of an instruction sheet.

52.2.6 For enclosed equipment, the intended enclosure shall be used or, when multiple enclosure options are provided, representative enclosures shall be selected as specified in 52.2.3.

52.2.7 Short circuit tests performed on a vacuum contactor are able to be tested without an enclosure, when a wire cage covered with surgical cotton surrounds the equipment in close proximity to the equipment under test to simulate the intended enclosure.

52.3 Sample preparation

52.3.1 The equipment is to be tested with 4 feet (1.2 m) of wire attached to each line terminal and with the wires routed through a 10 – 12 inch (250 – 305 mm) length of conduit installed on the enclosure. All openings are to be acceptably closed. The wire is to have an ampacity of at least 125 percent of the maximum full-load motor-current rating of the current element. The wire size is to be determined in accordance with Table 45.3 based on the wire temperature rating marked on the equipment. If the terminal will not receive that size of wire, or if the equipment is marked in accordance with 26.5.3 to limit the size of wires, the maximum allowable wire size is to be used. The load terminals are to be shorted together, using wire sized in the same manner as the line terminals.

Exception No. 1: The test wires may exceed 4 feet in length in accordance with 57.2.1.2.

Exception No. 2: For motor control devices rated more than 200 horsepower (150 kW), the line and load connections may be made with bus bars equivalent in cross-sectional area to the wires specified.

52.3.2 The metal enclosure is to be connected to the phase of the source of supply which is connected to the pole judged as having the least risk of arcing to ground. The connection is to be made to the load side of the limiting impedance by a 10 AWG (5.3 mm^2) solid copper wire that is 4 – 6 feet (1.22 – 1.83 m) long. Continuity shall be verified between the enclosure and the pole least at risk of arcing to ground.

Exception No. 1: The connection shall be made with 12 or 14 AWG (3.3 or 2.1 mm^2) solid copper wire when the branch-circuit conductors that the equipment is intended to be connected to are 12 or 14 AWG, respectively.

Exception No. 2: For equipment marked 600Y/347 or 480Y/277 volts, the enclosure shall be connected to the center of the wye.

52.3.3 The enclosures may be provided with length(s) of conduit of any convenient trade size.

Exception: If conduit is not provided, the conductors outside the enclosure may be restrained to prevent whipping during the test.

52.3.4 The armature or cross bar is to be held in the closed position either mechanically or by a separate electrical supply for a magnetically-operated device. The contacts of the motor control devices may be held closed only by the movement of the armature or cross bar.

53 Standard Fault Current Circuits

53.1 Protective devices

53.1.1 General

53.1.1.1 A combination motor controller, motor control device, or overload relay shall be tested according to the requirements in this section and shall additionally comply with Section 52, Short Circuit Test – General.

53.1.1.2 For non-time delay fuses, if the calculated value of the fuse is between two standard ratings as specified in 53.1.2.2, a fuse of the nearest standard rating but not more than four times the full-load motor-current rating is to be used. If the calculated value of the fuse is less than 1 ampere, a fuse rated 1 ampere is to be used, and no marking of fuse size is required on the product.

53.1.1.3 If the calculated value of the circuit breaker is between two standard ratings as specified in 53.1.3.2, a circuit breaker of the nearest standard rating less than the calculated value is to be used.

53.1.2 Fuses

53.1.2.1 The fuses used for the tests are to be specified by the manufacturer in accordance with Table 53.1.

Table 53.1
Ratings of Fuses Used for Tests

Type of fuse[a]	Current, amperes	Maximum percent of rated motor full-load current[b]	Fuse size marking required[j]
Nontime Delay	0 – 600	400[c,d]	No
Nontime Delay	0 – 600	< 400 but ≥ 300[e]	Yes
Nontime Delay	0 – 600	< 300 but > 225[f]	Yes
Time Delay	0 – 600	≤ 225[g]	Yes
Nontime Delay	601 – 6000	300[f,h]	No

Table 53.1 Continued on Next Page

Table 53.1 Continued

Type of fuse[a]	Current, amperes	Maximum percent of rated motor full-load current[b]	Fuse size marking required[j]
Nontime Delay	601 – 6000	< 300[i]	Yes
Time Delay	601 – 6000	225[g]	Yes

[a] Tests with 225 percent full load ampere time delay fuses are not representative of tests with 400 percent full load ampere nontime delay fuses.

[b] These values are to be used when the manufacturer does not specify fuse sizes and refers to a maximum percent level, such as "Fuse not to exceed 300 percent of motor full load amps."

[c] See 53.1.1.2.

[d] Tests with 400 percent nontime delay fuses cover use with 225 percent time delay fuses.

[e] Tests with nontime delay fuses rated less than 400 percent, and equal to or greater than 300 percent cover use with 175 percent time delay fuses.

[f] Tests with less than 300 percent nontime delay fuses requires additional testing with 225 percent (or as marked) time delay fuses.

[g] The product is marked to indicate the level of protection and that the branch-circuit protective device is able to be of the time-delay type.

[h] When the calculated value of the fuse is between two standard ratings as specified in 53.1.2.2, a fuse of the nearest standard rating and not more than three times the full-load motor-current rating is to be used.

[i] The protective device is able to be a nontime delay fuse smaller than the size specified in note h when the product is marked to indicate this limit of protection.

[j] When the fuse size employed for the short circuit test requires a marking, the device shall be marked as specified in 73.3.

53.1.2.2 Standard ampere ratings for fuses are 1, 3, 6, 10, 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.

53.1.2.3 For a combination motor controller, motor control device, or overload relay intended to be used with fuses, the protective devices used for the test are to be selected as follows:

a) When the fuse size is 600 A or less, tests may be conducted with Class RK5 fuses. Testing with Class RK5 fuses is considered representative of tests using Class CC, G, H, K, J, RK1, or T fuses. (Class H or K fuses are not permitted to be used for motor-branch-circuit protection with a motor control device rated more than 50 horsepower (37 kW)).

b) When the fuse size is 600 A or less, tests may be conducted with fuses other than Class RK5 (for example Class CC, G, J, RK1, or T), if the equipment is marked according to 73.3 to require the use of that class of fuse.

c) When the fuse size exceeds 600 A, tests shall be conducted with Class L fuses.

53.1.2.4 A motor control device with specified protective device ratings above and below 600 amperes is to be tested with a 600 ampere one-time, nonrenewable fuse at 10,000 amperes and in addition is to be tested in accordance with 53.3.3.1.

53.1.3 Circuit breakers

53.1.3.1 An inverse-time circuit breaker used for the test described in 53.1.3.3 and Table 53.2 is to be specified by the manufacturer in accordance with either of the following:

a) The inverse-time circuit breaker shall be rated not more than four times the maximum full-load motor-current rating for full-load currents of 100 amperes or less or not more than three times the maximum full-load motor-current rating for full-load currents greater than 100 amperes. When the calculated value of the circuit breaker is less than 15 amperes, a circuit breaker rated 15 amperes is to be used. No marking of the circuit breaker rating is required on the product.

b) The inverse-time circuit breaker is able to have a rating less than that specified in 53.1.3.1(a) when the product is marked to indicate the limit of protection as specified in 73.3.

Table 53.2
Ratings of Inverse-Time Circuit Breaker Used for Tests

Maximum ratings of inverse-time circuit breakers used for tests	Circuit breaker marking requirement	Maximum full load motor current rating, amperes
4 times rated maximum full-load motor current	No	100 A or less
3 times rated maximum full-load motor current	No	greater than 100 A
15 A	No	Where calculated value is less than 15 A
Other ratings less than specified above	Yes	–

53.1.3.2 Standard ampere ratings for 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, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000.

53.1.3.3 Short circuit tests on overload relays or devices incorporating an overload relay with an inverse-time circuit breaker as the protective device are to be conducted on the overload relay having the minimum resistance current element per size or construction of the current element. If burn-out of the elements occurs, the test is repeated with the minimum resistance element in the smallest size or construction that does not cause burnout.

53.1.3.4 An instantaneous trip circuit breaker provided as an integral part of a Type D combination motor controller or a self-protected Type E combination motor controller with an integral adjustable instantaneous trip circuit breaker mechanism shall be adjusted to its maximum setting or 13 times the full load current, whichever is less.

Exception: The device shall be adjusted to its maximum setting or 17 times the full load current, whichever is less, when used as the protection for high efficiency Design B motors.

53.2 Sample selection for overload relay

53.2.1 A sufficient number of overload-relay current elements considered to be representative of the line are to be subjected to short circuit tests in series with a motor protective device. Representative samples are to be selected on the basis of configuration, material, and resistance. Samples for the test are to be selected among motor control devices employing the largest and smallest size current element that may be used with the protective device specified for the motor control device.

53.2.2 The overload relay is to be tested in the motor control device with which it is intended to be used, if furnished as part of a motor control device. A shunt or current transformer that is used to reduce the current in the current element of the overload relay is considered to be a part of the relay for the purpose of this test.

Exception: Overload relays, supplied by current transformers which limit the current to the relay, do not have to be subjected to this test, provided that the current is limited to a level which the overload relay has already been evaluated.

53.3 Parameters

53.3.1 For all equipment

53.3.1.1 The equipment is to be subjected to the number and type of operations in accordance with Table 53.5 and shall comply with Table 56.1. Successive operations are to be conducted by closing the circuit on the equipment ("O" operation) by means of any appropriate switching device, using random closing.

53.3.1.2 The test circuit is to be capable of delivering the current specified in Table 53.3 or Table 53.4 for a given horsepower or full load current rating.

Table 53.3
Short Circuit Test Current Values for Devices Rated 600 Volts or Less

Maximum horsepower rating, hp[c]	Number of phases	Equivalent motor full load current, amperes maximum							Test current[a]	Power factor
		110 – 120 V	200 V	208 V	220 – 240 V	380 – 415 V	440 – 480 V	550 – 600 V		
0 – 1	1	16[b]	9.2[b]	8.8[b]	8.0[b]	5.1[b]	4.0[b]	3.2[b]	1000	0.7 – 0.8
over 1 – 2	1	24[b]	13.8[b]	13.2[b]	12.0[b]	7.7	6.0	4.8	5000	0.7 – 0.8
over 2 – 50	1	–	–	–	216	139	108	86	5000	0.7 – 0.8
0 – 1	3	8.4[b]	4.8[b]	4.6[b]	4.2[b]	2.3[b]	2.1[b]	1.7[b]	1,000	0.7 – 0.8
over 1 – 2	3	13.6[b]	7.8[b]	7.5[b]	6.8[b]	4.3	3.4	2.7	5,000	0.7 – 0.8
over 2 – 50	3	260	150	143	130	83	65	52	5,000	0.7 – 0.8
over 50 – 200	3	–	552	528	480	320	240	192	10,000	0.7 – 0.8
over 200 – 400	3	–	–	–	954	636	477	382	18,000	0.25 – 0.30
over 400 – 500	3	–	–	–	1180	786	590	472	30,000	0.20 or less
over 500 – 600	3	–	–	–	10,000 LRA	–	5,000 LRA	4,000 LRA	30,000	0.20 or less
over 600 – 900	3	–	–	–	15,000 LRA	–	7,500 LRA	6,000 LRA	42,000	0.20 or less
over 900 – 1600	3	–	–	–	26,800 LRA	–	13,400 LRA	10,720 LRA	85,000	0.20 or less
over 1600	3	–	–	–	more than 26,800 LRA	–	more than 13,400 LRA	more than 10,720 LRA	100,000	0.20 or less

NOTE – LRA is Locked Rotor Amperes.

[a] Symmetrical rms amperes.

[b] Applies only to overload relays, starters, combination motor controllers, and equipment provided with an overload relay.

[c] For equipment that is not rated in horsepower, the test current shall correspond to the smallest equivalent motor current in the table that is equal to or greater than the rated current of the equipment at the voltage(s) involved.

Table 53.4
Short Circuit Test Values for Devices Rated 601 – 1500 Volts

Full load current, amperes	Test current, symmetrical rms amperes	Power factor
0 – 50	5,000	0.7 – 0.8
51 – 200	10,000	0.7– 0.8
201 – 400	18,000	0.25 – 0.3
401 – 600	30,000	0.20 or less
601 – 850	42,000	0.20 or less
851 – 1500	85,000	0.20 or less
1501 or more	100,000	0.20 or less

53.3.1.3 Fuses and circuit breakers used as main devices need not be mounted in an enclosure. The conductor between the branch circuit protection and the motor control device shall be included in the 4 foot (1.2 m) length as described in 52.3.2.

53.3.2 Provided with fuses – equipment rated 200 hp or less

53.3.2.1 Short circuit tests with fuses on a device having a rating not greater than 200 horsepower (150 kW) are to be in accordance with (a), (b), or (c), as follows:

a) On a single-phase circuit with two poles and one current element in the circuit – three test operations for each current element selected;

b) If rated single-phase only and provided with two current elements – three test operations for each current element selected on a single-phase circuit with two poles and two current elements in the circuit; or

c) If rated 3-phase – two test operations for each current element selected on a 3-phase circuit with three poles and three current elements.

53.3.2.2 The poles – contacts – referred to in 53.3.2.1 may be omitted from the circuit after a sufficient number of tests have been conducted to determine that subsequent malfunction or breakdown of the equipment due to contact arcing is unlikely. Consideration is to be given to contact arcing while testing the intermediate as well as the higher-rated current elements.

53.3.3 Provided with circuit breaker – equipment rated 200 hp or less

53.3.3.1 Short circuit tests on a device having a maximum rating of 200 horsepower (150 kW) or less with an inverse-time or instantaneous-trip circuit breaker are to consist of:

a) Two operations on a 3-phase circuit with three poles and three overload relays in the circuit for a device having three or more poles.

b) For a product rated single phase only:

1) Two poles and two overload relays are to be used if overload relays are provided in each conductor to the motor and

2) Two poles and one overload relay are to be used for other arrangements.

53.3.4 For equipment rated over 200 hp

53.3.4.1 Short-circuit tests on a device having a maximum rating in excess of 200 horsepower (150 kW) are to consist of one test operation on a 3-phase circuit, with three poles and three overload relays in the circuit. The tests are to be performed with protective devices selected in accordance with either note (h) or (i) of Table 53.1 or 53.1.3.1 (a) or (b). If an inverse-time circuit breaker is adjustable, it is to be set at the maximum tripping time unless the product is marked to indicate a limit of protection. A product not provided with three overload relays is to be tested with three poles and two overload relays in the circuit.

Exception: The test may be performed for a period of time at least equivalent to the opening time of the protective device specified on the motor control device at the required level of test current.

53.3.4.2 The number of test operations for each current element selected is to be as specified in Table 53.5.

Table 53.5
Required Number of Test Operations

Rating		Number of poles for a device	Number of current elements[a]	Type of branch circuit protection and number of poles provided		Number of operations[b]
Horsepower	(kW)			Fuse	Circuit breaker	
0 – 200	(0 – 149)	1 phase, single pole	1	1	single pole inverse-time	3 "O" operations
		1 phase, 2 poles	2	2	2 pole inverse-time	3 "O" operations
		3 phase, 3 poles	3	3	3 pole inverse-time	2 "O" operations
201 – 1600	(150 – 1193)	3 phase, 3 poles	3	3	3 pole inverse-time	1 "O" operation

[a] Applies to devices provided with or incorporating a thermal overload relay. See 53.3.2.1, 53.3.3.1, and 53.3.4.1.

[b] Number of operations for each current element selected, when device is provided with or incorporates thermal overload relays.

54 High-Available Fault Current Circuits (Optional)

54.1 General

54.1.1 The optional requirements in this section cover combination motor controllers and motor control devices with or without overload relays for use on circuits having available short circuit currents in excess of the minimum levels specified in Table 53.3, and not more than 200,000 amperes rms symmetrical. For other than a combination motor controller with integral protective devices, the specific type of protective device shall be specified for the product and marked as specified in 73.3. The test current levels shall be one of the values given in Table 54.1.

Table 54.1
High Available Fault Current – Short Circuit Test Current Values RMS Symmetrical or DC Amperes

7,500	25,000	65,000
10,000	30,000	85,000
14,000	35,000	100,000

Table 54.1 Continued on Next Page

Table 54.1 Continued

18,000	42,000	125,000
20,000	50,000	150,000
22,000	–	200,000

54.1.2 Combination motor controllers and motor control devices with or without overload relays shall additionally comply with Section 53, Standard Fault Current Circuits, which is able to be conducted on a separate set of samples.

54.2 Sample selection

54.2.1 Overload relay

54.2.1.1 Samples for the test are to be selected among motor control devices employing the largest and smallest size current element that may be used with the protective device specified for the motor control device.

54.2.1.2 The maximum number of current elements that can be accommodated by the device are to be in place during each test. Three-phase tests are considered to cover single-phase tests for a device of the same design.

54.2.2 Protective devices

54.2.2.1 For a motor control device or overload relay intended to be used with circuit breakers, the protective devices used for the test are to be sized in accordance with 53.1.3.1 and are to be selected as follows:

a) A circuit breaker installed within a combination motor control device is considered to be representative of all other breakers of the same manufacturer, rating, and frame construction. The interrupting rating of the circuit breaker is to be at least the marked short-circuit current rating of the motor control device.

Exception: A circuit breaker with a lower interrupting rating is able to be used when the combination is evaluated and subjected to the appropriate requirements of UL 489.

b) For noncombination controllers, the circuit breaker to be used is to be selected from commercially available units of the molded-case type having essentially the same characteristics with respect to let-through (I^2t) and peak let-through current (I_p) and current-limiting features.

c) For circuit breakers with current limiters provided as part of the control device, the current limiter shall be selected such that when tested on a single-phase circuit, the peak let-through current and a clearing I^2t are not less than the maximum value established for the current limiter intended to be used with the motor control device being tested.

d) For instantaneous circuit breaker, they shall be adjusted to their maximum setting and no more than 13 times the full load current or 17 times the full load current for controllers marked for use with high-efficiency Design B motors.

Exception: Combination motor controller self-protecting control devices are provided with integral short-circuit and ground-fault protection.

54.2.2.2 For a motor control device or overload relay intended to be used with fuses, the protective devices used for the test are to be sized in accordance with 53.1.2.1 and are to be selected as follows:

a) Fuses specified for branch-circuit protection for motor control devices rated over 10,000 amperes shall be limited to high-interrupting capacity, current-limiting types – for example, Class CC, G, J, L, R, and T.

Exception: A motor control device rated 50 horsepower (37 kW) or less and tested at 10,000 amperes, is able to specify Class H or K fuses for motor-branch-circuit protection.

b) A motor control device that is required to be used with RK1 or RK5 fuses is to be tested with fuses having I^2t and I_p characteristics for Class RK5 fuses. All references to Class R fuses are intended to mean fuses with energy let-through (I^2t), characteristics of Class RK5 fuses.

Exception: A motor control device that is marked to restrict its use to RK1 fuses is able to be tested with fuses having energy let-through characteristics of a Class RK1 fuse.

c) A Class CC, G, J, L, R, or T fuse, or motor short-circuit protector is to be selected such that, when tested on a single-phase circuit, the peak let-through current and clearing I^2t are not less than the maximum value established for the fuse – see the UL 248 series of standards – or motor short-circuit protector rating that is intended to be used with the controller being tested. For a fuse with I_p and I^2t limits established for several different short-circuit current levels, the test fuse is to be selected to have at least the maximum values of the current corresponding to the marked short-circuit current rating of the motor control device.

Exception No. 1: A test limiter is able to be used in place of the fuses.

Exception No. 2: Combination motor controller self-protecting control devices are provided with integral short-circuit and ground-fault protection.

54.3 Procedure

54.3.1 A combination motor controller or motor control device with or without overload relays shall be tested according to the requirements in this section and shall additionally comply with Section 52, Short Circuit Test – General. The terminals of the test circuit described in 52.3.1 are to be connected together by a copper bar, and the test circuit is to be calibrated as described in Section 57, Calibration of Test Circuits, at the maximum available short circuit current for which the motor control device is rated.

54.3.2 The test circuit is to have the characteristics specified in Table 54.2.

Table 54.2
High-Capacity Short Circuit Test Values for Devices Rated 600 V or Less

Test current, amperes[a]	Power factor[b]
10,000 amperes or less	0.70 – 0.80
10,001 – 20,000	0.25 – 0.30
Greater than 20, 000	0.15 – 0.20

[a] Symmetrical rms amperes

[b] Lower power factor circuits than specified may be used.

54.3.3 For the short-circuit-closing test (“CO” shot), each switching device of the motor control device is closed on the test circuit. This requires separate tests for each switching device, as specified in Table 54.3: one in which the disconnecting means, when provided, is closed on the circuit, and a second in which the contactor is closed on the circuit. Complete physical closure of the switching contacts is not required to be established. When complete physical closure of the switching contact is established, the closing test on the disconnecting means is able to cover the withstand test (“O” shot) on the motor control device and the closing test on the motor control device is able to cover the withstand test on the disconnecting means. To determine whether complete physical closure of the contacts has occurred, the oscillogram of the short circuit current and voltage traces are reviewed between circuit initiation and current interruption by the protective device. A smooth sinusoidal waveform in this area of the trace is an indication of complete physical closure.

Table 54.3
Required Number of Test Operations

Disconnecting means provided	Type of test	Number of test operations
Yes	Disconnecting means closed on the circuit ("CO" shot)	1[a,b]
Yes	Motor control device closed on the circuit ("CO" shot)	1[a]
Yes	Circuit closed on equipment ("O" shot)	1
No	Motor control device closed on the circuit ("CO" shot)	1
No	Circuit closed on equipment ("O" shot)	1[c]

[a] If complete physical closure of the switching contact is established during closing tests ("CO" shots), the withstand test ("O" shot) is not required.

[b] When a motor control device and its control circuit are supplied from the same source (common control), the closing test on the disconnect switch is not required.

[c] When a stand-alone overload relay is subjected to this test, the overload relay shall be subjected to two "O" shots closing the circuit on the equipment under test.

54.3.4 The equipment is to be subjected to the number and type of operations in accordance with Table 54.3 and shall comply with Table 56.1. Successive operations on a motor control device or overload relay without a disconnecting means are to be conducted by alternating closing the equipment on the circuit ("CO" operation) and closing the circuit on the equipment ("O" shot), using random closing.

54.3.5 When closing the circuit on the equipment ("O" shot), the disconnecting means, when provided, and the motor control device are to be in the fully closed position. When manual motor control devices are to be closed onto the test circuit ("CO" shot), they are to be operated in a manner that would normally be anticipated in service (i.e., in a continuous, uniform movement of the operating handle from the "off" to the "on" position).

55 Group Installation (Optional)

55.1 General

55.1.1 A motor control device or overload relay intended for group installation at standard fault currents shall be tested in accordance with 55.2 and 55.3 and shall also comply with the short circuit test requirements in Section 53, Standard Fault Current Circuits, conducted on a separate set of samples. A motor control device or overload relay intended for group installation at high fault currents shall be tested in accordance with 55.2, 55.3, and 55.4. All devices for group installation according to 55.1.2 shall be marked in accordance with 73.4. All devices for group installation as described in 55.1.3 shall be marked in accordance with 73.5 and 73.6.

55.1.2 The requirements in this section cover a motor control device or overload relay:

a) For use on circuits having available short circuit currents at standard fault levels or at high fault levels; and

b) Protected by a circuit breaker or fuse(s), intended to provide branch circuit protection for two or more motors, or one or more motors and other loads. The protective device(s) shall be selected in accordance with 53.1, except the current rating of the protective device is not limited to those values specified in Table 53.1 or Table 53.2. The maximum size of the branch circuit protective device shall not exceed the ampere rating calculated from the following formula:

$$Amperes = [9.6 \times (maximum\ wire\ size)] - [2.2 \times (minimum\ motor\ FLA)]$$

in which:

Maximum wire size is the ampacity from Table 45.3 of the largest conductor size for which the device terminals have been evaluated; and

Minimum motor FLA is the smallest rated FLA (or equivalent FLA from horsepower rating per Table 47.2) marked on the device.

55.1.3 When intended for installation on the load side of a manual motor controller that has been previously found suitable for tap conductor protection, a motor controller is able to be evaluated to group installation requirements in this section while installed on the load side of the specified manual motor controller. No additional overcurrent protective devices are included in the test circuit.

55.2 Sample selection

55.2.1 A sample of a motor control device, three samples of an overload relay current element, or one sample of a three phase overload relay that complies in all other respects with requirements in this Standard shall be subjected to short circuit tests. The device is to be connected in series with either:

a) A nonrenewable cartridge fuse(s) or an inverse-time circuit breaker of the maximum standard rating with which the motor control device or element is intended to be used and not more than specified in 55.1.2(b); or

b) A manual motor controller suitable for tap conductor protection as in 55.1.3.

55.2.2 Samples of overload relays shall be selected in accordance with 53.2 for standard fault ratings.

55.2.3 Samples of overload relays are to be selected in accordance with 54.2.1.1 for high fault ratings.

55.3 Group installation for standard fault circuit ratings

55.3.1 A motor control device or overload relay having short circuit ratings at levels specified in Table 53.3 shall comply with Table 56.1 when subjected to a short circuit test described in 55.3.2.

55.3.2 The requirements in 53.3 are to be applied, and the test circuit is to be calibrated as described in Section 57, Calibration of Test Circuits, at the standard available short circuit current for which the motor control device or overload relay is rated.

55.4 Group installation for high capacity short circuit ratings

55.4.1 A motor control device or overload relay having short circuit ratings in excess of the levels specified in Table 53.3 shall comply with Table 56.1 when subjected to a short circuit test described in 55.4.2.

55.4.2 The requirements in 54.3 are to be applied and the test circuit is to be calibrated as described in Section 57, Calibration of Test Circuits, at the maximum available short circuit current for which the motor control device or overload relay is rated.

56 Standard and High Fault Acceptance Criteria

56.1 After the protective device or the motor control device has cleared the fault, an overload relay, industrial control equipment incorporating an overload relay, a starter, a combination motor controller, or a motor control device shall comply with Table 56.1.

Table 56.1
Maximum Damage Criteria

Product	Damage criteria reference
Motor control device	a – f
Starter, industrial control equipment incorporating an overload relay	a – g

All devices

a) The solid AWG wire connected between the live pole and the enclosure shall not open.

b) The door or cover shall not be blown open, and it shall be possible to open the door or cover. When deformation of the enclosure occurs, all resulting openings in the enclosure shall comply with 7.17.1 for accessibility of live parts under normal operating conditions.

c) There shall be no damage to a conductor or terminal connector and no conductor shall pull out of a terminal connector. There shall be no damage to bus bars, their insulators and connectors, including stab-in assemblies, and there shall be no evidence of shifting or pullout of bus bars from their mounting means or at terminals.

d) There shall be no breakage or cracking of insulating bases to the extent that the integrity of the mounting of live parts is impaired.

e) Discharge of parts or any risk of a fire shall not occur.

Motor control devices

f) The load switching function of the motor control device is able to be inoperative at the conclusion of the test. The contacts of the motor control device are able to weld or completely disintegrate.

Overload relays

g) When burnout of the current element of a mechanical overload relay occurs, the device shall be marked as specified in 75.7 and the test shall be repeated with the minimum resistance element in the smallest size or construction that does not burn out.

57 Calibration of Test Circuits

57.1 Circuit characteristics

57.1.1 Equipment rated for direct current is to be tested using a direct current electrical source; alternating-current equipment is to be tested on a 60-hertz essentially sinusoidal current electrical source. The open-circuit voltage of the test circuit is to be 100 to 105 percent of the voltage rating of the overload relay, except that the voltage may exceed 105 percent of the rated voltage with the concurrence of those concerned. The test circuit is to be capable of delivering the specified current when the system is short-circuited at the testing terminals to which the device under test is to be connected, and this is to be verified by means of an oscillograph.

57.1.2 For available fault current circuits, air core type reactors are to be employed in the line to obtain the power factor in accordance with Table 53.5. The reactors may be connected in parallel, but no reactor is to be connected in parallel with a resistor; except that a reactor in any phase may be shunted by a resistor if the power consumed by the resistor is in the range between 0.55 – 0.65 percent of the reactive volt-amperes in the reactor in that phase. The minimum value of the shunting resistance used with a reactor having negligible resistance is to be calculated from the equation:

$$R = 167\frac{E}{I}$$

in which *E* is the phase voltage across the reactor with phase current *I* flowing as determined by oscillographic measurement during the short circuit calibration or by proportion from meter measurements at some lower current.

57.2 Alternating-current circuits

57.2.1 General

57.2.1.1 The available current capacity of the circuit is to be at least the value required for the short-circuit-current rating of the motor control device. The frequency of the test circuit is to be 60 ±12 hertz for an alternating-current circuits.

57.2.1.2 The available rms symmetrical current is to be determined at the device terminals.

Exception No. 1: For a circuit rated 25,000 amperes or less, the available current may be determined at the test-station terminals.

Exception No. 2: The available current may be determined at the test-station terminals if for a circuit having a maximum available short-circuit current:

a) Between 25,001 – 50,000 amperes, the available current is determined to be 5 percent higher than the required test current: or

b) Between 50,001 – 200,000 amperes, the available current is determined to be 10 percent higher than the required test current.

If the available current is determined at the test-station terminal and the physical arrangement in the test station requires leads longer than 8 feet (2.4 m) per terminal, the additional length of leads is to be included in the circuit calibration.

57.2.2 Available current of 10,000 amperes or less

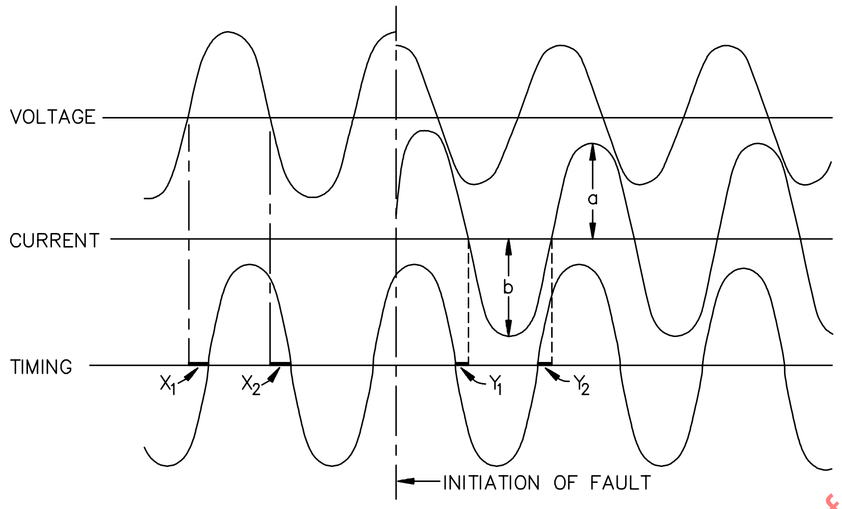
57.2.2.1 For an alternating-current circuit intended to deliver 10,000 amperes or less, the current and power factor are to be determined as follows:

a) For a 3-phase test circuit, the current is to be determined by averaging the rms values of the first complete cycle of current in each of the three phases; the voltage to neutral is to be used to determine the power factor.

b) For a single-phase test circuit, the current is to be the rms value of the first complete cycle – see Figure 57.1 – when the circuit is closed to produce an essentially symmetrical current waveform. The direct-current component is not to be added to the value obtained when measured as illustrated. In order to obtain the desired symmetrical waveform of a single-phase test circuit, controlled closing is recommended although random closing methods may be used. The power factor is to be determined by referring the open-circuit voltage wave to the two adjacent zero points at the end half of the first complete current cycle by transposition through a suitable timing wave. The power factor is to be computed as an average of the values obtained by using these two current zero points.

Figure 57.1

Determination of Current and Power Factor for Circuits of 10,000 Amperes and Less



$$Current = \frac{a+b}{2} \text{ rms calibration of instrument element}$$

$$Power\ Factor = \frac{Cosine\left[(Y_1+X_1) \times 180°\right] + Cosine\left[(Y_2+X_2) \times 180°\right]}{2}$$

Where X_1, X_2, Y_1, and Y_2 values of the power factor are fractions of the 1/2–cycle distance in which they occur.

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57.2.3 Available current of more than 10,000 amperes

57.2.3.1 For circuits intended to deliver more than 10,000 amperes, the current and power factor are to be determined in accordance with the requirements in 57.2.3.2 – 57.2.3.6. Instrumentation used to measure test circuits of over 10,000 amperes is to comply with the requirements in 57.4.

57.2.3.2 The rms symmetrical current is to be determined, with the supply terminals short-circuited by measuring the alternating-current component of the wave at an instant 1/2 cycle – on the basis of the test frequency timing wave – after the initiation of the short circuit. The current is to be calculated in accordance with Figure 7 in IEEE C37.09-1979(R1989).

57.2.3.3 For a 3-phase test circuit, the rms symmetrical current is to be the average of the currents in the three phases. The rms symmetrical current in any one phase is not to be less than 90 percent of the required test current.

57.2.3.4 The test circuit and its transients are to be such that 3 cycles after initiation of the short circuit, the symmetrical alternating component of current will not be less than 90 percent of the symmetrical alternating component of current at the end of the first 1/2 cycle, or the symmetrical alternating component of current at the time at which the overcurrent-protective device will interrupt the test circuit is at least 100 percent of the rating for which the motor control device is being tested. In 3-phase circuits, the symmetrical alternating component of current of all three phases is to be averaged.

57.2.3.5 The power factor is to be determined at an instant 1/2 cycle – on the basis of the test frequency timing wave – after the short circuit occurs. The total asymmetrical rms amperes are to be measured in accordance with 57.2.3.2 and the ratio M_A or M_M is to be calculated as follows:

$$M_A\,(3\ phase) = \frac{Av.\,3\ phases - Asymmetrical\ RMS\ Amperes}{Av.\,3\ Symmetrical\ RMS\ Amperes}$$

$$M_M\,(1\ phase) = \frac{Asymmetrical\ RMS\ Amperes}{Symmetrical\ RMS\ Amperes}$$

Using ratio M_A or M_M, the power factor is to be determined from Table 57.1.

Table 57.1
Short-Circuit Power Factor

Short-circuit power factor, percent	Ratio M_M[a]	Ratio M_A[a]	Short-circuit power factor, percent	Ratio M_M[a]	Ratio M_A[a]
0	1.732	1.394	30	1.130	1.066
1	1.696	1.374	31	1.121	1.062
2	1.665	1.355	32	1.113	1.057
3	1.630	1.336	33	1.105	1.053
4	1.598	1.318	34	1.098	1.049
5	1.568	1.301	35	1.091	1.046
6	1.540	1.285	36	1.084	1.043
7	1.511	1.270	37	1.078	1.039
8	1.485	1.256	38	1.073	1.036
9	1.460	1.241	39	1.068	1.033
10	1.436	1.229	40	1.062	1.031
11	1.413	1.216	41	1.057	1.028
12	1.391	1.204	42	1.053	1.026
13	1.372	1.193	43	1.049	1.024
14	1.350	1.182	44	1.045	1.022
15	1.330	1.171	45	1.041	1.020
16	1.312	1.161	46	1.038	1.019
17	1.294	1.152	47	1.034	1.017
18	1.277	1.143	48	1.031	1.016
19	1.262	1.135	49	1.029	1.014
20	1.247	1.127	50	1.026	1.013
21	1.232	1.119	55	1.015	1.008
22	1.218	1.112	60	1.009	1.004
23	1.205	1.105	65	1.004	1.002
24	1.192	1.099	70	1.002	1.001
25	1.181	1.093	75	1.0008	1.0004
26	1.170	1.087	80	1.0002	1.00005
27	1.159	1.081	85	1.00004	1.00002
28	1.149	1.075	100	1.00000	1.00000
29	1.139	1.070			

[a] See 57.2.3.5.

57.2.3.6 The power factor of a 3-phase circuit may be calculated by using controlled closing so that upon subsequent closings a different phase will be caused to have maximum asymmetrical conditions. The power factor of each phase could then be determined using the method described for single-phase circuits in 57.2.3.5. The power factor of the 3-phase circuit is considered to be the average of the power factors of each of the phases.

57.2.4 Recovery voltage

57.2.4.1 The recovery voltage is to be at least equal to the rated voltage of the motor control device. The peak value of the recovery voltage within the first complete half cycle after clearing and for the next five successive peaks is to be at least equal to 1.414 times the rms value of the rated voltage of the motor control device. Each of the peaks is not to be displaced by more than ±10 electrical degrees from the peak values of the open-circuit recovery voltage – that is, the displacement of the peak from its normal position on a sinusoidal wave. The average of the instantaneous values of recovery voltage each of the first six, half cycles measured at the 45 degree and 135 degree points on the wave is to be not less than 85 percent of the rms value of the rated voltage of the controller. The instantaneous value of recovery voltage measured at the 45 degree and 135 degree points of each of the first six, half cycles is in no case to be less than 75 percent of the rms value of the rated voltage of the motor control device.

57.2.4.2 If there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave when compared with the open-circuit secondary voltage wave before current flow in a circuit that employs secondary closing, the detailed measurement of recovery voltage characteristics as indicated in 57.2.4.1 is not required.

57.3 Direct current circuits

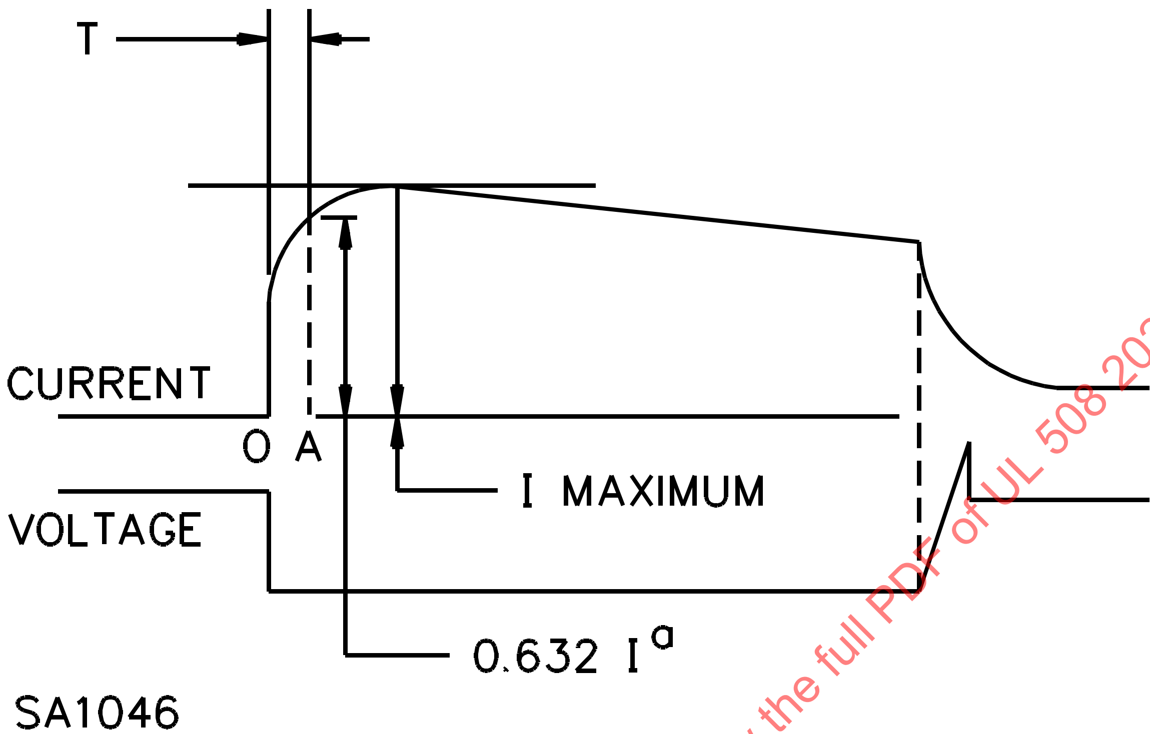
57.3.1 An equipment intended for use on a dc system is to be tested with dc and with the equipment connected so that the frame and enclosure will be positive in potential with regard to the nearest arcing point.

57.3.2 Oscillograph recordings, or an equivalent method, are to be used to determine circuit characteristics.

57.3.3 For a dc source, the requirements of 57.3.4 – 57.3.8 are to be applied. The time constant of the test circuit is to be determined by the method shown in Figure 57.2 and is to be no less than the value shown in Table 57.2.

Figure 57.2

Determination of the Short Circuit Test Constant (Oscillographic Method) of Direct-Current Circuits



[a] The value of the time constant is given by the abscissa OA corresponding to the ordinate 0.632I of the oscillograph of calibration of the circuit.

Table 57.2
Time Constant of Test Circuit

Rated interrupting current, amperes	Minimum time constant, seconds
10,000 or less	0.003
Over 10,000	0.008

57.3.4 The dc open circuit voltage measurement mentioned in 57.1.1 is to be made with a voltmeter. In addition, the open circuit voltage, as determined by the arithmetic average of the maximum and minimum values of the voltage wave read from the oscillograph, is to be within 99 percent and 105 percent of the rated voltage of the equipment, except that a higher voltage may be used if agreeable to all concerned.

57.3.5 The minimum point on the dc voltage wave is to be no less than 90 percent of the rated voltage of the equipment.

57.3.6 The available dc capacity of the circuit is to be no less than the value as required for the rating of the equipment as indicated in Table 53.3 or Table 54.2, as appropriate. The prospective current is to be determined with the supply terminals short circuited by measuring the maximum displacement on an oscillogram at a time, after the start of current, of no less than 4 times the required time constant. Any overshot above time-current curve (exponentional curve) is not to be considered.

57.3.7 The time constant of the circuit is the time measured on the oscillogram where the current is 63.2 percent of the prospective current.

57.3.8 If the current source has a ripples, measurements are to be made from the midpoint of the ripple.

57.4 Instrumentation for test currents above 10,000 amperes

57.4.1 The galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration and while testing are to be of a type having a flat (±5 percent) frequency response from 50 – 1200 hertz. For fast acting fuses, current limiters, or motor-short-circuit protectors, a galvanometer may need to have a flat frequency response from 50 – 9000 hertz or an oscilloscope may be needed to obtain accurate values of peak current, (I_p), and energy let-through, (I^2t).

57.4.2 Galvanometers are to be calibrated as described in 57.4.3 – 57.4.6.

57.4.3 When a shunt is used to determine the circuit characteristics, a direct-current calibrating voltage is normally used. The voltage applied to the oscillograph galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the nominal short-circuit current is flowing. The voltage is to be applied so as to cause the galvanometer to deflect in both directions. Additional calibrations are to be made using approximately 50 percent and approximately 150 percent of the voltage used to obtain the deflection indicated above, except that if the anticipated maximum deflection is less than 150 percent, such as a symmetrically closed single-phase circuit, any other suitable calibration point is to be chosen. The sensitivity of the galvanometer circuit in volts per inch (or millimeter) is to be determined from the deflection measured in each case, and the results of the six trials averaged. The peak amperes per inch (or millimeter) is obtained by dividing the sensitivity by the resistance of the shunt. This multiplying factor is to be used for the determination of the rms current as described in 57.2.3.2.

57.4.4 A 60 hertz sine-wave potential may be used for calibrating the galvanometer circuit, using the same general method described in 57.4.3. The resulting factor is to be multiplied by 1.414.

57.4.5 When a current transformer is used to determine the circuit characteristics, an alternating current is to be used to calibrate the galvanometer circuit. The value of current applied to the galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer is connected to the secondary of the current transformer and nominal short circuit current is flowing in the primary. Additional calibrations are to be made at approximately 50 percent and approximately 150 percent of the current used to obtain the deflection indicated above except that if the anticipated maximum deflection is less than 150 percent, such as in a symmetrically closed single-phase circuit, any other suitable calibration point is to be chosen. The sensitivity of the galvanometer circuit in rms amperes per inch (or millimeter) is to be determined in each case and the results averaged. The average sensitivity is to be multiplied by the current-transformer ratio and by 1.414 to obtain peak amperes per inch. This constant is to be used for the determination of the rms current as described in 57.2.3.2.

57.4.6 All the galvanometer elements employed are to line-up properly in the oscillograph, or the displacement differences are to be noted and used as needed.

57.4.7 The sensitivity of the galvanometers and the recording speed are to be such that the values of voltage, current, and power factor can be determined accurately. The recording speed is to be at least 60 inches (1.5 m) per second.

57.4.8 With the test circuit adjusted to provide the specified values of voltage and current and with a noninductive (coaxial) shunt that has been found acceptable for use as a reference connected into the circuit, the tests described in 57.4.9 and 57.4.10 are to be conducted to verify the accuracy of the manufacturer's instrumentation.

57.4.9 With the secondary open-circuited, the transformer is to be energized and the voltage at the test terminals observed to see if rectification is occurring making the circuit unacceptable for test purposes because the voltage and current will not be sinusoidal. Six random closings are to be made to demonstrate that residual flux in the transformer core will not cause rectification. If testing is done by closing the secondary circuit, this check can be omitted providing testing is not commenced before the transformer has been energized for approximately 2 seconds, or longer if an investigation of the test equipment shows that a longer time is necessary.

57.4.10 With the test terminals connected together by means of a copper bar, a single-phase circuit is to be closed as nearly as possible at the moment that will produce a current wave with maximum offset. The short circuit current and voltage are to be recorded. The primary voltage is to be recorded if primary closing is used. The current measured by the reference shunt is to be within 5 percent of that measured using the manufacturer's instrumentation and there is to be no measurable variation in phase relationship between the traces of the same current. Controlled closing is not required for polyphase circuits.

57.4.11 When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt is to be removed from the circuit. The reference coaxial shunt is not to be used during the final calibration of the test circuit nor during the testing of motor control device.

57.5 Calibration characteristics for protective device

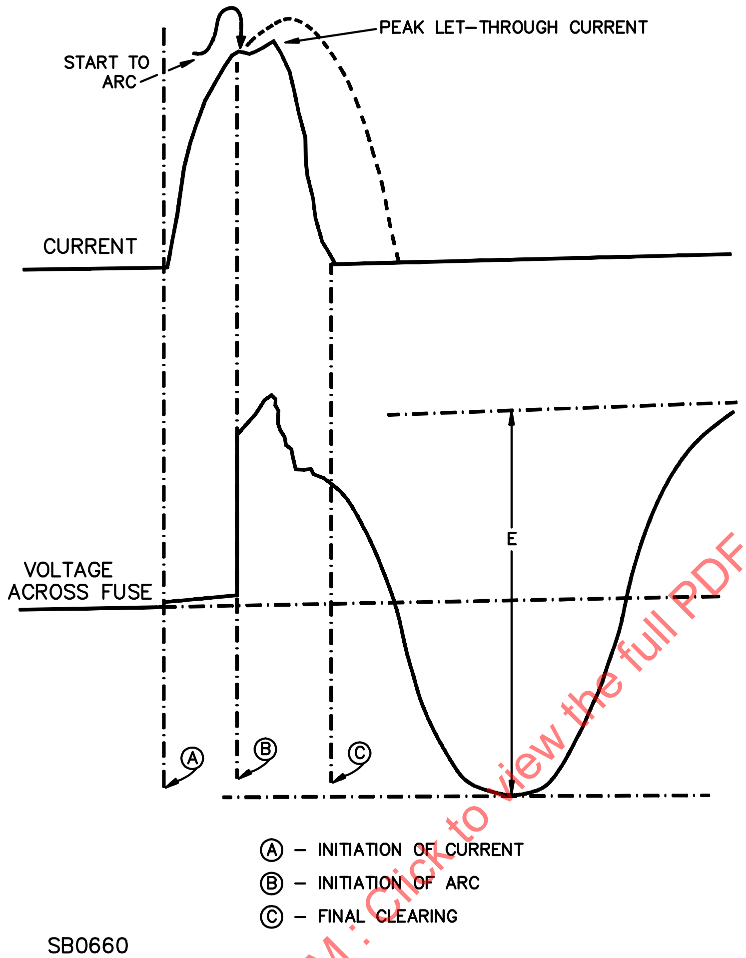
57.5.1 To obtain the required values specified in 54.2.2.2(c), it may be necessary to employ a fuse, current limiter, or motor short-circuit protector larger than that specified for use with the device being tested; or a commercially available test fuse designed and calibrated to exhibit I^2t and I_p characteristics at least equal to the maximum permitted limits for the fuse, current limiter, or motor short-circuit protector rating. The let-through characteristics are to be determined in accordance with 57.4.3 – 57.4.6.

57.5.2 Fuses, current limiters, or motor short-circuit protectors used for tests are to be selected from a batch from which two samples have been selected. The value of the I_p and I^2t determined for the two selecte samples is to be equal to or greater than the required values. These determinations are to be made in accordance with 57.5.3 and 57.5.4.

57.5.3 Figure 57.3 is typical of oscillograms obtained during the test of a fuse, current limiter, or motor short-circuit protectors on an alternating-current circuit; and represents a circuit that opened before the current could reach its first major peak. The peak let-through current I_p is to be determined as illustrated.

Figure 57.3

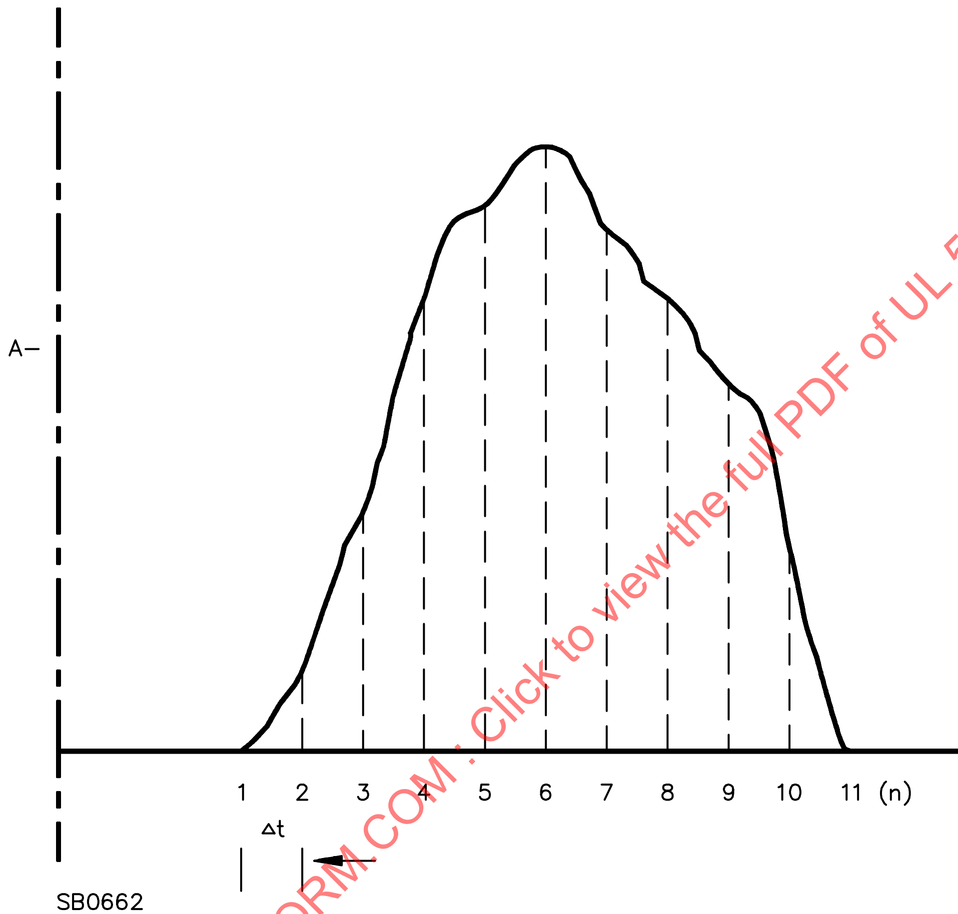
Peak Let-Through Current



57.5.4 The let-through energy (I^2t) is to be determined from an oscillogram showing a current trace during the interruption of the circuit by the fuse, current limiter, or motor short-circuit protectors. The determination is to be made by the application of Simpson's rule illustrated in Figure 57.4 or the use of an integrating planimeter.

Figure 57.4

Application of Simpson's Rule to Fuse Current Oscillogram to Obtain Let-Through I^2t



1. Odd numbers of ordinates (n) are to be chosen evenly spaced (Δt). The more uneven the curve, the more ordinates.

2. Each ordinate is to be measured, multiplied by ampere scale (indicated by A in this figure), and squared.

3. I^2 t is calculated as follows:

$I^2 t = (\Delta t/3)[({}_1{}^2 + I_n{}^2) + 4(I_2{}^2 + I_4{}^2 + I_6{}^2 ... I_{(n-1)}{}^2) + 2(I_3{}^2 + I_5{}^2 + I_7{}^2 ... I_{(n-2)}{}^2)]$

57.5.5 The time base in degrees-per-inch (degrees/cm) is to be determined by averaging the distance, between zero-line crossover points of the voltage wave or a timing wave, in which the fuse-current trace is most nearly centered.

58 Transient-Voltage-Surge Suppression Test

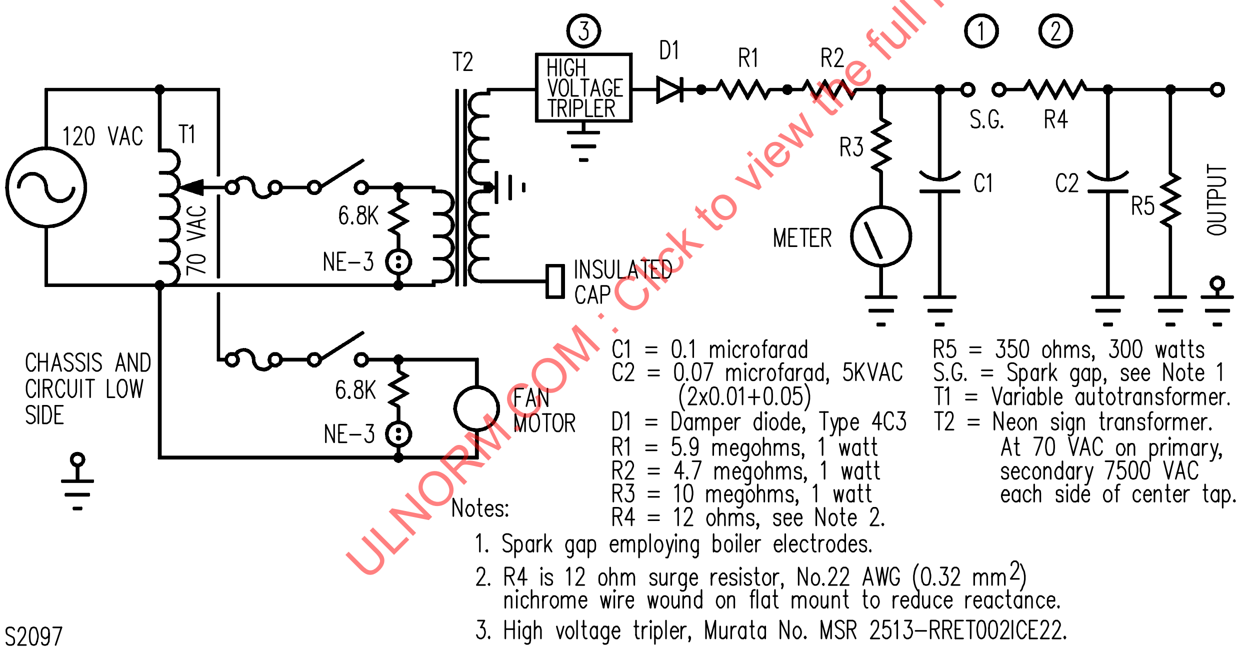
58.1 A surge-controlled circuit as specified in 37.3 and 37.4 shall withstand without breakdown a single 1.2 by 50 microseconds full-wave impulse with a crest value of 5.0 kilovolts. See IEEE 4-1995. The transient voltage surge shall not exceed 300 percent of the peak working voltage, or 300 volts, whichever is greater and the equipment shall be operative after conclusion of the test.

58.2 The wave form mentioned in 58.1 may typically be provided by an impulse generator illustrated in Figure 58.1 when operated under open-circuit conditions. Caution should be exercised to prevent back surges on the line.

58.3 The equipment is to be connected to a single-phase source of supply operating at rated voltage with the impulse generator connected across the equipment.

Figure 58.1

Typical Impulse Generator



59 Accelerated Aging Test

59.1 When tested as described in 59.2, a sealing compound shall not melt, become brittle, or otherwise deteriorate to a degree that will affect its sealing properties as determined by comparing the conditioned sample to an unconditioned sample.

59.2 A sealing compound is to be applied to the surface it is intended to seal. For a temperature rise not exceeding 35 °C (63 °F), a representative sample of the surface with the sealing compound applied is to be conditioned for 7 days in an air oven at 87 °C (189 °F).

60 Breakdown of Components Test

60.1 There shall be no emission of flame or molten metal nor ignition of cotton loosely placed over all openings of ventilated equipment or totally around open type devices when capacitors, diodes, or other solid state components are short- or open-circuited.

Exception: The test is not required:

a) If circuit analysis indicates that no other component or portion of the circuit will be seriously overloaded as a result of the assumed open circuiting or short circuiting of another component.

b) For components in Class 2 circuits (see 33.2).

c) For components in Limited Voltage/Current (see 33.3), Limited Energy involving open circuit potentials less than or equal to 30 V ac or 42.4 V peak (see 33.6), and Limiting Impedance (see 33.7) secondary circuits.

d) On power semiconductor devices if equivalent testing is accomplished during short circuit tests.

e) For components complying with requirements applicable to the component.

f) For components whose failure may result in an increased risk of fire or electric shock and that have previously been investigated and found suitable for the application.

60.2 The breakdown of the component shall be simulated after the device is fully energized and in operation.

60.3 Components shall be evaluated one at a time.

60.4 For an open type device, a wire mesh cage that is 1.5 times the size of the device may be provided to simulate the intended enclosure.

60.5 The outer enclosure or wire mesh cage (if any) and any grounded or exposed dead-metal part are to be connected through a 30-ampere fuse to the supply circuit pole least likely to arc to ground. The 30-ampere fuse shall not open. In addition to this, a fuse/circuit breaker having the current rating with the minimum value which caused after any short has occurred inside the device, may be connected in series with the product supply. This lowest current value is to be decided by the manufacturer as it depends upon product hardware.

61 Strain Relief Test

61.1 The device provided with a strain relief as in 26.11.6 shall withstand without damage to the cord or conductors and without displacement, a direct pull of 35 pounds (156 N) applied to the cord for 1 minute. Supply connections within the equipment are to be disconnected from terminals or splices during the test when applicable.

61.2 A field wiring lead shall withstand without damage or displacement a direct pull of:

a) 20 pounds (90 N) for 1 minute applied to a lead extending from the enclosure such as through a hub or nipple; and

b) 10 pounds (44.5 N) for 1 minute applied to a lead within a wiring compartment or an outlet box.

The field wiring leads at the point of connection to the equipment under test need not be disconnected from the terminal, splice or solder connection points during the test.

62 Push-Back Relief Test

62.1 To determine compliance with 26.11.9, a product shall be tested in accordance with 62.2 without occurrence of any of the conditions specified in 26.11.9 (a) – (d).

62.2 The supply cord or lead is to be held 1 inch (25.4 mm) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing which extends further than 1 inch is present it is to be removed prior to the test. When the bushing is an integral part of the cord, then the test is to be carried out by holding the bushing. The cord or lead is to be pushed back into the product in 1-inch (25.4-mm) increments until the cord buckles or the force to push the cord into the product exceed 6 pounds-force (26.7 N). The supply cord or lead within the product is to be manipulated to determine compliance with 26.11.9.

63 Wire Flexing

63.1 The wiring to components mounted on a door is to be tested by opening the door as far as possible – restraints such as a chain are to remain in place – and then closing it for 500 cycles of operation. Following this test, the equipment is to be subjected to the dielectric voltage withstand test described in 51.1.1 applied between conductors and between conductors and ground.

64 Printed Wiring Board Abnormal Operation Test

64.1 To determine whether spacings at specific points on printed wiring boards comply with 37.13, each point of the printed wiring board so identified shall be tested as described in 64.2 – 64.5 with adjacent printed circuit paths short-circuited one at a time until the operation of an integral protective device, the opening of a component as described in 64.2, or until thermal conditions have stabilized, up to a maximum of 7 hours. As a result of this test:

a) The overcurrent protection in the branch circuit to which the equipment is connected shall not open.

b) The cheesecloth or tissue paper shall not glow or flame.

c) The 3-ampere fuse connected in the equipment grounding circuit shall not open.

64.2 Operation of an overcurrent protection device integral to the equipment under test, before any abnormal condition results is acceptable. When a wire or a printed wiring board trace opens, the gap is to be electrically shorted and the test continued. This applies to each occurrence. When the circuit is interrupted by the opening of a component, the test is to be repeated twice, using new components as necessary.

64.3 A sample of the equipment employing the printed wiring board is to be wired as intended to an electrical supply circuit sized and protected to simulate end-use conditions.

64.4 A 3-ampere fuse is to be connected between the supply circuit pole least likely to arc to ground, and the outer enclosure or wire cage and grounded or exposed dead metal parts.

64.5 The equipment is to be placed on a white-tissue-paper covered softwood surface. Open equipment is tested in a representative enclosure or in a wire cage of dimensions as in 44.6. A single layer of cheesecloth is to be draped loosely over the entire enclosure or wire cage.

65 Secondary Circuits Test

65.1 General

65.1.1 Unless otherwise specified in the specific test section, the test measurements are to be made as follows:

a) The primary voltage supplied to the isolating source shall be not less than specified in Table 44.2 for the Temperature Test. For an isolating source with multiple primary voltage ratings, the highest voltage rating shall be used for this test. Overcurrent protective devices in the branch circuit shall not open as a result of this test.

b) The maximum open circuit voltage potential available to the secondary circuit under consideration is to be measured directly across the output terminals of the isolating source.

c) For an isolating source with multiple secondary circuits, only one secondary circuit is to be tested at a time. All other secondaries not under test are not required to be connected to a load.

d) The applicable voltage, current and volt-ampere capacity measurements shall be made directly across the secondary output terminals of the isolating source. When a tapped transformer winding is used to supply a full-wave rectifier, the measurements are to be made from either end of the winding to the tap. When the transformer is used as part of a switching-type power supply, the measurements are to be made after the transformer secondary winding rectification means.

65.2 Limited voltage/current secondary test

65.2.1 With the isolating source connected as described in 65.1.1, the open circuit voltage of each secondary shall not exceed 30 Vrms or 42.4 V peak and the available current in the secondary shall not exceed 8 amperes after the 1 minute test interval as described in 65.2.2.

65.2.2 The current available to the secondary circuit under evaluation is to be measured by connecting a variable resistive load across the source of that secondary and then constantly adjust the load to maintain a secondary current that is slightly more than 8 amperes during the 1 minute test interval. When an available current of more than 8 amperes is not able to be obtained under any condition of loading, up to and including a short circuit, then the test is to be discontinued for that circuit.

65.2.3 Where the circuit voltage and/or available current is limited by a fixed impedance or regulating network, the circuit shall be additionally tested under single component fault conditions. The circuit shall be tested as noted in 65.2.1 and 65.2.2 except the fixed impedance or regulating network shall be subjected to this test while open-circuited or short-circuited, one condition at a time. For a discrete, multiple terminal device, such as a transistor, SCR, triac, or similar device, any combination of terminals taken two at a time shall be open- or short-circuited. For an integrated circuit device, the following combinations of terminals shall be tested:

a) Each pair of adjacent terminals shorted;

b) Each input terminal shorted to referenced ground terminal;

c) Each output terminal shorted to referenced ground terminal;

d) Each input terminal shorted to each power supply;

e) Each output terminal shorted to each power supply; and

f) Each terminal open-circuited.

65.3 Limited energy secondary test

65.3.1 With the isolating source connected as in 65.1.1, the open circuit voltage of the secondary shall not exceed 100 V and the calculated volt-ampere capacity described in 65.3.2 shall not exceed 200 volt-amperes.

65.3.2 The maximum volt-ampere capacity available to the secondary circuit under consideration is to be measured by connecting a variable resistive load across the source of that secondary and then measuring the voltage and current while varying the resistive load from open-circuit to short circuit in 1-1/2 to 2-1/2 minutes. The maximum available volt-ampere capacity is then calculated by multiplying the simultaneously measured values of secondary voltage and secondary current.

65.4 Isolated power supply capacity test

65.4.1 With the isolating source connected as in 65.1.1, the open circuit voltage of the secondary shall not exceed 150 V and the calculated short circuit power described in 65.4.2 shall not exceed 10,000 volt-amperes.

65.4.2 The maximum short circuit power available to the secondary circuit under consideration is the product of the measured open circuit voltage and the measured maximum short circuit current of the isolating source with any protective devices bypassed.

65.5 Limited voltage secondary test

65.5.1 With the isolating source connected as in 65.1.1, an isolating source that is not provided with secondary overcurrent protection shall be subjected to the test described in 65.5.2. As a result of the test, there shall be no softening or discoloration of conductor insulation.

65.5.2 Each secondary circuit of the isolating source is operated with the secondary short circuited until ultimate results occur. The opening of an integral protective device or constant temperatures are indications of ultimate conditions.

65.6 Limiting impedance test

65.6.1 Limiting Impedance Abnormal Test

65.6.1.1 With the isolating source connected as in 65.1.1, a limiting impedance shall not emit molten metal or flames or ignite cotton loosely placed over all openings of ventilated equipment or totally around open type equipment when the components on the load side of the limiting impedance are short circuited. Additional trials of this test shall be performed under single component fault conditions of the limiting impedance as described in 65.6.1.3.

65.6.1.2 With the isolating source connected as in 65.1.1, a circuit supplied by a limiting impedance relied upon to reduce the risk of an electric shock, a 1500-ohm resistor is connected between the limiting impedance and ground. As a result of the test, the current measured through the 1500-ohm resistor shall not exceed 5 mA. Additional trials of this test shall be performed under single component fault conditions described in 65.6.1.3.

65.6.1.3 Except as noted in 33.7.2, any circuit component of the limiting impedance, such as a resistor, capacitor, or solid-state device shall be subjected to this test while open-circuited or short-circuited, one condition at a time. For a discrete, multiple terminal device, such as a transistor, SCR, triac, or similar device, any combination of terminals taken two at a time shall be open- or short-circuited. For an integrated circuit device, the following combinations of terminals shall be tested:

a) Each pair of adjacent terminals shorted;

b) Each input terminal shorted to referenced ground terminal;

c) Each output terminal shorted to referenced ground terminal;

d) Each input terminal shorted to each power supply;

e) Each output terminal shorted to each power supply;

f) Each terminal open-circuited.

65.6.2 Limiting impedance 15 W determination, alternate method

65.6.2.1 As an alternate method of determining limiting impedance components, a circuit is able to be evaluated as described in 65.6.2.2. As a result of this test, the limiting impedance shall be subjected to the Limiting Impedance Abnormal test in 65.6.1.

65.6.2.2 Starting at the input to the circuit, the maximum wattage available to the secondary circuit under consideration is to be measured by connecting a variable resistive load between the load side point of each component in line with the source and the supply return. The variable resistance is to be adjusted to a value which maintains a level of 15 watts as measured by a wattmeter. Each component capable of maintaining 15 watts or more for a period of 5 seconds is to be identified as a primary circuit component.

66 Leakage Current Test

66.1 The leakage current of cord-and-plug-connected equipment rated for a nominal 120-, 208-, or 240-V supply when tested in accordance with 66.3 – 66.8 shall not be more than 3.5 mA for grounded, 3-wire, portable and stationary equipment employing a standard attachment plug rated 20 A, or less.

66.2 Leakage current refers to all currents, including capacitively coupled currents, that may be conveyed between exposed conductive surfaces of the equipment and ground or other exposed surfaces of the equipment.

66.3 All exposed conductive surfaces are to be tested for leakage currents. Leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one surface to another if simultaneously accessible. Parts are considered to be exposed surfaces unless they are guarded by an enclosure considered acceptable for protection against the risk of electric shock. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages that are not considered to involve a risk of electric shock. If all accessible surfaces are bonded together and connected to the grounding conductor of the power-supply cord, the leakage current can be measured between the grounding conductor and the grounded supply conductor. If exposed dead metal parts of the equipment are connected to the neutral supply conductor, this connection is to be open during the test.

66.4 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 by 20 cm (4 by 8 inches) in contact with the surface. If the surface is less than 10 by 20 cm (4 by 8 inches), the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the equipment.

66.5 The measurement circuit for leakage current for single phase equipment is to be as illustrated in Figure 66.1. For 3-phase equipment, the leakage current shall be the sum of measurements from each phase to neutral. The measurement instrument is defined in (a) – (c). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument; it need not have all the attributes of the defined instrument.

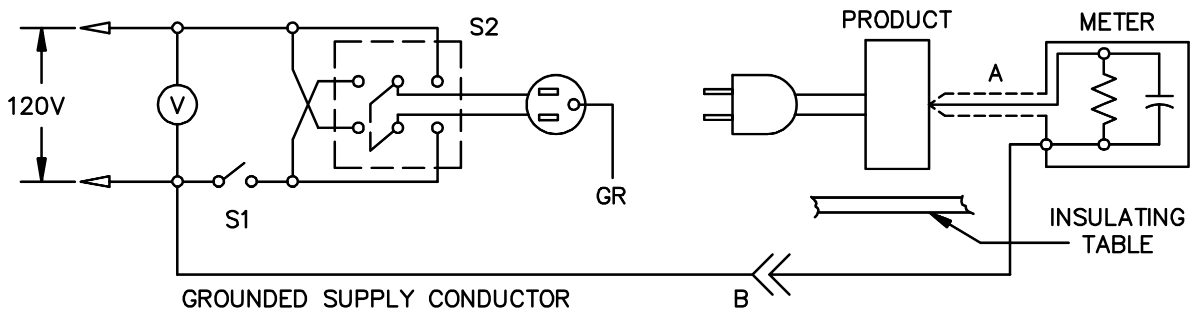
a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.

b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

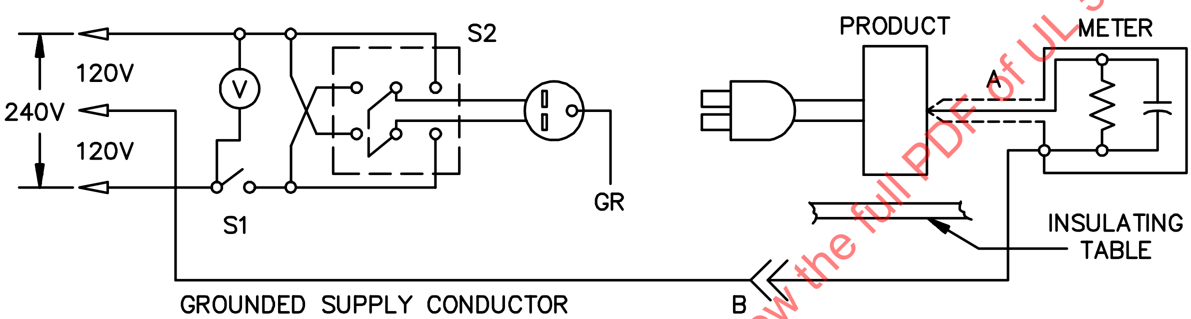
c) Over a frequency range of 0 – 100 kHz, the measurement circuitry is to have a frequency response – ratio of indicated to actual value of current – that is equal to the ratio of the impedance of a 1500-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 3.5 mA, the measurement is to have an error of not more than 5 percent at 60 Hz.

Figure 66.1

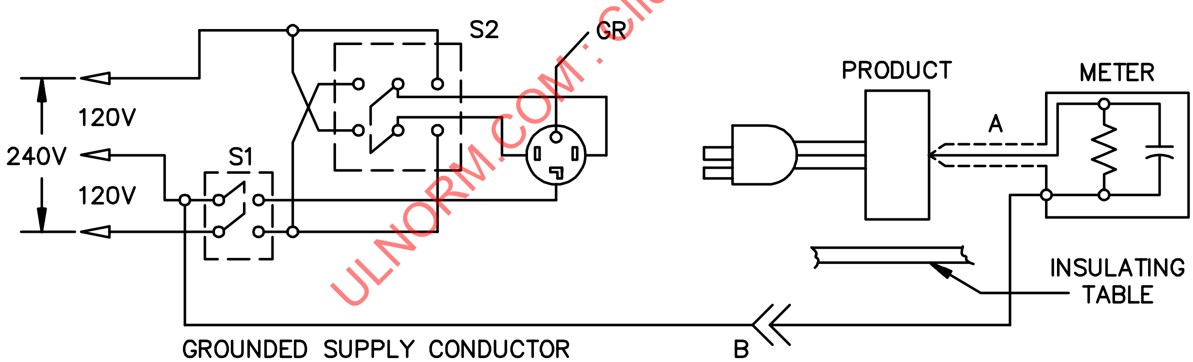
Leakage-Current Measurement Circuits



Equipment intended for connection to a 120 V power supply, as illustrated above.



Equipment intended for connection to a 3–wire, grounded neutral power supply, as illustrated above.



Equipment intended for connection to a 3–wire, grounded neutral power supply, as in the 240 V example illustrated above.

A – Probe with shielded lead.

B – Separated and used as clip when measuring currents from one part of equipment to another.

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66.6 Unless the meter is being used to measure leakage from one part of the equipment to another, the meter is to be connected between the accessible parts and the grounded supply conductor.

66.7 A sample of the equipment is to be tested for leakage current starting with the as-received condition – as-received being without prior energization except as may occur as part of the production-line testing. The grounding conductor, if any, is to be open at the attachment plug. The supply voltage is to be in accordance with Table 44.2. The test sequence, with reference to the measuring circuit, Figure 66.1, is to be as follows:

a) With switch S1 open, the equipment is to be connected to the measuring circuit. Leakage current is to be measured using both positions of switch S2, and with the equipment switching devices in all their normal operating positions.

b) Switch S1 is then to be closed energizing the appliance and within 5 seconds the leakage current is to be measured using both positions of switch S2, and with the equipment switching devices in all their normal operating positions.

c) The leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is considered to be obtained by operation as in the normal temperature test.

66.8 Normally a sample will be carried through the complete leakage-current-test programs described in 66.7, without interruption for other tests. With the concurrence of those concerned, the Leakage Current Tests may be interrupted for the purpose of conducting other nondestructive tests.

67 Switches Intended for Mounting in a Flush-Device Box and Suitable for Lighting Control

67.1 With respect to 42.4.2, the leakage current conducted through an equipment-grounding or the equipment-bonding conductor or connection of an industrial switch shall be tested in accordance with 67.2. An industrial switch in the as-received condition is to be subjected to this test. Two more switches shall be tested, one switch with one of the limiting means in the Exception to 42.4.2 defeated, and the other switch with the other means in the Exception to 42.4.2 defeated.

67.2 The test set up shall be in accordance with 67.3 – 67.7, except S2 described in 67.7 need not be switched to the second position. Switch S2 is to be maintained in the normal power setting for normal operation for this measurement. The measurements shall be taken from the points listed below to the grounded (identified) supply conductor:

a) Grounding/bonding connection or conductor;

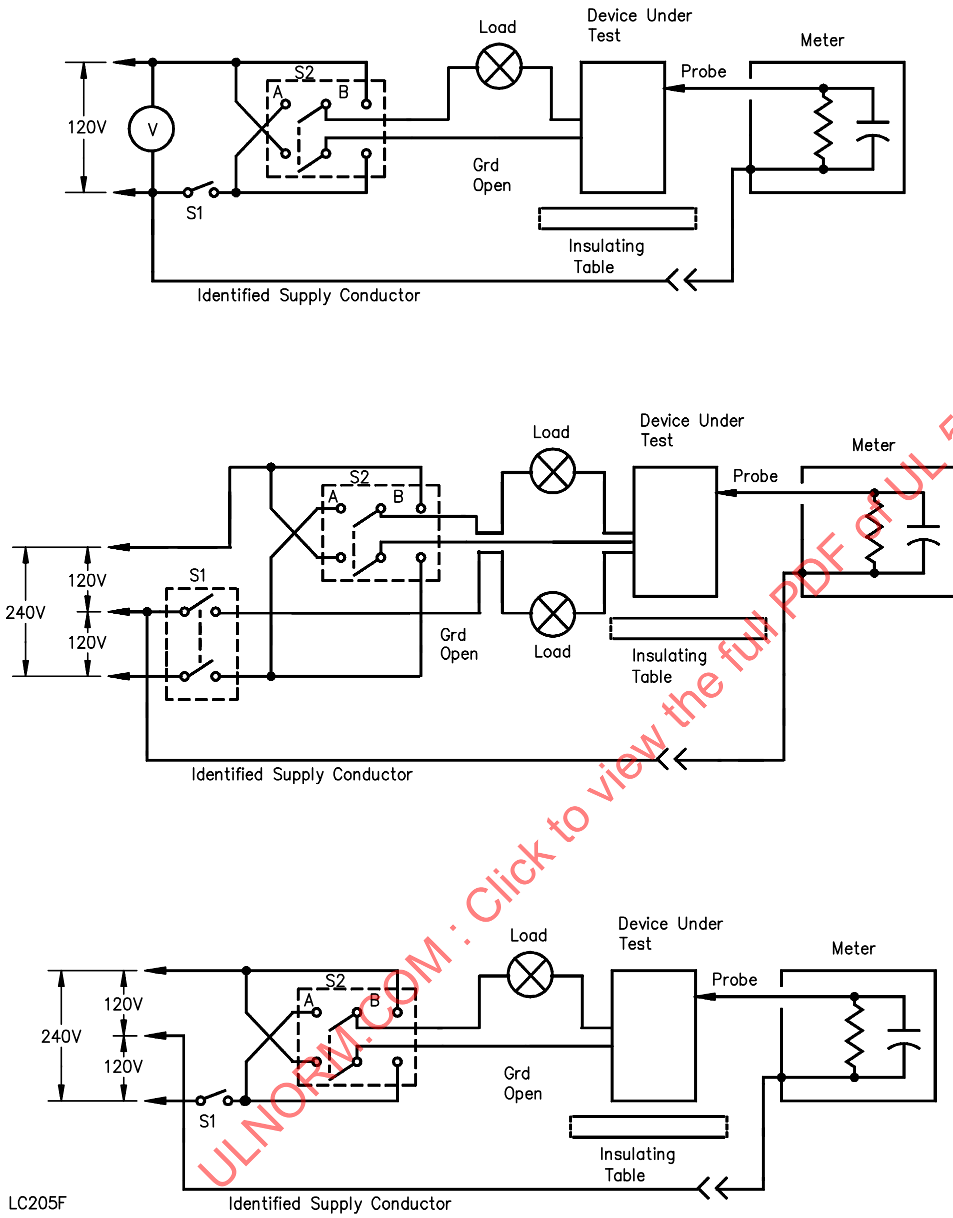
b) Equipment-bonding connection or conductor, if present; and

c) All exposed metal parts, when installed as intended but with the cover plate and field replaceable parts removed.

67.3 The test circuit is to be as shown in Figure 67.1.

Figure 67.1

Leakage Current Test Circuits



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67.4 The meter may be electronic or a direct-indicating type, and is to:

a) Indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor;

b) Be calibrated at 60 Hz;

c) Indicate the rms value of a pure sine wave with an accuracy of 5 percent at an indication of 0.5 mA; and

d) Have a terminal impedance of 1500 ohms shunted by a 0.15 microfarad capacitor.

67.5 The test frequency is to be 60 hertz, and the test voltage is to be as specified in Table 67.1.

Table 67.1
Test Voltages

Industrial switch rating volts AC	Test voltage V
110 – 120	120
220 – 240	240
254 – 277	277
347	347
440 – 480	480
550 – 600	600
All other ratings	Rated voltage

67.6 At the start of the test, the industrial switch is to be at room temperature with all industrial switches in the closed position and the S1 switch open. See Figure 67.1. The leakage current is to be measured within 5 seconds of closing the S1 switch, and again after 1 hour of continuous operation. The leakage current is to be measured.

67.7 The leakage current is to be measured with the S2 switch in position A, with the S2 switch in position B, and with the S1 switch both closed and open. See Figure 67.1.

68 Protection Against Contact with Live Parts of Door Mounted Components Test

68.1 To determine compliance with 41.1, a 50 mm (1.97 in) diameter rigid sphere is applied with a pushing force of 50 N (11.3 lbs) to all openings around uninsulated live parts. At the end of the test, the sphere shall not contact any uninsulated live part involving a potential of more than 30 volts rms (42.4 volts peak) and obstacles shall not be damaged or removed by the pushing force. A signal circuit, consisting of a low-voltage supply in series with an indicating lamp, connected between the probe and the uninsulated live parts is able to be used as a means to determine contact with live parts.

69 Electronic Fluorescent Ballasts, CFLs, and LED Drivers

69.1 A lighting control for use with electronic ballasts, self-ballasted LED and Compact Fluorescent Lamps (CFL), LED drivers and similar loads with capacitive load characteristics having a rated current (steady state current) and rated voltage in accordance with Table 69.1, Table 69.2, or Table 69.3 shall be tested as described in 69.2 – 69.4 to determine if the lighting control is compatible with an electronic fluorescent ballast, CFL, or LED driver that operates within the parameters defined by Table 69.1, Table 69.2, or Table 69.3 and ANSI C82.11.

Table 69.1
Bulk Energy Capacitances

System (VAC)	Bulk energy capacitance: μF per Ampere of steady state current
120	175
277	125

Table 69.2
Peak Current Requirements[a]

Steady state current (A)	Peak current (A), 120 VAC	Pulse Width 120 VAC(mS) (See Note 2)	I^2t (A^2 sec) 120 VAC (See Note 1)	Peak current (A), 277 VAC	Pulse Width 277 VAC(mS) (See Note 2)	I^2t(A^2 sec) 277 VAC (See Note 1)
0.5	75	0.34	11	77	0.07	11
1	107	0.48	24	131	0.71	27
2	144	0.70	41	205	0.85	76
3	166	0.89	51	258	0.98	111
5	192	1.20	74	320	1.20	205
8	221	1.25	98	370	1.25	274
10	230	1.50	106	430	1.50	370
12	235	1.80	110	440	1.80	387
15	239	2.00	114	458	2.00	420
16	242	2.10	117	480	2.10	461

NOTES –

1) The values used to calculate I^2t are the peak current shown in Table 69.2 and a pulse duration of 2 mS (t).

2) Pulse widths shown in the Table 69.2 and will provide adequate performance with electronic ballasts having pulse widths up to 2 ms, in accordance with ANSI C82.11.

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Table 69.3
Peak Current Requirements With Pulse Width Less Than or Equal to 2.35 MS for Endurance Test

Steady state current (A)	Peak current (A), 347 Vac	Pulse width 347 Vac (ms). See Note 2	I^2t (A^2 sec) 347 Vac. See Note 1
0.5	198	0.34	92
1	270	0.47	173
2	354	0.70	294
3	396	0.86	369
5	450	1.15	476
8	492	1.5	569
10	508	1.67	606
12	529	1.86	658

Table 69.3 Continued on Next Page

Table 69.3 Continued

Steady state current (A)	Peak current (A), 347 Vac	Pulse width 347 Vac (ms). See Note 2	I^2t (A^2 sec) 347 Vac. See Note 1
15	550	2.05	711
16	552	2.10	716

NOTES

1 – The values used to calculate I^2t are the peak current shown and pulse duration of 2.35 ms (t).

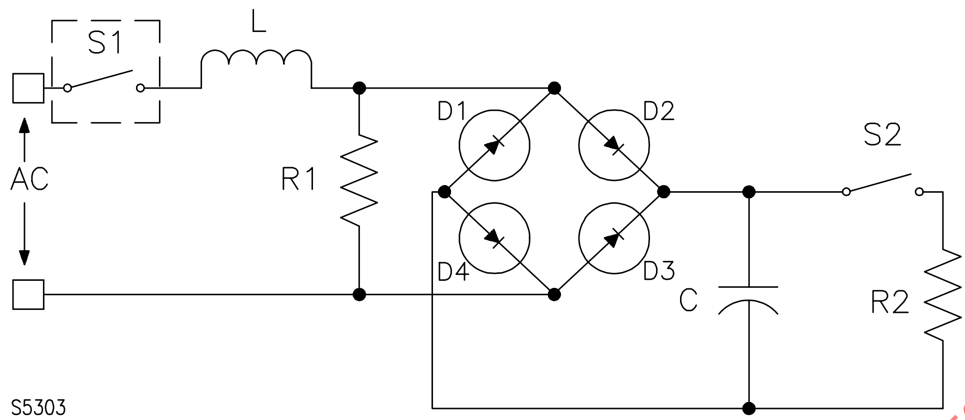
2 – Pulse widths shown will provide adequate performance with electronic ballasts having pulse widths up to 2.35 ms, in accordance with ANSI_ANSLG C82.11, or ANSI_ANSLG C82.14.

69.2 The test circuit, as shown in Figure 69.1, shall provide the inrush characteristics meeting or exceeding those characteristics defined in Table 69.2 in parallel with an AC resistive load based on the steady state current rating of the switch or lighting control being tested.

69.3 The series coil values must be adjusted based on the input line characteristics of the test laboratory to achieve the peak currents listed in Table 69.2. The series coil shall be sized such that it does not saturate during testing and shall be able to handle the resulting power dissipation with less than 10 °C temperature rise. Peak current and pulse width are illustrated in Figure 69.2.

Figure 69.1

Typical Test Circuit Diagram[a]



Reference	Description
AC	Test voltage is either 277 VAC or 120 VAC
S1	Device Under Test
L	Series Inductor, its value of inductance (L) and resistance (R) are selected. When combined with the AC line source impedance it provides the specified Reference Waveforms
R1	AC synthetic load resistor, value to provide desired continuous current. (e.g., 0.5A, 1A, 2A, . . .16A)
D1 through D4	Bridge rectifier
C	Capacitor load bank, design value to provide 125 µF for each continuous amp of load current at a test voltage of 277 VAC, and 175 µF for each continuous amp of load current at a test voltage of 120 VAC.
S2	Capacitor discharge switch
R2	Bleeder resistor, value to provide appropriate capacitor load bank discharge rate

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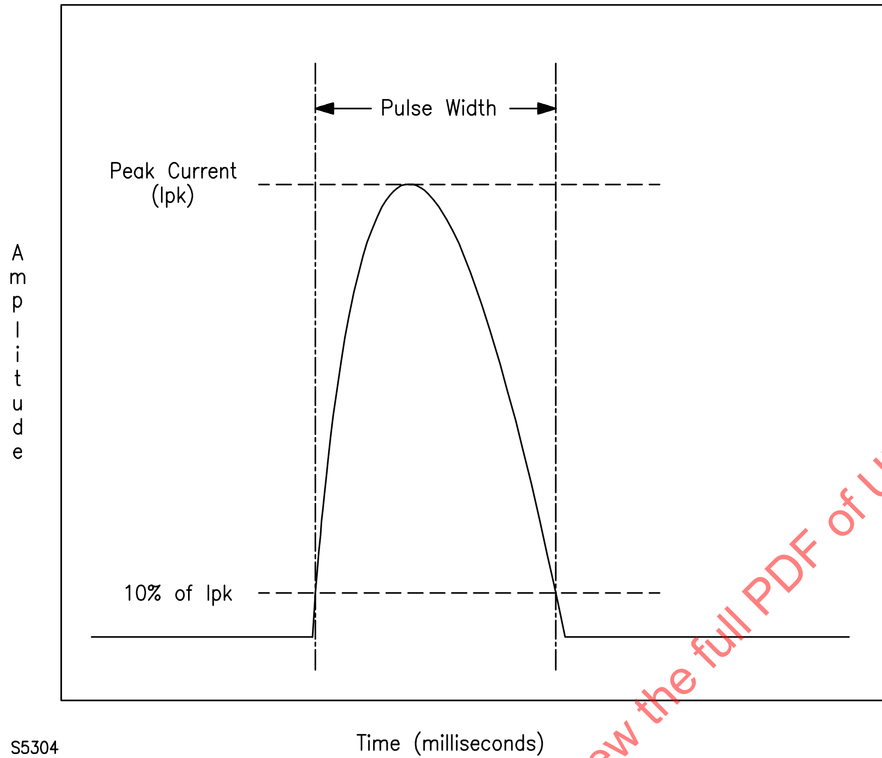
Figure 69.2

Waveform Per Synthetic Measurement of Pulse Width and Peak Current



69.4 The circuit shall provide a method to discharge the capacitor bank in between test cycles without influencing the performance of the device under test. This is accomplished by S2 and R2 in Figure 69.1. S2 should be switched alternately with S1 and R2 should be sized to allow for complete discharge of C during the period that S1 is open.

70 Terminal Assembly Test

70.1 An industrial switch provided with a terminal that may be connected to either a grounded (neutral) conductor or a grounding conductor as in 42.4.3, when tested as described in this section, shall not exhibit:

a) Damage to the industrial switch, including but not limited to breakage of the housing, misalignment of bonding components or stripping of the terminal plate or screws; and

b) Dielectric Voltage Withstand breakdown during application of the test potential.

70.2 Six devices are to be tested. Three of the six devices shall be wired with the smallest AWG conductor size and remaining three devices wired with the largest conductor size, as specified by the manufacturer. If the device is also intended for both solid and stranded AWG conductors, both solid and stranded shall be tested with additional samples.

70.3 The conductor insulation shall be prepared by removing the insulation from the conductor according to manufacturer's strip gauge, and then inserted into the grounded (neutral) terminal and terminal screw tightened according to the manufacturer's identified torque and held in position for 1 minute. The terminal screw is then loosened, and conductor is removed from the terminal. A newly-prepared conductor is then inserted into the grounded (neutral) terminal and terminal screw tightened according to the manufacturer's identified torque and held in position for 1 minute. This assembly process is to be performed five times. On the fifth time, the prepared conductor shall remain in the terminal and be subjected to the Dielectric Withstand test described in 51.1.1 – 51.1.5, applied between the terminal and ground.

71 Pressure Tests

71.1 General

71.1.1 A pressure-operated switch shall comply with the pressure test in 71.2 for enclosed devices, or 71.3 for open devices, when:

a) The device is actuated by an external source of pressure;

b) The device employs a Bourdon tube, a flexible metal bellows, a diaphragm, or similar device; and

c) The maximum rated pressure is 300 psig (2069 kPa) or more.

71.2 Parts contained in an enclosure

71.2.1 A sample is to be filled with water to exclude air and then connected to a hydraulic pump. The pressure is to be raised gradually to the required test pressure as follows and in this order:

a) The hydraulic test pressure is to be raised to two times the maximum rated pressure and held for one minute.

b) The hydraulic test pressure is to be then raised to three times the maximum rated pressure of the device and held for one minute. A leaking gasket or flexible member is to be replaced by a heavier material to reach the required pressure value.

c) The hydraulic test pressure is to be then raised to four times the maximum rated pressure of the device and held for one minute. A leaking gasket or flexible member is to be replaced by a heavier material to reach the required pressure value.

d) When the test pressure in (c) is not attainable, such as due to a ruptured disc, a sample of the outer enclosure shall either maintain a hydraulic test pressure equal to the maximum rated pressure for one minute, or relieve pressure equal to the maximum rated pressure.

71.2.2 As a result of the test in 71.2.1(a), the device shall withstand the test pressure without rupture and without leakage at gaskets or fittings.

71.2.3 As a result of the tests in 71.2.1(b) and either 71.2.1(c) or 71.2.1(d), the device shall withstand the test pressure and no part of the device shall be released outside the enclosure.

71.3 Parts not contained in an enclosure

71.3.1 A sample is to be filled with water to exclude air and then connected to a hydraulic pump. The pressure is to be raised gradually to the required test pressure as follows and in this order:

a) The hydraulic test pressure is to be raised to two times the maximum rated pressure and held for one minute; and

b) The hydraulic test pressure is to be then raised to four times the maximum rated pressure of the device and held for one minute

71.3.2 As a result of the test in 71.3.1(a), the device shall withstand the test pressure without rupture and without leakage at gaskets or fittings.

71.3.3 As a result of the test in 71.3.1(b), the device shall withstand the test pressure without rupture.

DEVICE RATING

72 Details

72.1 Unless otherwise indicated elsewhere in this Standard, industrial control equipment shall be rated in volts; and also in horsepower, amperes, volt-amperes, or any combination thereof; and the rating shall indicate whether the equipment is for direct or alternating current. The rating of alternating-current equipment shall include the number of phases and, if necessary, the frequency; except that the rating of equipment obviously intended for single-phase use only need not include the number of phases. The rating of a controller for slip-ring motors shall include the secondary rated current.

72.2 Equipment shall be rated for service in an ambient temperature or surrounding air temperature of 40 °C (104 °F) or at a higher or lower ambient temperature or surrounding air temperature at an interval from 40 °C (104 °F) in a whole number multiple of ±5 °C (9 °F), such as 45, 50, 55, 60.

72.3 A motor control device rated more than 1 horsepower (746 W output) and 300 V or more than 2 horsepower (1492 W output), an overload relay, or industrial control equipment incorporating an overload relay shall have a short circuit current rating.

72.4 The rating of industrial control equipment that requires a remote control device shall include the volt-ampere rating, or the equivalent, of any operating-coil with a sealed rating of more than 125 volt-amperes or more than the value specified in Table 72.1.

Table 72.1
Ratings for Operating Coils

Rating of device	Rating of coil, volt-amperes
(Size 1) 30 amperes or less	30
(Size 2) 50 amperes	75
(Size 3 and 4) 150 amperes	100
(Size 5 or greater) 300 amperes or more	125

72.5 Industrial control equipment, intended for use with a motor with standard horsepower and voltage ratings as given in Table 47.2 or Table 47.3, shall be rated in horsepower and may additionally include the full-load and locked-rotor current. When provided, the full-load current rating shall be the current specified in Table 47.2 or Table 47.3 for the associated horsepower and voltage, and the locked-rotor current rating shall be as indicated in Table 47.4 for 3-phase ac motors, six times the full load current indicated in Table 47.2, or ten times that indicated in Table 47.3.

72.6 The rating of a magnetic motor controller may also include a size designation as described in 73.27. Equipment designated as a specific size shall be rated with the continuous current and horsepower ratings corresponding to that size as specified in Table 72.2 and Table 72.3.

Table 72.2
Ratings for Magnetic Motor Controller Sizes

Size of controller	Continuous current rating, amperes	Three phase horsepower ratings, volts, ac			
		60 hertz		50 hertz	60 hertz
		200	230	380	460 or 575
00	9	1-1/2	1-1/2	1-1/2	2
0	18	3	3	5	5
1	27	7-1/2	7-1/2	10	10
2	45	10	15	25	25
3	90	25	30	50	50
4	135	40	50	75	100
5	270	75	100	150	200
6	540	150	200	300	400
7	810		300		600
8	1215		450		900
9	2250		800		1600
NOTE – As specified in Table 2-4-1 of NEMA ICS2-1993.					

Table 72.3
Ratings for Magnetic Motor Controller Sizes

Size of controller	Continuous current rating, amperes	Single phase horsepower ratings, volts AC	
		60 hertz	
		115	230
00	9	1/3	1
0	18	1	2
1	27	2	3
1P	36	3	5
2	45	3	7-1/2
NOTE – As specified in Table 2-4-2 of NEMA ICS2-1993.			

72.7 The ratings of equipment intended to control a motor load rated more than 500 horsepower (373 kW output) or non-standard horsepower and voltage shall, in addition to the horsepower ratings, include the maximum full-load current, and for 3 phase ratings, the locked rotor current, for each rating.

72.8 With reference to 72.1, the rating of the device controlling an external load shall have the load designation marked in accordance with Table 72.4.

Table 72.4
Ratings of a Device Controlling an External Load

Load	Load designations
General Purpose, ac	Amperes
Resistance (heating), ac	Amperes, resistance, only
General Purpose, dc or resistance (heating), dc	Amperes
Incandescent lamp	Amperes or watts, tungsten
Ballast (electric discharge lamp)	Amperes, ballast
Electronic Fluorescent Ballast (electric discharge lamp)	Amperes, electronic fluorescent ballast
Coil	Code designation, volt-amperes, standard or heavy pilot duty
Motor – General Use	Horsepower (also see 72.5 and 72.6)
Capacitive Switching	kVar, Full-Load amperes (FLA)
LED driver or self-ballasted LED	Amperes, LED
Self-ballasted CFL	Amperes, CFL
Capacitive load similar to electronic ballast	Amperes, (Load description)

MARKING

73 General

73.1 Industrial control equipment shall be plainly marked with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified – hereinafter referred to as the manufacturer's name;

b) The electrical rating;

c) The catalog number or equivalent.

All marking shall be located so as to be visible after installation.

73.2 Equipment shall be marked to indicate the maximum ambient temperature rating or surrounding air temperature rating for which the equipment was evaluated.

Exception: Equipment with an ambient temperature rating of 40 °C (104 °F) is not required to be marked.

73.3 A motor control device rated more than 1 horsepower (746 W output) and 300 V or more than 2 horsepower (1492 W output), a starter (contactor incorporating an overload relay), an overload relay, or industrial control equipment incorporating an overload relay – other than a combination motor controller – shall be marked "Suitable For Use On A Circuit Capable Of Delivering Not More Than ___________ rms Symmetrical Amperes, ___________ Volts Maximum." The short circuit current rating is not to be more than the value for which the controller was tested in accordance with Table 53.3 or Table 54.2. When the short circuit tests are conducted with fuses only as specified in Exception No. 1 of 52.1.4, the marking shall include "Use Fuses Only". When the standard fault short circuit tests are conducted with a protective device of a size requiring a marking as in Table 53.1, 53.1.3.1(b) or 53.1.2.3(b), the marking shall additionally include the type of protective device used, the maximum size of the protective device and in the case of 53.1.2.3(b) the Class rating of the fuse. When high available fault short circuit testing is conducted in accordance with 54.1.1, the marking shall also include the following or the equivalent:

a) "When Protected by ___________ Class Fuses"; or

b) "When Protected By A Circuit Breaker Having An Interrupting Rating Not Less Than ___________ rms Symmetrical Amperes, ___________ Volts Maximum".

Exception No. 1: The marking is able to be on a separate sheet or in the installation instruction when there is not room on the device for the marking.

Exception No. 2: Any overload relay which derives its operating currents from an associated magnetically-coupled only (primary winding not part of current transformer) current transformer, for which current saturation at low current level has been demonstrated, is not required to be marked with a short circuit current rating. The current transformer referenced in this exception is able to be either separate from, or an integral part of, the device.

73.4 For group installation, a motor control device or overload relay as described in 55.1.2 shall be marked with the following or the equivalent:

a) When tested using both fuses and circuit breakers of the maximum allowable size: "Suitable for motor group installation on a circuit capable of delivering not more than ____ rms symmetrical amperes, ____ V max";

b) When tested using only fuses rated at the maximum size specified in 55.1.2(b), the marking shall additionally state: "when protected by (A) ";

c) When tested using branch circuit protective devices rated less than the maximum size specified in 55.1.2(b), the marking shall additionally state: "when protected by (B) with a maximum rating of (C) ".

where:

(A) – "Fuses" or, when specified for a high fault short circuit rating, "Class ___ fuses";

(B) – The type of overcurrent protective devices, either "fuses" or "a circuit breaker." When specified for a high fault short circuit rating, "Class ___ fuses" or "A circuit breaker having an interrupting rating not less than ___ rms symmetrical amperes, ___ V maximum";

(C) – The maximum ampere rating of the overcurrent protective device used for the short circuit test in 55.3 or 55.4.

73.5 A manual motor controller additionally evaluated for use as tap conductor protection in group installations shall be marked with the following or the equivalent: "Suitable for tap conductor protection in motor group installations on a circuit capable of delivering not more than ____ rms symmetrical amperes, ____ V max".

73.6 When a motor controller has been evaluated for group installations only on the load side of a manual motor controller with instantaneous trip or a manual motor controller suitable for tap conductor protection in group installations, only the manual motor controller shall be marked as specified in 73.4 or 73.5, respectively. The motor controller or manual motor controller shall be marked as follows: " (A) suitable for group installation on the load side of (B)" or the equivalent.

Where (A) and (B) are the manufacturer name and model number of the motor controller and manual motor controller respectively.

73.7 The marking required by 73.1 need not be located on the outside of an enclosure provided it is readily visible by opening a door or removing a cover after installation.

73.8 The marking required by 12.1 shall be visible after installation and shall specify the environmental condition type number or numbers.

73.9 The marking referenced in 7.16.1(d) shall include the following statement or equivalent, "For Use on a Flat Surface of a Type _______ Enclosure." The type or types of enclosures for which the component has been evaluated and found to be acceptable shall be marked in the blank space.

73.10 A device intended for control of a specific load may be marked to indicate the intended use of the control, such as "Resistance only," "Tungsten only," "Ballast," "Resistance Air Heating."

73.11 A device not tested in accordance to Section 69 which is intended to control a specific model electronic ballast, self-ballasted LEDs or CFLs, LED driver, or other similar loads with capacitive load characteristics shall be marked with the manufacturer's name and model number of the electronic ballast(s), self-ballasted LEDs or CFLs, LED driver(s), or other similar loads with capacitive load characteristics with which the device is intended to be used. The marking shall be on the device or provided with the device on the packaging or stuffer sheet.

73.12 Industrial control equipment shall be marked with only one single and/or three phase horsepower rating for each assigned voltage.

73.13 If the manufacturer produces or assembles industrial control equipment at more than one factory, each finished item of equipment shall have a distinctive marking, by which it may be identified as the product of a particular factory.

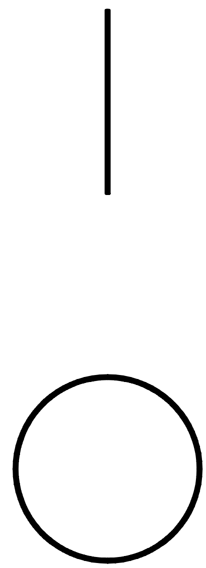
73.14 An oil tank may be marked to indicate the proper oil level. If a visual oil indicator is provided, the marking shall indicate the proper oil level with the starter assembled. If a visual indicator is not provided, the marking shall indicate the proper oil level prior to assembly.

73.15 The position of the handle of a manual motor controller, drum controller, or the like – other than a push button station, a selector switch, or both – shall be marked as a guide to proper operation. Such marking shall not be subject to rubbing off, washing off, or otherwise being rendered unreadable during normal use. See 11.1.

73.16 In reference to the requirement in 73.15, the "ON" and "OFF" positions of a control device may be marked using the symbols illustrated in Figure 73.1.

Figure 73.1

"On" and "Off" Symbols



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IEC Publication 417, Symbols 5007 and 5008

73.17 For equipment that may be assembled in different combinations, all components shall be identified and reference shall be made on the basic equipment to all components that may be assembled together.

73.18 An industrial control device that has been investigated as a part of a system shall be marked to identify other parts of the system with which it is intended to be used.

73.19 A rheostat or resistor that does not have the required electrical spacings and is intended for use only as series resistance shall be marked "For use as a series resistor."

73.20 Industrial control equipment employing an automatic reset overload relay and a wiring diagram indicating 2-wire control shall be marked to indicate that a motor connected to the circuit may start automatically when the relay is in the automatic reset position. The marking shall be permanently secured to enclosed equipment and shall be furnished with open types.

73.21 With reference to the requirement in 19.2.3, a controller with ratings requiring an additional protective device to be provided as an accessory kit shall be marked to identify the kit to be used in that controller.

73.22 With reference to the requirement in 19.2.2, a controller shall be marked with the maximum ampere rating of motor branch-circuit short-circuit protective-device corresponding to the size of control-circuit wire used within the equipment as specified in Table 19.2.

73.23 If a supplementary fuse is provided in accordance with 19.2.5, there shall be a marking near the fuseholder specifying the voltage and current rating of the replacement fuse.

73.24 When a branch-circuit type fuse (other than supplementary) is provided in accordance with 19.2.5 or 19.2.6 and when the fuseholder will accept a fuse having a higher current rating than covered in 19.2.1 a marking specifying the maximum fuse size shall be provided near the fuseholder.

73.25 A relay intended for television applications and tested in accordance with Section 49 shall be marked "TV-X," where "TV" signifies the television and "X" is the steady-state current rating of the relay to be replaced by the actual ampere value (such as TV-5, TV-3, and the like).

73.26 If a fuse used to determine compliance with item 3 of Table 45.1 is a Class G or K, there shall be a marking near the fuseholder specifying the class of the replacement fuse.

73.27 A motor controller marked as a specific size in accordance with Table 72.2 and Table 72.3 shall be marked with all and only with the horsepower ratings specified in Table 72.2 and Table 72.3. Controllers with three or more poles may omit single phase ratings. Two pole controllers shall not be marked with three phase ratings. Marking of the continuous current and 50 hertz ratings is optional.

73.28 A controller that complies with the elevator control requirements in Overload Test, Section 47, and Endurance Test, Section 48, may be marked to indicate that the device is suitable for use in elevator control applications.

73.29 The marking referred to in 53.1.3.1 and Table 53.1 may be located on the current element table.

73.30 With respect to 42.3.2, industrial control equipment containing a power or control transformer feeding circuits leaving the equipment from a secondary winding not conductively connected to the primary shall be marked to indicate the need for connecting the secondary neutral conductor to a grounding electrode in accordance with existing installation requirements pertaining to separately derived systems.

Exception: The marking is not required when the grounding electrode conductor terminal is not required in accordance with the Exception to 42.3.2.

73.31 A secondary circuit intended to be supplied from a Class 2 transformer or power source in the field shall be marked "Class 2" next to the voltage rating of the device (i.e. 30Vac, Class 2), or the equivalent.

73.32 A secondary circuit evaluated to the requirements in Exception No. 1 of 33.3.3 or 33.4.1 shall be provided with installation instructions that specify the use of the isolating source and ratings of the overcurrent protective devices required to be installed in the field.

73.33 A motor controller evaluated for use only with a specific overload relay as in the exception to 52.1.3 shall be marked with the manufacturers name and part number of the overload relays to be used.

73.34 When required by 26.11.5, cord-connected equipment shall be marked with the voltage and ampere rating of the required overcurrent protection.

73.35 Equipment intended for use in a pollution degree 2 environment, as noted in 37.6, or incorporating a secondary circuit complying with the limited voltage circuit requirements in 33.4 shall be marked "For use in Pollution Degree 2 Environment" or similar.

73.36 When equipment containing an overload relay is tested at a current less than the maximum setting of the overload relay or less than the maximum current in a current element table, in accordance with 45.9, the equipment shall be marked “Maximum current ___ A”, or the equivalent.

73.37 Equipment restricted for use in industrial machinery equipment in accordance with NFPA 79, shall be marked “For use only in industrial machinery NFPA 79 applications” or similar.

73.38 A secondary circuit intended to be supplied from a Limited Power Source in the field shall be marked "Limited Power Source" next to the voltage rating of the device (i.e. 30 Vac, Limited Power Source), or the equivalent.

73.39 Bus bar systems intended for use only in Branch Circuit Applications shall be marked “Branch Circuit Bus Bar System” or equivalent.

73.40 With reference to 42.4.2 and 42.4.3, an industrial switch shall be marked with the following or equivalent statement: “For use in replacement or retrofit applications only where the grounded (neutral) conductor is not provided in the outlet box.” When an equivalent wording is used it shall contain “replacement or retrofit applications only”.

73.41 With reference to 50.2(c), an overload relay or the controller with which an overload relay is used shall be marked to indicate the relay class designation in accordance with Table 50.1. The marking may be provided on the current element table that is provided on or with the product.

74 Wiring Terminal Markings

74.1 Wiring terminals shall be marked to indicate the proper connections for the power supply, load, control circuit, and the like, or a wiring diagram coded to the terminal marking shall be securely attached to the equipment.

Exception No. 1: The terminals need not be marked if the wire connections are plainly evident, as for a 2-terminal switching device.

Exception No. 2: A wiring diagram with multiple circuit arrangements may be provided loose or in an envelope provided the nameplate or similar permanent attachment visible after installation references the wiring diagram, for example, by number.

Exception No. 3: For open-type equipment, the wiring diagram may be furnished loose with the equipment.

74.2 A terminal for the connection of a grounded supply circuit conductor shall be identified by means of a metallic plated coating substantially white in color and shall be readily distinguishable from the other terminals, or proper identification of the terminal for the connection of the grounded supply circuit conductor shall be clearly shown in some other manner, such as on an attached wiring diagram. If wire leads are provided, the lead intended to be connected to a grounded supply circuit shall have a white or gray color and shall be readily distinguishable from other leads.

74.3 A single white terminal – in other than a single-pole device – for the connection of an ungrounded conductor is not acceptable, but two or more terminals may be white if:

a) It does not make any difference how line connections are made;

b) It is obvious which terminal is intended for the connection of the grounded conductor; or

c) The line connections are plainly indicated on a wiring diagram.

74.4 If low-voltage equipment or a part of low-voltage equipment is intended to be wired in the field to become only part of a Class 1 circuit or a Class 2 circuit wired with Class 1 wire, the terminals of the equipment or part of the equipment shall be marked accordingly. Low-voltage switching or powerconsuming equipment or a part of equipment that is intended to be wired in the field to become part of a Class 2 circuit only shall be marked accordingly, but a low-voltage power-supply device that includes a transformer is not required to be marked to indicate that it is acceptable for use in a Class 2 circuit only. Low-voltage equipment or a part of equipment that is acceptable for connection to either a Class 1 or a Class 2 circuit is not required to be so marked.

74.5 Equipment incorporating two or more separate circuits that are capable of being connected to separate power supplies but that are intended to be connected to a common power supply shall be marked "All circuits must have a common disconnect and be connected to the same pole of the disconnect," or with an equivalent wording. The wiring diagram of the equipment shall illustrate a typical connection of the various circuit connected to the common power supply.

74.6 Equipment employing a special fitting for the connection to a specific wiring system shall be marked to indicate that it must be installed with such a wiring system.

74.7 Equipment that is acceptable for installation with a nonmetal-enclosed wiring system only shall be marked to indicate that it must be installed with such a wiring system.

74.8 Equipment having field-wiring terminals shall be marked with the following, if applicable, or the equivalent:

a) "Al Only" or "Use Aluminum Conductors Only" if the terminal is acceptable only for connection to aluminum wire.

b) "Cu/Al" or "Use Copper or Aluminum Conductors" or "Use Copper, Copper-Clad Aluminum, or Aluminum Conductors" if the terminal is acceptable for connection to either copper or aluminum wire.

c) "Cu Only" or "USE COPPER OR COPPER-CLAD ALUMINUM CONDUCTORS" if the terminal is acceptable for connection to either copper or copper-clad aluminum wire.

74.9 Industrial control equipment shall be marked to indicate the temperature rating (60 °C only, 60/75 or 75 °C only) of the field installed conductors for which the equipment has been investigated.

Exception: A field-wiring terminal need not be marked to indicate the temperature rating if it is intended for the connection of a control circuit conductor only.

74.10 A wiring terminal that is not intended to receive a conductor one size larger than that specified in 26.5.1 shall be marked to restrict its use to the smaller size conductor.

74.11 If leads, wire binding screws, or pressure wire connectors are not provided on the equipment as shipped, the equipment shall be marked stating which pressure wire connector or component terminal kits are acceptable for use with the equipment. A wire connector of the type mentioned in the marking may be installed in the equipment at the factory with instructions, if necessary, to effect proper connection of the conductor. A terminal kit shall carry an identifying marking, wire size, and manufacturer's name or trademark.

74.12 With reference to 26.6.2, equipment shall be marked to show a range of values or a nominal value of tightening torque in pound-inches to be applied to the clamping screws of all terminal connectors for field wiring. The marking may be located adjacent to the terminal or on the wiring diagram.

74.13 A multi-pole device intended for same polarity use is marked "same polarity" or equivalent.

74.14 With reference to 26.7.1, wiring instructions shall be provided requiring the use of female quick-connect terminals suitable for field wiring. Female quick-connect terminals suitable for factory-wiring only are not permitted.

75 Cautionary Markings

75.1 Cautionary markings shall be located on a part that cannot be removed without impairing the operation or appearance of the equipment.

75.2 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 specified otherwise in individual marking requirements, shall not be less than 1/16 inch (1.6 mm) high.

75.3 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 being performed.

75.4 If more than one disconnect switch may be required to disconnect all power within a control assembly or compartment, the assembly or compartment shall be marked with the word "CAUTION" and the following or the equivalent, "Risk of Electric Shock – More than one disconnect switch may be required to de-energize the equipment before servicing."

75.5 The marking required by 75.4 shall be in a permanent location on the outside of the equipment or on a stationary fixed, nonremovable part inside the equipment. The warning marking shall not be placed inside the cover or on the connection diagram attached to the inside of a cover.

75.6 The marking required for enclosures that are intended for field assembly of the bonding means in accordance with 7.6.1 shall be located where visible during installation, such as inside the cover, and consist of the word "CAUTION" and the following or the equivalent, "Bonding between conduit connections 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 connection. Use grounding bushings and jumper wires."

75.7 An overload relay that has a replaceable element or industrial control equipment incorporating an overload relay shall be marked with the word "WARNING" and the following or the equivalent: "To provide continued protection against a risk of fire and electric shock, the complete overload relay must be replaced if burnout of the current element occurs."

Exception No. 1: For an overload relay with replaceable type thermal elements, if the calibrated elements are within the replaceable thermal unit, then only the thermal unit need be replaced upon heater burnout.

Exception No. 2: For an overload relay with replaceable type thermal elements having the calibrated current sensing element in the basic nonreplaceable part of the overload relay, the marking is not required provided that subsequent to the short circuit tests conducted in accordance with Section 52, the overload relay is calibrated in accordance with Section 50.

Exception No. 3: For an overload relay with nonreplaceable type thermal elements, if the design of the overload relay is such that it prevents operation of the device in the event of burnout of any of the thermal units, the marking is not required.

75.8 Motor controllers intended for use on circuits having high available fault currents as indicated in 54.1.1 shall be marked with the word "WARNING" and the following or equivalent, "The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. To reduce the risk of fire or electric shock, current-carrying parts and other components of the controller should be examined and replaced if damaged. If burnout of the current element of an overload relay occurs, the complete overload relay must be replaced."

75.9 A control with direct-current motor ratings that does not comply with the requirements in 26.5.1(d)(1) shall be marked with the word "WARNING" and the following or the equivalent, "Do not connect to a circuit supplied by a single-phase, half-wave rectifier"; and a control that does not comply with the requirements in 26.5.1(d)(2) shall be marked with the word "WARNING" and the following or the equivalent, "Do not connect to a circuit supplied by a single-phase rectifier of the half-wave or full-wave type."

75.10 A device that requires a lower torque value than specified in Table 9.1 shall be marked with the following or the equivalent: "Tighten to ____ pound-inches (____ N·m). Overtorquing may cause enclosure breakage."

75.11 A knife switch complying with the Exception to 17.4, shall be marked with the word "WARNING" and the following or equivalent: "Risk of Electric Shock – The load side of this switch may be energized by backfeed when in the open position."

Exception: If there is not sufficient room on the switch for the marking, the marking may be on a separate pressure-sensitive label or equivalent. Instructions shall be provided to inform the installer to secure the marking adjacent to the switch in a location that will be visible after installation.

75.12 If required by the exception to 7.15.11, a marking shall be provided to instruct the installer to fill the opening with a Type 12 conduit fitting.

75.13 Each accessible enclosure surface in excess of the maximum temperatures specified in Table 45.2 shall be marked "WARNING – HOT SURFACE – RISK OF BURN", or the equivalent.

75.14 Equipment provided with a replaceable lithium battery shall have a caution marking close to the battery that consists of the word “WARNING” and the following or equivalent, “Risk of explosion if battery is replaced by an incorrect type. Replace battery only with the same type of battery. Dispose of used batteries according to the instructions.”

INSTRUCTIONS AND MARKINGS PERTAINING TO ACCESSORIES

76 Details

76.1 The equipment markings shall include identification of an accessory to be attached in the field, or a reference to a separate publication that identifies all such accessories. For equipment such as an open device for which the required marking may be on a separate sheet, the accessory information may also be on the separate sheet.

Exception: If a new accessory has been designed for an existing product, the accessory shall be marked with the identification of the equipment on which it is intended to be used.

76.2 An accessory that is not shipped from the factory in the same carton as the equipment with which it is intended to be used shall be plainly marked with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified;

b) The electrical rating; and

c) The catalog number or equivalent.

Exception: The electrical rating of the accessory need not be on the accessory if the accessory electrical rating is marked on the equipment for which it is intended.

76.3 An accessory shall be provided with installation and wiring instructions.

76.4 If an overload-protective device is provided within an enclosure that does not have a hinged cover, and a kit is available for resetting the device from outside the enclosure, in accordance with 7.4.2(c), the kit number shall be marked on the enclosure or in the installation instructions.

77 Marking Location

77.1 The required markings and the location for enclosed industrial control equipment and open industrial control equipment shall be in accordance with Table 77.1. The markings noted in Table 77.1 are a brief summary of the marking requirements given elsewhere in this Standard. For complete details on the required marking, see the marking reference specified in Table 77.1.

Table 77.1
Marking Location for Industrial Control Equipment

Marking reference	Required marking[a]	Location[b]	
		Enclosed	Open
	GENERAL		
73.1	Manufacturers name, trademark, or identifier, electrical rating, catalog number or equivalent	B	D
73.2	Ambient temperature rating or surrounding air temperature rating	G	G
	Exception: No marking is required for 40 °C (104 °F) ambient temperature rating.	–	–
73.3	Short circuit rating and fuse type/circuit breaker and size	B	F
73.4	Marking for group installation	B	F
73.5	Suitable for tap conductor protection in group installations short circuit marking	B	F
73.6	Motor controller tested with manual motor controller for group installation	B	F
73.7	Exception to 73.1	B	D
73.8	Marking for environmental type(s)	B	–
73.9	Marking for flat surface of type(s)	–	F
73.10	Specific load marking, indicating intended use	B	D
73.12	One hp rating per voltage	B	D
73.13	Marking for more than one factory	E	E
73.14	Oil tank mark for oil level	B	B
73.15	Guide to proper operation of device(s)	B	B
73.16	Use of "ON" and "OFF" markings (See Figure 73.1)	A	–
73.17	Instructions for assembly in different combinations	F	F
73.18	Marking for use with other parts of a system	F	F
73.19	Marking for series resistor	F	F
73.20	Overload relay "may start automatically" when in automatic reset position	B	B

Table 77.1 Continued on Next Page

Table 77.1 Continued

Marking reference	Required marking[a]	Location[b]	
		Enclosed	Open
73.21	Devices provided with a protective device in an accessory kit	B	F
73.22	Maximum control circuit protective-device size corresponding to the size of control-circuit wire	B	F
73.23	Marking for supplementary fuse near fuseholder per 19.2.5	B	C
73.24	When fuseholder accepts higher fuse size per 19.2.6	B	C
73.25	"TV" markings	B	D
73.26	Marking for replacement fuse per item 3 of Table 45.1	B	C
73.27	Hp ratings for Size 00 – 9 motor controllers	B	D
73.28	Motor controller for elevator applications	B	D
73.29	Maximum fuse or breaker rating	B	D
73.30	Grounding electrode conductor terminal marking	F	F
73.31	Secondary circuit supplied from a Class 2 transformer or power source in the field	B	D
73.32	Secondary circuit intended to be supplied from an isolating source or protected by overcurrent protective devices installed in the field	F	F
73.33	Motor controller specified for use with specific overload relays	F	F
73.34	Marking for cord-connected equipment	F	F
73.35	Marking for use in pollution degree 2 environment	F	F
73.36	Marking of maximum current for equipment with overload relays	B	D
73.41	Overload relay class designation	F	F
WIRING TERMINAL MARKINGS			
74.1	Marking for proper connections	F	F
	Exception No. 1: Marking not required for wire connections plainly evident	–	–
	Exception No. 2: Wiring diagram with multiple circuit arrangements	B	F
74.2, 74.3	Terminal connection of ground supply conductor	F	F
74.4	Marking for low voltage wiring	F	F
74.5	Circuits capable of being connected to separate supplies but intended to be connected to common supply	F	F
74.6	Equipment with special fitting for connection	F	F
74.7	Equipment that is acceptable for nonmetal-enclosed wiring system	F	F
74.8	Field wiring terminal marking for wire type (Al, Cu)	F	F
	Exception: Marking not required when intended for connection to copper control circuit conductors	–	–
74.9	Temperature rating of field installed conductors	F	F
	Exception: Exception: Marking not required when intended for connection to control circuit conductors only.	–	–
74.10	Field wiring terminal not intended to receive conductor one size larger per 26.5.1	F	F
74.11	Marking for providing terminals separately in terminal kit	F	F

Table 77.1 Continued on Next Page

Table 77.1 Continued

Marking reference	Required marking[a]	Location[b]	
		Enclosed	Open
74.12	Torque values marking for field terminals per 26.6.2	F	F
	Exception: Marking in 26.6.2 not required when field terminal connected to control circuit conductor if investigated for 7 lb-in.	–	–
74.13	Same polarity marking per 74.13	F	F
74.14	Quick-connect terminals	F	F
CAUTIONARY MARKINGS			
75.1	Placement of cautionary markings	B	B
75.3	Instructing operator or servicing instructions	B	B
75.4, 75.5	Provided with more than one disconnect means	A	–
75.6	For enclosures that are intended for field assembly of the bonding means in accordance with 7.6.1	F	F
75.7	Replacement markings for overload relay that has replacement elements	B	B
	Exception No. 1: Thermal unit replaced upon heater burnout	B	B
	Exception No. 2: Marking not required for overload relay with replaceable type thermal elements having calibrated current sensing element in nonreplaceable part of overload relay	–	–
	Exception No. 3: Marking not required for overload relay with nonreplaceable type thermal elements that prevents operation of the device	–	–
75.8	Marking for motor controllers having indication that high available fault current interrupted	B	B
75.9	Control with direct-current motor ratings that does not comply with 26.5.1(d)(1)	F	F
75.10	Device which requires a lower torque value than Table 9.1	F	F
75.11	Knife switch complying with Exception to 17.4 where switch may be energized by back feed when in open position	A	–
	Exception: Marking provided adjacent to switch and visible after installation	B	–
75.13	Hot surface marking for accessible parts of enclosure	A	–
75.14	Replaceable lithium batteries	C	C
INSTRUCTIONS AND MARKINGS PERTAINING TO ACCESSORIES			
76.1	Accessories	G	G
	Exception: New accessory on existing product	G	G
76.2	Accessories	B	D
	Exception: Rating of accessory	H	H
76.3	Accessories provided with instructions	F	F
76.4	Kit available for overload protection device in accordance with 7.4.2(c)	F	F
REDUCED VOLTAGE STARTERS			
85.1	Marking "Heavy or Medium Duty"	B	F
SOLID STATE AC MOTOR CONTROLLERS			
97.1	See Sections 73 – 75		
97.2	Replacement fuse near fuseholder	B	C

Table 77.1 Continued on Next Page

Table 77.1 Continued

Marking reference	Required marking[a]	Location[b]	
		Enclosed	Open
FLOAT- AND PRESSURE-OPERATED SWITCHES			
108.1	Sections 73 – 75		
108.2	Pressure ratings	B	D
108.3	Float switch for sewage application	A	–
108.4	Float switch for use with thermally protected sump pump	A	–
SEMICONDUCTOR RELAYS AND SWITCHES			
118.1	See Sections 73 – 75		
MERCURY SWITCHES			
124.1	See Sections 73 – 75		
AUXILIARY DEVICES			
132.1	See Sections 73 – 75		
132.2	Indicate operators for intended use	D	F
132.3	Code markings	G	G
132.4	Indicate Use of Same Polarity	D	D
LAMP DIMMERS			
141.1	See Sections 73 – 75		
MISCELLANEOUS DEVICES			
151.1	See Sections 73 – 75		
EQUIPMENT RATED 601 – 1500 VOLTS			
	See Sections 73 – 75		
PROXIMITY SWITCHES[c]			
162.1	See Sections 73 – 75		
162.2	Code designation	G	G
162.3	For devices with conductors smaller than 18 AWG, indicate rating of over-current protection to be used	F	F
162.4	Type rating of proximity switch on smallest packaging	F	F

[a] These are a brief summary of marking requirements. For complete details see the specific Marking Reference.

[b] For marking locations identified below, "A" is the highest order of location, and "H" is the lowest order of location. At the option of the manufacturer, a higher order of location category is able to be used.

A. Marking shall be visible when the enclosure cover is on and the door is closed.

B. For enclosed devices, marking shall be visible:

1. When the enclosure cover is removed or the door is open;
2. When other devices are mounted nearby as intended; and
3. When devices are installed side by side.

The marking shall not be obscured by attachments such as a disconnect switch operating handle. For open-type devices, marking is on a separable, self-adhesive permanent label that is shipped with the device.

C. Marking is located on or adjacent to the part involved such that it is visible when the part becomes accessible.

D. Marking is visible when the device is mounted singularly. The marking may be on the side of the device, and is not required to be visible when the device is mounted next to other devices.

E. Marking is able to be anywhere on the device and is not required to be visible after installation.

Table 77.1 Continued on Next Page

Table 77.1 Continued

Marking reference	Required marking[a]	Location[b]	
		Enclosed	Open
F. Marking is shipped separately with the device. In addition, the device shall be marked, marking location D, with a reference to the information, such as by diagram number or document number.			
G. Marking is provided on a separate sheet which is available from the manufacturer, and not shipped with the product.			
H. Marking is shipped separately with kit.			
[c] Small devices, such as proximity or photoelectric switches, are able to be marked with only one electrical rating, and all other electrical ratings are provided on a separate sheet or on the device carton.			

MANUFACTURING AND PRODUCTION TESTS

78 Production-Line Dielectric Voltage-Withstand Test

78.1 Equipment provided with a power-supply cord with an attachment plug for connection to a nominal 120 V or higher voltage circuit shall withstand without electrical breakdown, as a routine production-line test, the application of an alternating-current potential at a frequency within the range of 40 – 70 Hz or a direct-current potential between the primary wiring, including connected components, and accessible dead metal parts that are likely to become energized.

78.2 The production-line test shall be in accordance with either Condition A or B of Table 78.1.

Table 78.1
Production-Line Test Conditions

Equipment rating volts	Condition A			Condition B		
	Potential volts ac	Potential volts dc	Time seconds	Potential volts ac	Potential volts dc	Time seconds
250 or less	1000+2V [a]	1400	60	1200+2V [a]	1700	1
More than 250	1000+2V [a]	1400+2.8V [a]	60	1200+2.4V [a]	1700+3.4V [a]	1

[a] Maximum marked voltage.

78.3 The test potential is able to be gradually increased to the required value but the full value is to be applied for 1 second or 1 minute as required.

78.4 The equipment is able to be at normal operating temperature, at room temperature, or at any intermediate temperature for the test.

78.5 The test shall be conducted when the equipment is fully assembled. It is not intended that the equipment be unwired, modified, or disassembled for the test.

a) A part, such as a snap cover or friction-fit knob, that would interfere with performance of the test need not be in place.

b) The test is able to be performed before final assembly if the test represents that for the completed equipment. Any component not included shall not affect the results with respect to determination of possible risk of electric shock resulting from miswiring, defective component, insufficient spacings, and the like.

78.6 Solid-state and similar components that might be damaged by a secondary effect (induced voltage surge, excessive heating, and the like) of the test are able to be short-circuited by means of a temporary electrical jumper or the test is able to be conducted without the component electrically connected, providing the wiring and terminal spacings are maintained.

78.7 The test equipment shall have a means of indicating the test potential, an audible or visual indicator of electrical breakdown, and, for automated or station-type operations, either a manually reset device to restore the equipment after electrical breakdown or an automatic-reject feature for any unacceptable unit. When an alternating-current test potential is applied, the test equipment shall include a transformer having an essentially sinusoidal output.

78.8 When the test equipment is adjusted to produce the specified voltage, and a resistance of 120,000 ohms is connected across the output, the test equipment is to indicate an unacceptable performance within 0.5 second. A resistance of more than 120,000 ohms is able to be used to produce an indication of unacceptable performance when the manufacturer elects to use a tester having higher sensitivity.

78.9 When the rated output of the test equipment is less than 500 VA, the equipment shall include a voltmeter in the output circuit to directly indicate the applied test potential.

78.10 When the rated output of the test equipment is 500 VA or more, the test potential is able to be indicated by:

a) A voltmeter in the primary circuit or in a tertiary winding circuit;

b) By a selector switch marked to indicate the test potential; or

c) In the case of equipment having a single test-potential output, by a marking in a readily visible location to indicate the test potential.

If an indicating voltmeter is not used, the test equipment shall include a visual means, such as an indicator lamp, to indicate that the test voltage is present at the test-equipment output.

78.11 Test equipment other than that described by 78.7 – 78.10 is able to be used if found to accomplish the intended factory control.

78.12 For the test, either a sufficient number of control devices are to be closed or separate applications of the test potential made so that all parts of the primary circuit are tested.

79 Production-Line Grounding-Continuity Test

79.1 Equipment that has a power-supply cord with an attachment plug shall be tested, as a routine production-line test, to determine that grounding continuity is provided between the grounding blade or pin of the attachment plug and the accessible dead metal parts that are likely to become energized.

79.2 Only a single test need be conducted if the accessible metal selected is conductively connected to all other accessible metal.

79.3 Any indicating device (an ohmmeter, a battery and buzzer combination, or the like) is able to be used to determine compliance with the grounding continuity requirement.

80 Production-Line Polarization-Continuity Test – Cord and Plug Connected Equipment

80.1 Equipment provided with an attachment plug shall maintain electrical continuity between the grounding blade of the attachment plug and all accessible parts and shall be verified as a routine production-line test. The continuity shall be determined either visually or through the use of an electrical test.

PART V – REDUCED-VOLTAGE STARTERS

CONSTRUCTION

81 General

81.1 A reduced voltage starter shall comply with the construction requirements in Sections 13 – 43 and 81.2 or 81.3, as applicable.

81.2 Reduced voltage starters incorporating semiconductor switching means shall be evaluated in accordance with the requirements in Part VI – Solid State AC Motor Controllers.

81.3 A manual autotransformer-starter switch shall be provided with an off position, a running position, and at least one starting position. An interlock shall be provided so that the starter switch cannot be thrown directly from the off to the run position. The starter switch shall be arranged so that it:

a) Will be held in the off and running positions;

b) Cannot be left in a starting position; and

c) Cannot be left unattended in any position that does not include the overload-protective devices in the circuit.

PERFORMANCE

82 Operation Test

82.1 After 100 operations under the most severe normal conditions for which it is intended, a rheostat, an autotransformer, a speed regulator, or a similar device, or a starter containing such a device shall show no serious burning of the contacts or other faults. The release mechanism of a motor-starting rheostat shall not be impaired by such a test.

82.2 The requirement in 82.1 is intended to demonstrate the ability of the device to close and interrupt the circuit under normal conditions of operation, including starting and operating with the motor loaded to full load at normal speed.

83 Duty Cycle Test

83.1 An autotransformer or reactor starter shall be identified as medium or heavy duty and shall not show resultant flaming or molten droppings when the maximum rated voltage is applied to line terminals, and when tested as indicated in 83.2 and 84.1. If the transformer windings are oil immersed, the oil shall not overflow its containing case.

83.2 The test may be terminated before the end of the period specified in Table 84.1 if the autotransformer is protected from overheating by a reliably operating, nonadjustable thermostat or similar device.

83.3 A starting duty resistor shall be constructed so that when tested as described in 83.4 – 83.6 no flaming or molten droppings shall result.

83.4 For a direct current motor, a voltage between 100 and 110 percent of maximum rated voltage is to be applied across the entire resistor and the starting mechanism connected to the first step of resistance. When greater than rated motor current results, external resistance is to be added to reduce the current to rated value. When less than rated current results, the starting mechanism is to be adjusted to the subsequent step of resistance that results in not more than rated current, with or without added resistance. In either case, the device is to be left in the resulting position for 3 minutes.

83.5 For an alternating current motor, a voltage between 100 and 110 percent of maximum rated voltage shall be applied to the line terminals, and 300 percent of full-load current of the motor shall be applied through each leg for the first 15 seconds of each 15 consecutive 4-minute periods.

83.6 The tests described in 83.3 – 83.5 are able to be terminated before the end of the specified period by an operating, nonadjustable thermostat or similar device.

RATINGS

84 Details

84.1 Ratings for heavy and medium duty controllers shall be based on the duty cycles and load conditions specified in Table 84.1.

84.2 A reduced-voltage starter shall comply with the rating requirements in Section 72.

Table 84.1
Controller Duty Cycles and Load Conditions

1.	HEAVY DUTY	
	ON	1 minute
	OFF	1 minute
	REPEAT	4 times (for a total of five cycles)
	REST	2 hours
	ON	1 minute
	OFF	1 minute
	REPEAT	4 times (for a total of five cycles)
	TAP	lowest tap
	LOAD	motor with rotor locked or an equivalent inductive load
	POWER FACTOR	50 percent or less
2.	MEDIUM DUTY – MANUAL CONTROLLERS, 300 HORSEPOWER OR LESS	
	ON	15 seconds
	OFF	3 minutes 45 seconds
	REPEAT	3 times (for a total of four cycles)
	REST	2 hours
	ON	15 seconds
	OFF	3 minutes 45 seconds
	REPEAT	3 times (for a total of four cycles
	TAP	65 percent
	TAP CURRENT	300 percent of motor full-load current
	POWER FACTOR	50 percent or less

Table 84.1 Continued on Next Page

Table 84.1 Continued

3.	MEDIUM DUTY – MAGNETIC CONTROLLERS FOR MOTORS, 200 HORSEPOWER OR LESS	
	ON	15 seconds
	OFF	3 minutes 45 seconds
	REPEAT	14 times (for a total of 15 cycles)
	REST	2 hours
	ON	15 seconds
	OFF	3 minutes 45 seconds
	REPEAT	14 times (for a total of 15 cycles)
	TAP	65 percent
	TAP CURRENT	300 percent of motor full-load current
	POWER FACTOR	50 percent or less
4.	MEDIUM DUTY – MAGNETIC CONTROLLERS FOR MOTORS, RATED MORE THAN 200 HORSEPOWER	
	ON	30 seconds
	OFF	30 seconds
	REPEAT	2 times (for a total of 3 cycles)
	REST	1 hour
	ON	30 seconds
	OFF	30 seconds
	REPEAT	2 times (for a total of 3 cycles)
	TAP	65 percent
	TAP CURRENT	300 percent of motor full-load current
	POWER FACTOR	50 percent or less

MARKING

85 Details

85.1 An autotransformer and a reactor shall be marked "Heavy Duty" or "Medium Duty", as applicable for the intended use.

PART VI – SOLID-STATE AC MOTOR CONTROLLERS

CONSTRUCTION

86 General

86.1 The construction of a solid state controller incorporating a semiconductor switching means for on and off control of a motor load and with or without reduced voltage starting shall be in accordance with the requirements of Sections 13 – 43, inclusive.

PERFORMANCE

87 General

87.1 The performance of a solid state motor controller shall be investigated by subjecting a representative sample or samples in commercial form to the tests indicated in this section. Those tests to be conducted in a sequence are specified in Table 87.1. Consideration shall be given to heat sink capability, solid state device ratings, and other criteria in determining samples for testing representative of a line of similarly constructed controllers.

Table 87.1
Sequence of Tests for Solid State AC Motor Controllers

Standard reference	Test	Sample number[a]			
		1	2	3	4
		Sequence	Sequence	Sequence	Sequence
Section 88	Temperature	1			
Section 89	Dielectric Voltage-Withstand	3	3		
Section 90	Overvoltage and Undervoltage	2			
Section 91	Overload		1		
Section 92	Endurance		2		
Section 93	Short Circuit			1	
Section 94	Breakdown of Components				1

[a] All or any combination of sequences may be conducted on a single sample if agreeable to those concerned. More than one sample may be used if more than one rating is being tested. One sequence need not be completed as a prerequisite to the starting of another.

Table 87.2
Sequence of Tests for Solid State Motor Controllers with Reduced Voltage Starting Feature

Test reference	Test	Sample number[a]						
		1	2	3	4	5	6	7
		Sequence	Sequence	Sequence	Sequence	Sequence	Sequence	Sequence
Section 88	Temperature	1						
Section 89	Dielectric Voltage-Withstand	3			3	2	2	2
Section 90	Overvoltage and Undervoltage	2						
Section 93	Short Circuit		1					
Section 94	Breakdown of Components			1				
95.2	Controller Overload				1			
95.3	Single Phasing				2			
95.4	Inoperative Blower Motor					1		
95.5	Clogged Filter						1	
95.6	Current Limiting Control							1

[a] All of any combination of sequences may be conducted on a single sample if agreeable to those concerned. More than one sample may be used if more than one rating is being tested. One sequence need not be completed as a prerequisite to the starting of another.

87.2 Tests shall be conducted at rated frequency at a test potential not less than 120, 208, 240, 277, 480, or 600 volts as appropriate for the voltage rating, except that the Temperature test in Section 88 may be conducted at a potential less than the potential specified if the load current load is adjusted to produce the maximum normal heating, and if the power semiconductors are capable of conduction as intended at the test voltage.

88 Temperature Test

88.1 When operating in the normal mode resulting in maximum heating and as described in 88.2 and Section 45, solid state contactors shall not attain a temperature at any point sufficiently high to constitute a risk of fire, to adversely affect any materials or components employed in the device, or exceed, at stabilized temperature, the temperature rises specified in Table 45.1.

88.2 For the purpose of evaluating the temperature limit of the material, insulating material at the junction in lieu of required spacings is considered as being at the junction temperature. To determine the insulating material temperature, reference temperatures (case, tab, heat sink, or the like) are to be measured and the junction temperature is to be calculated based on the semiconductor manufacturer's power dissipation and thermal resistance data.

89 Dielectric Voltage-Withstand Test

89.1 The dielectric voltage-withstand test described in Section 51 is to be conducted immediately after the temperature test with the sample at stabilized temperature and, where necessary, having the power semiconductor (in power circuit) shorted. If placement of thermocouples could adversely affect the results of the dielectric voltage-withstand test, the test may be conducted on a sample without thermocouples that has been operated as defined for the temperature test until temperatures have stabilized.

Exception: The test between terminals of opposite polarity need not be conducted.

90 Overvoltage and Undervoltage Test

90.1 A control that employs an electromagnet shall comply with the overvoltage and undervoltage tests described in Section 46.

91 Overload Test

91.1 A solid-state motor controller shall comply with the appropriate overload test described in Section 47.

Exception: This test is not required for a motor controller having a reduced voltage starting feature.

92 Endurance Test

92.1 A solid-state motor controller shall comply with the appropriate endurance test described in Section 48.

Exception No. 1: This test is not required for a motor controller having a reduced voltage starting feature.

Exception No. 2: If the endurance test is to be conducted at rated current and there is no inrush current, the endurance test need not be conducted.

93 Short Circuit Test

93.1 Evaluation of short circuit test

93.1.1 Equipment rated 1-1/2 horsepower (1119 W output) or more shall comply with the following after the test described in 93.3.1 – 93.4.1. When no horsepower rating is marked, see Table 47.2 and Table 47.3 for equivalent FLA ratings.

a) The cotton indicator shall not have ignited when tested without an enclosure as in 93.3.1.

b) When tested in an enclosure, the door or cover shall not be blown open and it shall be possible to open the door or cover. Deformation of the enclosure shall not result in the accessibility of live parts as determined by the requirements specified in 7.17.1.

c) Wires shall not be pulled out of connectors and the wire insulation shall not burn out.

d) The device is not required to be operational after testing.

93.2 Selection of samples

93.2.1 A sufficient number of samples considered to be representative of a product line are to be subjected to short circuit tests. Representative samples are to be selected on the basis of such features as configuration and ratings.

93.3 Test procedure

93.3.1 Open equipment is to be tested in an enclosure judged to be representative of that likely to be encountered in service except that tests may be conducted without an enclosure and considered representative of tests conducted using an enclosure if agreeable to those concerned. If tests are to be conducted without an enclosure, surgical cotton is to be placed on a wire cage surrounding and in close proximity to the equipment under test so as to closely simulate the intended enclosure.

93.3.2 The solid state motor controller is to be connected to a test circuit as noted in 93.4 and then loaded such that the output devices are actuated when the controller is energized.

93.3.3 Actuation of the output device to a full "on" state is attainable by any one of the following methods of loading:

a) The connection of an actual motor to the motor output terminals such that enough loading is provided to actuate the output devices;

b) The connection of a resistive or resistive-inductive load to the motor output terminals such that enough loading is provided to actuate the output devices; or

c) The connection of a remote circuit to each controller such that the output devices are actuated to a full "on" state independent of any loading.

93.3.4 Upon actuation of the output devices, a short is introduced across the motor output terminals and the controller is operated until the protective devices open the short circuit.

93.3.5 For each sample selected, the controller is only required to be subjected to one short circuit test.

93.4 Test circuit

93.4.1 The requirements in Sections 52 – 55 are to be applied except as noted in 93.3 and the test circuit is to be calibrated as described in Section 57, Calibration of Test Circuits, at the maximum available short circuit current for which the motor controller is rated.

94 Breakdown of Components Test

94.1 A solid state contactor shall comply with the requirements in 60.1.

94.2 With reference to 94.1, each of the following conditions is considered as resulting in abnormal operation of an ac rated controlled load. These conditions are considered to be unacceptable.

a) Asymmetrical switching other than half-wave;

b) Half-wave operation for a single-phase controller rated less than 5 horsepower; or

c) Transmitting 1 cycle or more of voltage source to the motor with the control in the off position thus permitting possible rotation of a de-energized motor.

95 Operation Tests

95.1 General

95.1.1 A solid state motor controller with a reduced voltage starting feature is to be subjected to the test sequence as described in 87.2.

95.1.2 During and upon completion of the operation tests, the solid state motor controller with reduced voltage starting features shall be electrically and mechanically operable and there shall be no evidence of a risk of fire or electric shock. The fuse specified in 95.1.3 shall not open and the surgical cotton specified in 95.1.3 shall not glow or flame. The Dielectric Voltage-Withstand Test specified in Section 89 shall not result in dielectric breakdown.

95.1.3 To asses the risk of electric shock, the outer enclosure (if any) and grounded or exposed dead metal parts are to be connected through a 30-ampere fuse to the supply circuit pole least likely to arc to ground. For grounded control circuits, the enclosure and grounded or exposed dead metal parts are to be connected through the 30-ampere fuse to ground. Surgical cotton is to be placed at all openings, handles, flanges, joints, and the like on the outside of the enclosure.

Exception: The cotton is not required to be provided when circuit breakers (either inverse-time or instantaneous trip types) complying with UL 489, are being relied upon to provide branch circuit short circuit protection.

95.1.4 Before all operation tests, the test sample is to be mounted, connected, and operated as described in the Temperature Test, Section 45.

95.1.5 A solid state circuit intended to provide short circuit or overload protection is to be defeated during the operation tests unless specifically evaluated. These tests are to be conducted with the voltage ramp setting adjusted for the minimum ramp time.

95.2 Controller overload

95.2.1 A motor controller having the coil circuit interlocked or sequenced such that in normal operation the contactor does not make or break load current is to be tested at the maximum current permitted by the current limiting control, if provided, but at least 150 percent of full-load current. Five operations are to be conducted.

95.3 Single phasing

95.3.1 A three-phase solid state motor controller with reduced voltage starting features is to be operated with one line disconnected at the input. The test is to be conducted by disconnecting one line with the controller operating at maximum normal load and is to be repeated by initially energizing the device with one disconnected. The test is to continue until the temperature stabilizes.

95.4 Inoperative blower motor

95.4.1 A solid state motor controller with a reduced voltage starting feature having forced ventilation is to be operated at rated load with an inoperative blower motor or motors until the test is terminated by a protective device or until the temperature stabilizes.

95.5 Clogged filter

95.5.1 An enclosed solid state motor controller with a reduced a voltage starting feature having filtered ventilation openings is to be operated with the openings blocked to represent clogged filters. The test is to be conducted initially with the ventilation openings blocked approximately 50 percent. The test is then to be repeated under a full blocked condition until terminated by a protective device or until temperature stabilizes.

95.6 Current limiting control

95.6.1 A solid state motor controller with a reduced voltage starting feature incorporating a current limiting control is to be operated with the load increased to cause the device to operate in the current limiting mode. When the current limiting control is adjustable, it is to be adjusted to the setting producing the most severe results. The duration of the test is not to exceed the maximum time required for operation of the overload protective device or system supplied.

RATING

96 Details

96.1 A solid-state motor controller shall be rated as described in Section 72 except a solid state motor controller with reduced voltage starting features shall be rated in horsepower (hp) and FLA (full load current) and shall indicate whether equipment is for direct current or alternating current. The rating for alternating current shall include the number of phases and frequency.

MARKING

97 Details

97.1 Marking shall be in accordance with the requirements in Sections 73 – 75.

97.2 A marking shall be provided specifying that a replacement fuse is to be of the same type and rating as originally supplied. The marking shall be located on or adjacent to the fuseholder or the mounting studs of a fuse that is required to comply with the requirements in Section 93.

PART VII – FLOAT- AND PRESSURE-OPERATED SWITCHES

GENERAL

98 Glossary

98.1 FLOAT-OPERATED SWITCH – A switch that is mechanically operated by the position of a float in a liquid. The float does not contain electrical parts and is the only part of the device that comes in contact with the liquid.

98.2 FLOAT SWITCH – A cord-connected switch that is enclosed in a float and suspended by the power supply cord into a vessel containing water or sewage. The switch is actuated by the position of the float in the liquid.

98.3 MAXIMUM RATED PRESSURE – The maximum pressure the switch assembly is intended to be subjected, including abnormal pressure, as specified by the manufacturer.

98.4 MAXIMUM RATED OPERATING PRESSURE – The highest value of the pressure range that the switch is intended to control as specified by the manufacturer.

CONSTRUCTION

99 General

99.1 Float and pressure operated switches shall comply with the construction requirements of Sections 13 – 43.

99.2 A float and pressure operated switch shall comply with the requirements in Section 100, Supply-Connections – Permanently-Connected Devices, or in Section 101, Supply Connections– Cord- and Plug-Connected Devices, as appropriate.

99.3 A polymeric material that is used as the enclosure for a float switch or encloses or acts as a complete or partial enclosure of electrical components in a float operated switch shall comply with 7.5.1 and the Water Exposure and Immersion Tests in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

99.4 The enclosures of pressure operated and float-operated switches incorporating complete or partial enclosures of electrical components, such as those constructions meant to be mounted to the wall of a vessel, and pressure operated switches incorporating complete or partial enclosures of electrical components, such as those constructions meant to be mounted to the wall of a vessel shall comply with the construction, performance, and marking requirements for enclosures in Sections 7 – 12 this Standard.

99.5 A pressure vessel, an air filter, a piston operator, or similar device shall withstand hydrostatic strength tests consistent with the intended use unless it is certified by the National Board of Boiler and Pressure Vessel Inspectors and bears an ASME Code inspection symbol other than the UM symbol.

100 Supply Connections – Permanently-Connected Devices

100.1 A pressure switch or similar equipment intended to be supported only by rigid conduit shall be provided with a conduit hub or nipple.

100.2 A pressure switch employing a flare or compression fitting as the pressure connection shall have provision for fastening a conduit hub or nipple unless mounting brackets or holes are provided.

100.3 A conduit hub or nipple attached to the enclosure of a pressure switch or similar equipment by swaging, staking, or similar means shall comply with the pullout, bending, and torque test requirements described in Section 105.

100.4 The effective lead length outside of the float-operated device shall not be less than 4 inches (102 mm).

100.5 The length of a grounding lead, if provided, shall not be less than 6 inches (152 mm). See also 42.2.1 if the lead is insulated.

101 Supply Connections – Cord- and Plug-Connected Devices

101.1 A cord-connected device shall be provided with a length of hard service or junior hard service flexible cord and shall comply with 26.11.3 and 26.11.5.

Exception: A cord-connected float switch provided with a 15A attachment plug and receptacle intended for use with single phase thermally protected sump pumps shall be:

a) Provided with an 18 AWG cord when rated not more than 7.2 FLA, or provided with a 16 AWG cord when rated not more than 9.8 FLA; and

b) Marked as in 108.4.

101.2 When provided, an attachment plug shall comply with 26.11.4.

101.3 The flexible cord of a float switch shall comply with 26.11.1 and shall also be water resistant, designated by "W", such as a Type SW or SJW cord.

PERFORMANCE

102 General

102.1 Float switches, float-operated switches, and pressure operated switches shall be subjected to the applicable tests specified in this section. The tests are to be conducted in the sequence indicated in Table 102.1. A device that employs a solid-state switching device shall also comply with applicable tests in Part VI, Solid-State AC Motor Controllers, or Part VIII, Semiconductor Relays and Switches. A device that employs a mercury switch shall also comply with the applicable tests in Part IX, Mercury Tube Switches.

Table 102.1
Sequence of Tests

Standard reference	Test	Sample number[a]					
		1	2	3	4	5	6
		Sequence	Sequence	Sequence	Sequence	Sequence	Sequence
Section 45	Temperature	1					
Section 103	Overload		1				
Section 104	Endurance		2				
Section 51	Dielectric Voltage-Withstand	2	3				
Section 52	Short Circuit			1			

Table 102.1 Continued on Next Page

Table 102.1 Continued

Standard reference	Test	Sample number[a]					
		1	2	3	4	5	6
		Sequence	Sequence	Sequence	Sequence	Sequence	Sequence
Section 71	Pressure				1		
Section 105	Hub and Nipple					1	
Section 106	Float Switch						1

[a] All or any combination of sequences may be conducted on a single sample if agreeable to those concerned. More than one sample may be used if more than one rating is being tested. One sequence need not be completed as a prerequisite to the starting of another.

103 Overload Test

103.1 A float- or pressure-operated switch shall perform acceptably when subjected to a test as described in Section 47 on a test circuit having the parameters described in Table 103.1 for ac and dc motor loads and general use ratings. For other ratings, the test circuit shall have parameters described in Table 47.1.

Table 103.1
Parameters for Overload Test

Device used for	Amperes[a]	Closed test circuit voltage ratio[a]	Power factor	Operations		
				Number	Rate in seconds	
					On	Off
AC Motor Load[b,c]						
Part 1	6[e]	1.1 – 1.0	0.4 – 0.5	50	1	9
Part 2	1.5	1.1 – 1.0	0.75 – 0.8	50	1	9
AC General Use	1.5	1.1 – 1.0	0.75 – 0.8	50	1	9
DC Motor Load[b,c]						
Part 1	10	0.55 – 0.5	d	50	1	9
Part 2	1.5	0.55 – 0.5	d	50	1	9
DC General Use	1.5	1.1 – 1.0	1.0	50	1	9

[a] Ratio of test value to rated value.

[b] When the switch is provided with an overload relay, or some similar means that causes the switch contacts to open in response to the stalled rotor current of the motor, then the test current, voltage, power factor, operations rate, and number of operation are to be in accordance with Section 47 for an across-the line starter. A mechanical adjustment, such as that of a float-, or lever-, of a float-operated switch or tool-operated adjustment for the pressure setting of a pressure-operated switch, to set the actuation point for the switch due to liquid level or pressure is not identified as being a similar means.

[c] For devices used for motor loads the overload test is to be conducted in two parts. For part 1, the device shall not be required to break current. Both parts 1 and 2 (100 operations total) shall be conducted on the same sample.

[d] Non-inductive resistance

[e] For single phase motors only. For three phase ac motor loads, the test current is as noted in Table 47.4.

104 Endurance Test

104.1 A float- or pressure-operated switch shall comply with the requirements of the endurance test as described in Section 48 on test circuits in accordance with Table 104.1 for ac and dc motor load and general use ratings. For other ratings, the test circuit shall have parameters as described in Table 48.1.