UL 916

STANDARD FOR SAFETY

Energy Management Equipment

UL Standard for Safety for Energy Management Equipment, UL 916

Fifth Edition, Dated October 22, 2015

Summary of Topics:

This revision of UL 916 dated October 21, 2021 includes changes in requirements in Supplement SA to address energy management equipment that use remote or cloud-based interface for communication and to clarify functional safety requirements referencing UL 60730-1; SA1, SA1.4, SA1.5, SA2.1, SA2.2, SA2.4, SA2.6 – SA2.9, SA3.1 – SA3.6, Section SA4 and SA5.6.

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated August 27, 2021.

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UL 916

Standard for Energy Management Equipment

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Fifth Edition

October 22, 2015

This UL Standard for Safety consists of the Fifth Edition including revisions through October 21, 2021.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover energy management equipment and associated sensing devices rated 600 volts or less and intended for installation in accordance with the National Electrical Code, NFPA 70.

1.2 This equipment energizes or de-energizes electrical loads to achieve a desired use of electrical power. The equipment is intended to control electrical loads by responding to sensors or transducers monitoring power consumption, by sequencing, by cycling the loads through the use of preprogrammed data logic circuits, or any combination thereof. Devices responding to signals from a utility company may receive the signals over the power lines or as radio signals.

1.3 These requirements also cover equipment intended for connection only to a low-voltage circuit of limited power supplied by a Class 2 transformer.

1.4 These requirements do not cover switching devices operated by a mechanical or electromechanical clock mechanism to energize or de-energize loads. These requirements do cover electronic clock operated energy management equipment.

1.5 Controls intended to be installed in air handling spaces or in other environmental air space (plenums) are covered under the scope of this standard.

2 Components

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

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

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

b) Is superseded by a requirement in this standard.

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

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

3 Units of Measurement

3.1 When a value for measurement is followed by a value in other units in parentheses, the first stated value is the requirement.

3.2 Unless otherwise indicated, all voltage and current values mentioned in this standard are root-mean-square (rms).

4 Undated References

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

5 Glossary

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

5.2 CLASS 2 SYSTEM – A circuit, transformer, or power source having energy- and voltage-limiting characteristics as described in the National Electrical Code, ANSI/NFPA 70.

5.3 CONTROLLED ENVIRONMENT – An environment relatively free of contaminants. A controlled environment may also be provided by means of a totally closed, gasketed enclosure or the equivalent.

5.4 DEAD-CASE-MOUNTED SEMICONDUCTOR – A semiconductor, such as a triac or silicon-controlled rectifier, employing an integral metal tab or stud that is insulated from live parts.

5.5 FIELD-WIRING TERMINAL – A wiring terminal on permanently-connected equipment to which supply connections are made when the equipment is installed in the field.

5.6 ISOLATED LIMITED-ENERGY LOW-VOLTAGE CIRCUIT – A circuit (also hereafter referred to as a low-voltage circuit) involving a potential of not more than 42.4 volts peak supplied by one of the following:

a) An energy-limiting Class 2 transformer;

b) A non-energy-limiting Class 2 transformer and an overcurrent protective device. The protective device is:

1) Not to be of the automatic reclosing type;

2) To be trip-free from the reclosing mechanism; and

3) Not to be readily interchangeable with a device of a different rating;

c) A combination of an isolated transformer secondary winding and a fixed impedance that complies with all the performance requirements for an energy-limiting Class 2 transformer or power source;

d) A dry-cell battery having output characteristics not greater than those of an energy-limiting Class 2 transformer or power source; or

e) A combination of a rechargeable battery and a fixed impedance that complies with all of the performance requirements for an energy-limiting Class 2 transformer or power source.

5.7 ISOLATED LIMITED-ENERGY SECONDARY CIRCUIT – A circuit derived from an isolated secondary winding of a transformer having a maximum capacity of 100 volt-amperes and an open-circuit secondary-voltage rating not exceeding 1000 volts.

5.8 ISOLATION – Electrical separation between two locations.

5.9 JUNCTION TEMPERATURE – A theoretical temperature based on a simplified representation of the thermal and electrical behavior of a semiconductor device.

5.10 MAXIMUM CASE TEMPERATURE – A specification, usually in the form of a curve of on-state current versus maximum case temperature, that refers to the maximum case temperature of a thyristor with regard to the on-state current. The case is an external point on the thyristor where this temperature is related to the maximum junction temperature for the thyristor.

5.11 NONISOLATED LIMITED-ENERGY LOW-VOLTAGE CIRCUIT (POWER SOURCE) – A circuit derived from a source of supply classified as line-voltage by connecting impedance in series with the supply circuit as a means of limiting the voltage and power to comply with Class 2 characteristics.

5.12 OPPOSITE POLARITY – A difference of potential between two points, where shorting of these two points would result in a condition involving overload, rupturing of printed wiring board tracks, components or fuses, and the like.

5.13 OPTICAL ISOLATOR – A photon-coupled device consisting of a light source and sensor integrated into a single package that provides circuit isolation.

5.14 PILOT DUTY RATING – A rating applied to electromagnetic loads.

5.15 PORTABLE EQUIPMENT – Cord- and plug-connected equipment that is capable of being carried or moved about.

5.16 PRIMARY CIRCUIT – The wiring and components that are conductively connected to the supply circuit.

5.17 PULSE TRANSFORMER – A transformer intended to pass pulse waveforms as distinguished from sine waves.

5.18 SAFETY CIRCUIT – A primary or secondary circuit that contains a control relied upon to reduce the risk of fire, electric shock, or injury to persons at the controlled equipment.

5.19 SAFETY CONTROL – An automatic control and interlock (including relays, switches, and other auxiliary equipment used to form a system) which is intended to reduce the risk of fire, electric shock, or injury to persons.

5.20 SECONDARY CIRCUIT – A circuit supplied from a secondary winding of an isolating transformer.

5.21 STATIONARY EQUIPMENT – Cord- and plug-connected equipment that is intended to be fastened in place, or located in a dedicated space.

5.22 USER SERVICING – Any form of servicing that can be performed by personnel other than those who are trained to maintain the particular equipment is considered user servicing. Some examples of user servicing are:

a) The attachment of accessories by means of attachment plugs and receptacles or by means of other separable connectors.

b) The changing of tapes and the like that do not involve complicated operations.

c) The replacement of recording tapes, disks, program boards, punched cards, or paper forms. Replacement of lamps and fuses and resetting of circuit breakers located in an operator-access area unless the lamps, fuses, or circuit breakers are marked to indicate replacement or resetting only by qualified service personnel.

d) The making of routine operating adjustments necessary to adapt the unit for its different intended functions.

e) Routine cleaning of data-handling media.

CONSTRUCTION

6 General

6.1 An electronic or solid-state circuit used in a back-up, limiting, or other safety control, including controls that require a calibration test, is evaluated on the basis of its compliance with the requirements in this standard. Electronic components shall comply with the requirements for the application.

6.2 A circuit extending from the equipment and intended for connection to a low-voltage Class 2 circuit as defined in the National Electrical Code, ANSI/NFPA 70, shall not involve a potential of more than 30 volts rms (42.4 volts peak) and be supplied by:

a) A primary battery;

b) A standard Class 2 transformer; or

c) A combination of a transformer and a fixed impedance that, as a unit, complies with all the performance requirements for a Class 2 transformer.

6.3 A circuit derived from a line-voltage circuit by connecting resistance in series with the supply circuit as a means of limiting the voltage and current is considered to be a low-voltage circuit when the impedance has been investigated for such use. See Isolating Resistor Evaluation, Section 67.

6.4 The equipment shall use materials that comply with the requirements for the application and shall be made and finished with the degree of uniformity and grade of workmanship practicable in a well-equipped factory.

7 Frame and Enclosure

7.1 General

7.1.1 Equipment shall be formed and assembled so that it will have the strength and rigidity necessary to resist the abuses to which it may be subjected, without increasing the risk of fire, electric shock, or injury to persons due to total or partial collapse resulting in a reduction of spacings, loosening or displacement of parts, or other serious defects.

7.1.2 Equipment that complies with the requirements in 7.1.3 – 7.8.6 is considered to comply with 7.1.1.

7.1.3 Electrical parts of the equipment, other than a supply cord or low-voltage terminals, shall be located or enclosed so that the risk of unintentional contact with uninsulated live parts will be reduced.

Exception: An enclosure is not required for equipment intended for field installation within the enclosure of another product provided that:

a) All required markings are provided as specified in Sections 72 – 75 and

b) The temperature, overvoltage and undervoltage tests are conducted with the equipment in a 40 ±2°C (104 ±3.6°F) ambient. See Barriers, Section 37, and the Overvoltage and Undervoltage Tests, Section 43.

7.1.4 Equipment incorporating an air-filtering system or utilizing a tight-fitting enclosure may be subject to an investigation to determine whether it provides the equivalent of a controlled environment.

Exception: A gasketed enclosure is considered to provide an enclosed environment.

7.1.5 An air filter acting as an enclosure part shall comply with the requirements for Class 1 filters as specified in the Standard for Air Filter Units, UL 900. If abnormal tests show that an equivalent flame barrier exists, then an air filter is not considered to be an enclosure part and may be omitted.

7.2 Covers

7.2.1 An enclosure and a part of an enclosure such as a door or cover shall be provided with means for firmly securing it in place.

7.2.2 Sheet-metal screws threading directly into metal shall not be used to attach a cover, door, or other part that is removed to install field wiring or for operation of the equipment. Machine screws and self-tapping machine screws may thread directly into sheet-metal walls. See 18.1.19.

7.2.3 Sheet-metal screws mounting internal components that are not removed for installation or operation may thread directly into metal.

7.2.4 An enclosure cover shall be hinged if it gives access to a fuse or other overcurrent device, the functioning of which requires renewal, or if it is necessary to open the cover in connection with normal operation of the device.

Exception: A hinged cover is not required if the only overload-protective devices enclosed are:

a) Supplementary fuses in control circuits, provided the devices and circuit loads are within the same enclosure;

b) Supplementary overcurrent devices rated 2 amperes or less for loads not exceeding 100 volt-amperes;

c) Extractor fuses having an integral enclosure; or

d) Overcurrent devices connected in a low-voltage circuit. See 5.6.

7.2.5 A door or cover giving access to a fuse or thermal cutout in other than a low-voltage circuit shall:

a) Shut closely against a 1/4 inch (6.4 mm) rabbet or the equivalent,

b) Have turned flanges for the full length of four edges, or

c) Have angle strips fastened to it.

Flanges or angle strips shall fit closely with the outside of the walls of the box proper and shall overlap the edges of the box not less than 1/2 inch (12.7 mm). A construction determined to provide equivalent protection or a combination of flange and rabbet may be used. See Figure 7.1 and Figure 7.2.

Figure 7.1

Rabbet

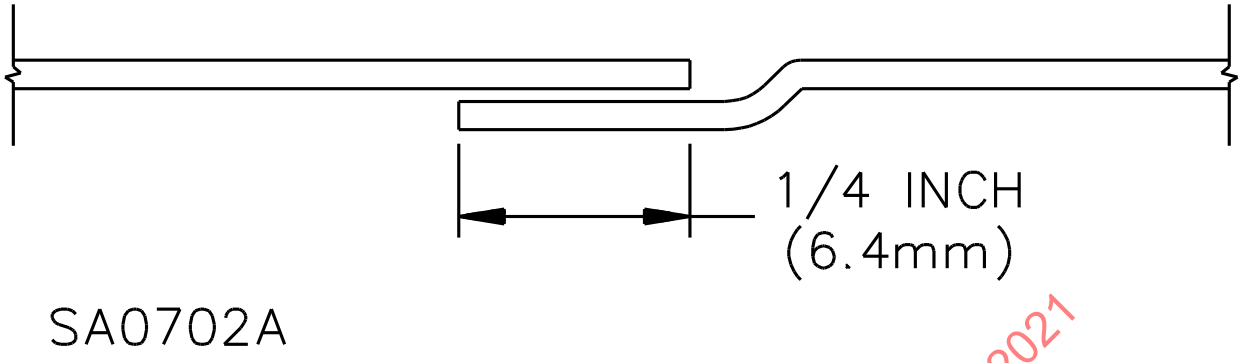
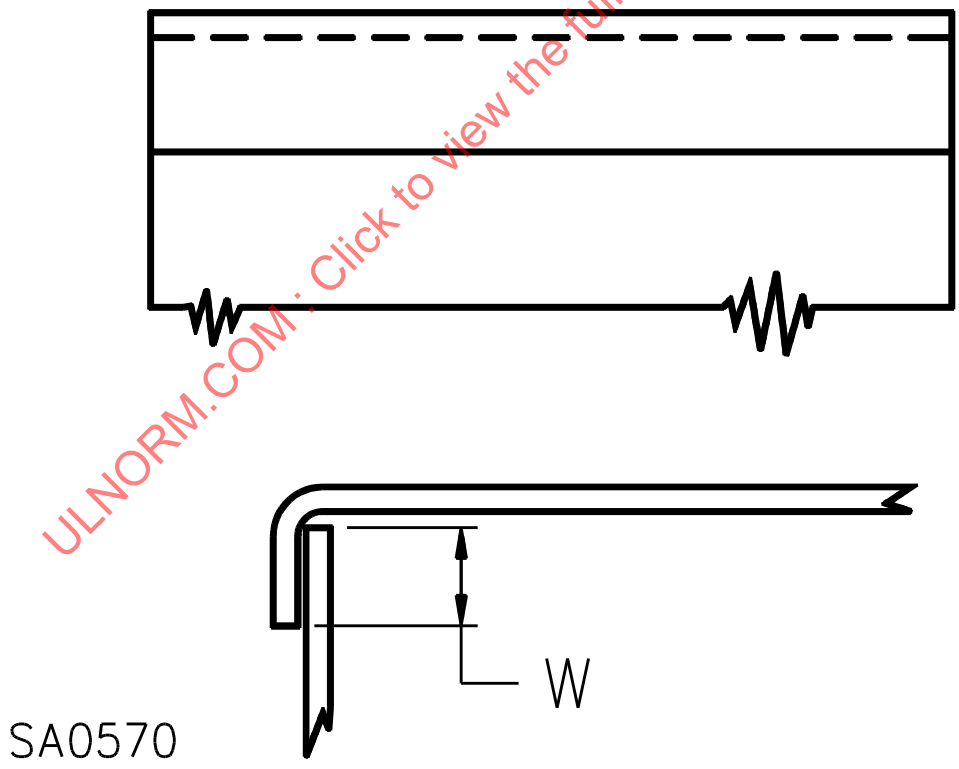


Figure 7.2

Measurement of overlap



7.2.6 A strip used to provide a rabbet and an angle strip fastened to the edges of a door shall be secured at not less than two points, not more than 1-1/2 inches (38.1 mm) from each end of each strip and at points between these end fastenings not more than 6 inches (152 mm) apart.

7.2.7 If a cover is required by 7.2.4 to be hinged, then the cover shall not depend solely upon screws or other similar means requiring the use of a tool to hold it closed, but shall be provided with a spring latch or catch, or a hand operable captive fastener.

7.2.8 A snap-on cover that gives access to bare live parts or film-coated wire and that does not require a tool for removal shall have no apparent means of removal, such as an extending tab, and shall withstand the Cover Retention Test, Section 62.

7.2.9 The continuity of a bonding means for a snap-on or fastener-attached cover shall comply with the requirements in Bonding of Internal Parts, Section 20.

7.3 Transformers

7.3.1 A transformer shall be housed within its own enclosure or within the main enclosure of the equipment, or within a combination of the two.

7.3.2 A sheet-steel transformer enclosure shall have a thickness of at least 0.026 inch (0.66 mm) if uncoated and at least 0.029 inch (0.74 mm) if galvanized.

Exception: Sheet steel having a thickness of at least 0.020 inch (0.51 mm) if uncoated and at least 0.023 inch (0.58 mm) if galvanized may be used for a drawn end bell having maximum dimensions of 2-1/4 inches (57.2 mm) on the flat portion and 1-1/2 inches (38.1 mm) at the base of the drawn portion.

7.3.3 A cast-metal transformer enclosure shall comply with the requirements in 7.4.1. A transformer enclosure of other material shall have the necessary strength and rigidity and otherwise comply with the requirements for the application.

7.4 Cast metal

7.4.1 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, die-cast metal shall be minimum:

a) 3/32 inch (2.4 mm) thick for an area greater than 24 square inches (154.8 cm^2) or having any dimension more than 6 inches (152 mm).

b) 1/16 inch (1.6 mm) thick for an area of 24 square inches or less and having no dimension more than 6 inches. The area limitation may be obtained by the provision of reinforcing ribs subdividing a larger area.

c) 0.035 inch (0.89 mm) thick if the enclosure will not be used as a splice box and if the voltage rating of the complete device is such that the voltage between any two conductors is 250 volts or less and is limited to direct current or single-phase alternating current.

d) 0.028 inch (0.71 mm) thick if the enclosure houses only low-voltage circuits.

7.5 Sheet metal

7.5.1 Other than at points where a wiring system is to be connected, the thickness of a sheet-metal enclosure shall not be less than that specified in Table 7.1 and Table 7.2.

Table 7.1
Minimum thickness of sheet metal for electrical enclosures – carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness uncoated,		Minimum thickness metal coated,	
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,					
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inch	(mm)	inch	(mm)
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited					
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)	0.020[d]	(0.51)	0.023[d]	(0.58)
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited					
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)	0.026[d]	(0.66)	0.029[d]	(0.74)
8.0	(20.3)	Not limited		12.0	(30.5)	Not limited					
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)	0.032	(0.81)	0.034	(0.86)
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited					
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)	0.042	(1.07)	0.045	(1.14)
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited					
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)	0.053	(1.35)	0.056	(1.42)
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited					
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)	43.0	(109.2)	0.060	(1.52)	0.063	(1.60)
25.0	(63.5)	Not limited		39.0	(99.1)	Not limited					
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)	0.067	(1.70)	0.070	(1.78)
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited					
38.0	(96.5)	47.0	(119.4)	54.0	(137.2)	66.0	(167.6)	0.080	(2.03)	0.084	(2.13)
42.0	(106.7)	Not limited		64.0	(162.6)	Not limited					
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)	84.0	(213.4)	0.093	(2.36)	0.097	(2.46)
52.0	(132.1)	Not limited		80.0	(203.2)	Not limited					
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)	0.108	(2.74)	0.111	(2.82)
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited					
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)	0.123	(0.123)	0.126	(3.20)

[a] See 7.5.4 for description of supporting frame and method for accomplishing equivalent reinforcing.

[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 common supports 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 0.034 inch (0.86 mm) thick if zinc coated and not less 0.032 inch (0.81 mm) thick if uncoated.

Table 7.2
Minimum thickness of sheet metal for enclosures– aluminum, copper, or brass

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]					
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,		Minimum thickness,	
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inch	(mm)
3.0	(7.6)	Not limited		7.0	(17.8)	Not limited			
3.5	(8.9)	4.0	(10.2)	8.5	(21.6)	9.5	(24.1)	0.023[d]	(0.58)

Table 7.2 Continued on Next Page

Table 7.2 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness,	
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,			
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inch	(mm)
4.0	(10.2)	Not limited		10.0	(25.4)	Not limited			
5.0	(12.7)	6.0	(15.2)	10.5	(26.7)	13.5	(34.3)	0.029	(0.74)
6.0	(15.2)	Not limited		14.0	(35.6)	Not limited			
6.5	(16.5)	8.0	(20.3)	15.0	(38.1)	18.0	(45.7)	0.036	(0.91)
8.0	(20.3)	Not limited		19.0	(48.3)	Not limited			
9.5	(24.1)	11.5	(29.2)	21.0	(53.3)	25.0	(63.5)	0.045	(1.14)
12.0	(30.5)	Not limited		28.0	(71.1)	Not limited			
14.0	(35.6)	16.0	(40.6)	30.0	(76.2)	37.0	(94.0)	0.058	(1.47)
18.0	(45.7)	Not limited		42.0	(106.7)	Not limited			
20.0	(50.8)	25.0	(63.5)	45.0	(114.3)	55.0	(139.7)	0.075	(1.91)
25.0	(63.5)	Not limited		60.0	(152.4)	Not limited			
29.0	(73.7)	36.0	(91.4)	64.0	(162.6)	78.0	(198.1)	0.095	(2.41)
37.0	(94.0)	Not limited		87.0	(221.0)	Not limited			
42.0	(106.7)	53.0	(134.6)	93.0	(236.2)	114.0	(289.6)	0.122	(3.10)
52.0	(132.1)	Not limited		123.0	(312.4)	Not limited			
60.0	(152.4)	74.0	(188.0)	130.0	(330.2)	160.0	(406.4)	0.153	(3.89)

[a] See 7.5.4 for description of supporting frame and method for accomplishing equivalent reinforcing.

[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 common supports 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.

7.5.2 At points at which a wiring system is to be connected, uncoated steel shall be at least 0.032 inch (0.81 mm) thick, zinc-coated steel shall be at least 0.034 inch (0.86 mm) thick, and nonferrous metal shall be at least 0.045 inch (1.14 mm) thick.

7.5.3 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.

7.5.4 With reference to Table 7.1 and Table 7.2, a supporting frame is a structure of angle or channel, or a folded rigid section of sheet metal, that is rigidly attached and has essentially the same outside dimensions as the enclosure surface and sufficient torsional rigidity to resist the bending moments that may be applied via the enclosure surface when it is deflected. Equivalent reinforcing may be accomplished by constructions that will produce a structure that is as rigid as one built with a frame of angles or channels. 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.

7.6 Nonmetallic

7.6.1 The requirements in 7.6.2 – 7.6.8 apply to polymeric enclosures.

7.6.2 A nonmetallic enclosure or enclosure part shall have mechanical strength and durability and be formed so that operating parts will be protected against damage and shall resist the abuses likely to be encountered during installation and normal use and service.

7.6.3 An enclosure or enclosure part shall protect persons against a risk of electric shock, and the material shall not create or contribute to a risk of fire, electric shock, or injury to persons.

7.6.4 Among the factors that are to be taken into consideration when judging a nonmetallic enclosure are:

a) Mechanical strength;

b) Resistance to impact;

c) Moisture absorption;

d) Resistance to combustion and to ignition from electrical sources;

e) Dielectric properties, insulation resistance, and resistance to arc tracking; and

f) Resistance to distortion and creeping at temperatures to which the material may be subjected under conditions of normal or abnormal use.

A material shall not display a loss of these properties beyond the minimum required level as a result of aging. Tests on nonmetallic enclosures for stationary equipment and equipment intended to be permanently connected electrically shall be conducted in accordance with Sections 81 – 96.

7.6.5 Enclosures for portable equipment shall be evaluated in accordance with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

7.6.6 A polymeric enclosure intended for connection to a permanent wiring system shall withstand the tests described in 61.1.1 – 61.1.6.

7.6.7 If continuity of a grounding system relies on dimensional integrity of a nonmetallic material, the dimensional stability of the material shall be considered in addition to the factors mentioned in 7.6.4. The material shall withstand the Creep and Overcurrent Test, Section 96.

7.6.8 If a bonding means is not assembled to the equipment, the equipment shall be marked in accordance with 75.7.

7.6.9 A part, such as a dial or nameplate, that is a part of an enclosure shall be metal or other material as specified for the enclosure in 7.4.1 – 7.6.4.

7.6.10 A nonmetallic part, such as a reset knob, lever, or button that protrudes through a hole in the enclosure that is not larger than an area of 1 square inch (6.45 cm^2) shall be made of material classified V-2 or better in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

7.6.11 A nonmetallic part that protrudes through a hole having an area larger than 1 square inch (6.45 cm^2) shall be made of material that complies with the requirements in 7.6.2 – 7.6.4 and 7.6.9. See 8.2.1.

7.6.12 A nonmetallic cover attached by screws shall comply with the Cover Retention Test, Section 62, with the screws loosened one full turn.

7.6.13 Electrical controls employing polymeric parts that are intended to be installed in air handling spaces or in other environmental air space (plenums) shall be investigated for the application and their fire-resistance and low-smoke-producing characteristics in accordance with the Standard for Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces, UL 2043.

7.7 Windows

7.7.1 Glass covering an observation opening shall be secured in place so that it cannot be readily displaced in service, and shall provide mechanical protection for the enclosed parts.

7.7.2 Glass for an opening not more than 4 inches (101.6 mm) in any dimension shall be at least 1/16 inch (1.6 mm) thick, and glass for a larger opening, but not more than 144 square inches (929 cm^2) in area and having no dimension greater than 12 inches (304.8 mm), shall be at least 1/8 inch (3.2 mm) thick. Glass used to cover an area larger than 144 square inches shall not be less than 1/8 inch thick and shall conform to one of the following:

a) The glass shall be of a nonshattering or tempered type that, when broken, shall conform to the performance specifications in the Performance Specifications and Methods of Test for Safety Glazing Material Used in Buildings, ANSI Z97.1-1975; or

b) Shall withstand the 2.5 foot-pound (2.4 J) impact specified in the Glass Window Impact Test, Section 64.

7.7.3 A transparent material other than glass used as a covering over an opening in an enclosure shall comply with the requirements in 7.6.2 – 7.6.4 and 7.6.9 – 7.6.12.

7.8 Raintight and rainproof enclosures

7.8.1 When subjected to the Rain Test, Section 60, an enclosure designated as:

a) Raintight shall be constructed so that rain does not enter the enclosure.

b) Rainproof shall be constructed so that rain does not interfere with the operation of the apparatus used within the enclosure.

7.8.2 A raintight or rainproof enclosure shall be marked as specified in 72.7.

7.8.3 A gasket used to make an enclosure raintight or rainproof shall be tested as specified in the Accelerated Aging Tests, Section 58.

7.8.4 A raintight or rainproof enclosure shall be provided with external means for mounting.

Exception: A rainproof enclosure may be provided with internal means for mounting if the mounting means is constructed so that water cannot enter the enclosure.

7.8.5 An opening for conduit in a raintight enclosure, other than in the bottom of the enclosure, shall either be threaded, or accommodate a specific hub complying with the requirements for such devices.

7.8.6 An opening for conduit in a rainproof enclosure shall either:

a) Be threaded or

b) Accommodate a specific hub complying with the requirements for such devices unless the opening is located wholly below the lowest terminal lug or other live part within the enclosure. There shall be provision for drainage of the enclosure if a knockout or unthreaded hole is provided other than in the bottom.

8 Openings in Enclosures

8.1 Ventilating openings

8.1.1 A ventilating opening shall not be provided in an enclosure that houses a fuse or any portion of a circuit breaker other than the operating handle, unless the construction affords containment of electrical breakdown disturbances equivalent to that provided by an enclosure complying with the requirements in 7.2.5 – 7.2.7.

8.1.2 A ventilating opening shall not be provided in a compartment or part of an enclosure that contains field-wiring splices in a line-voltage circuit.

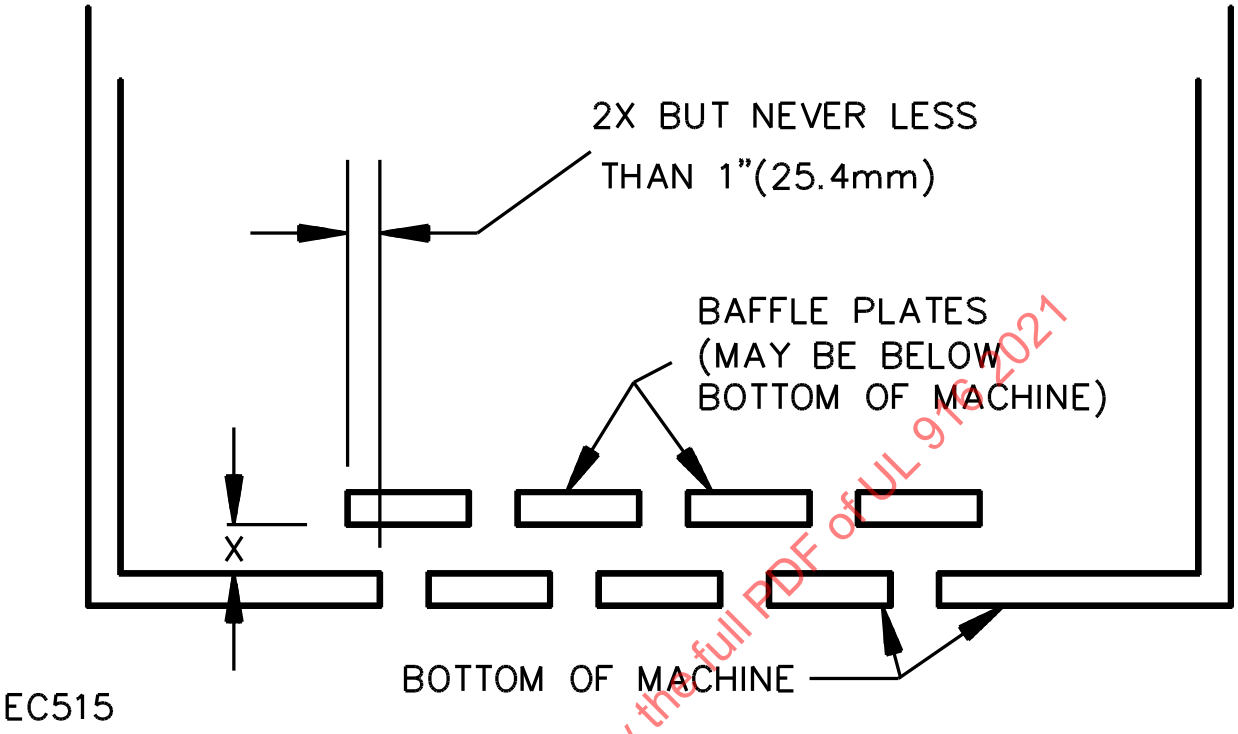
8.1.3 A ventilating opening shall not be located in a mounting surface of an enclosure.

8.1.4 The shortest distance between a ventilating opening and the bottom of an enclosure or a wall-mounting surface shall be at least one-quarter of the enclosure height or depth, respectively, or 1 inch (25.4 mm), whichever is less.

8.1.5 A ventilating opening may be provided in the bottom surface of an enclosure if the opening does not permit materials to fall directly out from the interior of the unit. Figure 8.1 illustrates a construction that meets this requirement.

Figure 8.1

Bottom panel baffles



8.1.6 There shall be no emission of flame or molten material through a ventilating opening, or manifestation of risk of fire, during normal tests or during abnormal tests, such as transformer burnout and burnout of a relay with blocked armature.

8.1.7 Unless the construction of equipment provided with forced ventilation is such that there is no direct path between live parts and the outlet opening, burnout tests in addition to those mentioned in 8.1.6 shall be conducted to determine that there is no emission of flame or molten material through that opening.

8.1.8 Air from a ventilating opening, either forced or otherwise, shall not be directed:

a) Into a duct or into a concealed space in a building,

b) Against the mounting surface, and

c) So that a disturbance may be propagated to other equipment.

8.1.9 See Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 12, for requirements for accessibility of live parts in an enclosure having ventilating openings.

8.2 Other openings

8.2.1 The smaller dimension (width) of an opening in an enclosure around a dial, adjusting knob, lever, handle, pointer, or the like shall not be more than 1/8 inch (3.2 mm) for any setting or position of the dial, knob, or other members.

8.2.2 Except for the openings described in 8.1.1 – 8.1.7, an enclosure shall have no open holes other than:

a) Not more than four unused holes intended for mounting various components inside the enclosure. The largest dimension of each such opening shall not be more than 3/16 inch (4.8 mm).

b) Not more than four holes 1/8 inch (3.2 mm) or less in diameter for the escape of air or drainage of paint during a painting process, located as close to the corners of the enclosure as possible, preferably at the rear of the enclosure.

c) A drainage opening in a rainproof enclosure that shall not exceed 1/4 by 1/4 inch (6.4 by 6.4 mm).

d) Not more than:

1) Four holes for mounting an enclosure having a maximum dimension of 18 inches (457 mm);

2) Six holes for an enclosure with a maximum dimension more than 18 inches but less than 48 inches (1.2 m); and

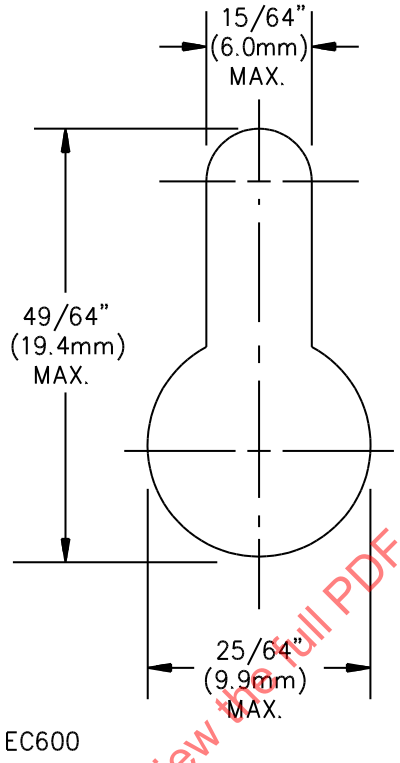
3) Eight holes for an enclosure with a maximum dimension of 48 inches or more.

Four of the holes for mounting an enclosure with a maximum dimension of 12 inches (305 mm) may be keyhole slots having the configuration illustrated in Figure 8.2. The dimensions specified in Figure 8.2 may vary if the area is equivalent. Four of the holes for mounting a larger enclosure may be keyhole slots, the dimensions of which are not specified, and which will be evaluated with regard to the enclosure dimensions and configurations.

e) The unclosed portion of an opening for passage of a capillary tube, an air pipe, a bellows, or other necessary mechanism, which shall not exceed 1/16 inch (1.6 mm).

Figure 8.2

Keyhole slot



8.2.3 A plate or plug for an unused conduit opening or other hole in an enclosure shall have a thickness not less than:

a) 0.014 inch (0.36 mm) for steel or 0.019 inch (0.48 mm) for nonferrous metal for a hole having a 1/4 inch (6.35 mm) maximum dimension and

b) 0.027 inch (0.69 mm) for steel or 0.032 inch (0.81 mm) for nonferrous metal for a hole having a 1-3/8 inch (34.9 mm) maximum dimension. A closure for a larger hole shall have a thickness equal to that required for the enclosure of the equipment, or a standard knockout seal shall be used.

Such a plate or plug shall be securely mounted.

8.3 Screens and expanded metal

8.3.1 The wires of a screen shall not be less than 16 AWG (1.3 mm^2) if used in openings 1/2 square inch (3.2 cm^2) or less in area, and shall not be less than 12 AWG (3.3 mm^2) for larger openings.

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

Exception: Expanded metal mesh that complies with the requirements in 8.3.3 may be used.

8.3.3 In small equipment where the indentation of a guard or enclosure will not alter the clearance between uninsulated, movable, current-carrying parts and grounded metal so as to adversely affect

performance or reduce spacings below the minimum values specified in Table 29.1, 0.020 inch (0.51 mm) expanded metal mesh – 0.023 inch (0.58 mm) if zinc coated – may be used, if:

a) The exposed mesh on any one side or surface of the device so protected has an area of not more than 72 square inches (464.5 cm^2) and has no dimension greater than 12 inches (305 mm) or

b) The width of an opening so protected is not greater than 3-1/2 inches (88.9 mm).

8.4 Wire openings

8.4.1 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or if an equivalent construction is used, there shall not be less than three threads in the metal, and the construction of the equipment shall be such that a conduit bushing can be attached.

8.4.2 If threads for the connection of conduit are not tapped all the way through a hole in:

a) An enclosure wall,

b) Conduit hub, or

c) A similar part,

there shall not be less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors that affords protection to the conductors equivalent to that provided by a standard conduit bushing and that has an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

8.4.3 In an enclosure threaded for support by rigid conduit, at least five full threads shall be provided for engaging the conduit.

8.4.4 A conduit hub or nipple attached to the enclosure of a pressure switch or similar equipment by swaging, staking, or similar means shall withstand the pullout, torque, and bending tests described in 61.1.2 – 61.1.4.

8.4.5 Equipment provided with a conduit nipple and no mounting holes, and marked for direct attachment to an outlet box, need not be subjected to the torque, bending moment, and pull tests, but shall withstand the impact specified in 61.1.6.

Exception: A metallic enclosure with a welded-on nipple need not be subjected to the test described in 61.1.6.

8.4.6 Each clamp and fastener for the attachment of:

a) Conduit;

b) Electrical metallic tubing;

c) Armored cable;

d) Nonmetallic flexible tubing;

e) Nonmetallic-sheathed cable;

f) Service cable; or

g) Similar items

that is supplied as a part of an enclosure shall comply with the requirements in the Standard for Conduit, Tubing, and Cable Fittings, UL 514B.

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

8.4.8 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 a spacing between uninsulated live parts and the bushing less than that required by this standard.

8.4.9 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum required by this standard shall be provided between uninsulated live parts and a conduit bushing installed at any location likely to be used during installation. Permanent marking on the enclosure, a template, or a full-scale drawing furnished with the equipment may be used to limit such a location.

8.4.10 With regard to the requirement in 8.4.9, means shall be provided so that an opening for conduit can be made without subjecting internal parts to contamination resulting from the presence of metallic particles.

8.4.11 In measuring a spacing between an uninsulated live part and a bushing installed in the knockout referred to in 8.4.8 and 8.4.9, it is to be assumed that a bushing having the dimensions in Table 8.1 is in place, and that a single locknut is installed on the outside of the enclosure.

8.4.12 No wire other than wires leading to a part mounted on a door or cover shall be brought out through the door or cover.

Table 8.1
Dimensions of bushings

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

9 Mounting

9.1 Equipment that is intended to be fastened in place shall have provision for mounting it securely in position. Bolts, screws, or other parts used for mounting the equipment shall be independent of those used to secure components of the equipment to the frame, base, or panel.

9.2 Portable equipment shall not be provided with means for permanent mounting.

10 Mechanical Assembly

10.1 A control switch, lampholder, attachment-plug receptacle, or plug connector provided as a part of the equipment shall be mounted securely and shall be prevented from turning by means other than friction between surfaces.

10.2 A lock washer, applied as intended, may be used to prevent a control switch from turning.

10.3 The equipment shall be assembled in accordance with 10.4 – 10.6 so that it will not be adversely affected by the vibration of normal operation.

10.4 Screws and nuts that attach operating parts to movable members shall be upset or otherwise locked to prevent loosening under the conditions of actual use.

10.5 An uninsulated live part, including a terminal, shall be secured to its supporting surface by a means 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 by this standard. Contact assemblies shall be secured so as to provide continued alignment of contacts.

10.6 A lock washer, applied as intended, may be used at a terminal or connection stud.

11 Operating Mechanism

11.1 The equipment shall be investigated under conditions of actual service to determine if it complies with all applicable requirements.

11.2 For equipment using electronic or solid-state components or circuits to control a motor, solenoid coil, or other inductive load, it shall be determined that the controlled load will not be caused to overheat due to half-waving or wave distortion of the controller output. This may be accomplished by testing the combination in accordance with 48.2.1, by incorporating protective devices into the controller, or by other equivalent means.

11.3 An operating mechanism shall not subject manually-operated switch parts to undue stress.

11.4 The position of an operating handle shall be marked, if necessary, as a guide for proper operation.

11.5 A control that has or is intended to have a marked off position or an implied off position shall:

a) Open all ungrounded conductors of the circuit with an air gap when the adjusting means is in the off position and

b) Be prevented from functioning automatically when in the off position either by a positive mechanical means or the equivalent.

11.6 With reference to the requirements in 11.5, the off state of a solid-state switch is not considered to be an open circuit.

11.7 A component, such as a resistor, capacitor, diode, and the like, shall not be connected across the contacts of a safety control or a protective or limiting device.

Exception: A component may be connected across the contacts of a safety control if investigated and determined to comply with the requirements for use in the end product.

12 Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts

12.1 To reduce the risk of unintentional contact that may involve a risk of electric shock from an uninsulated live part or film-coated wire, 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 12.5) less than 1 inch (25.4 mm), such a part or wire shall not be contacted by the probe illustrated in Figure 12.1.

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 12.1.

Exception: A motor other than one used in either a hand-held product or a hand-supported portion of a product need not comply with these requirements if it complies with the requirements in 12.2.

Figure 12.1

Articulate probe with web stop

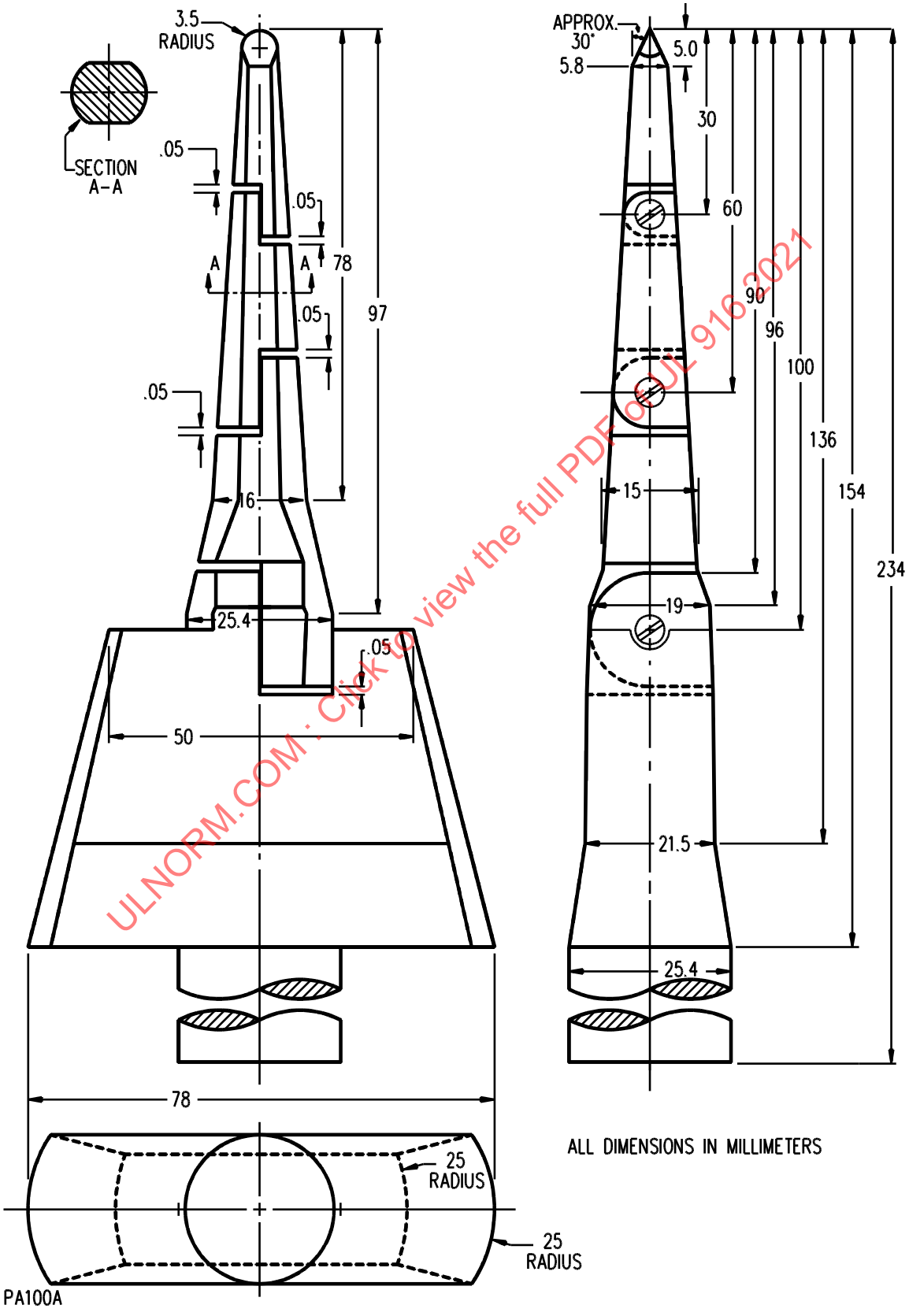


Table 12.1
Minimum distance from an opening to a part that may involve a risk of electric shock or injury to persons

Minor dimension[a] of opening,		Minimum distance from opening to part,	
inches[b]	(mm)	inches[b]	(mm)
3/4[c]	(19.1)	4-1/2	(114.0)
1	(25.4)	6-1/2	(165.0)
1-1/4	(31.8)	7-1/2	(190.0)
1-1/2	(38.1)	12-1/2	(318.0)
1-7/8	(47.6)	15-1/2	(394.0)
2-1/8	(54.0)	17-1/2	(444.0)
d	d	30	(762.0)

[a] See 12.5 for explanation of diameter of opening.

[b] Between 3/4 and 2-1/8 inches, interpolation is to be used to determine a value between values specified in the table.

[c] Any dimension less than 1 inch applies to a motor only.

[d] More than 2-1/8 inches, but not more than 6 inches (152.0 mm).

12.2 With reference to a part or wire in an integral enclosure of a motor as mentioned in the Exception to 12.1:

a) An opening may have a minor dimension (see 12.5) less than 3/4 inch (19.1 mm) if:

1) A moving part cannot be contacted by the probe illustrated in Figure 12.2;

2) Film-coated wire cannot be contacted by the probe illustrated in Figure 12.3;

3) In a directly accessible motor (see 12.7), an uninsulated live part cannot be contacted by the probe illustrated in Figure 12.4; and

4) In an indirectly accessible motor (see 12.6), an uninsulated live part cannot be contacted by the probe illustrated in Figure 12.2.

b) An opening may have a minor dimension of 3/4 inch or more if a part or wire is spaced from the opening as specified in Table 12.1.

Figure 12.2

Probe for moving parts and uninsulated live parts

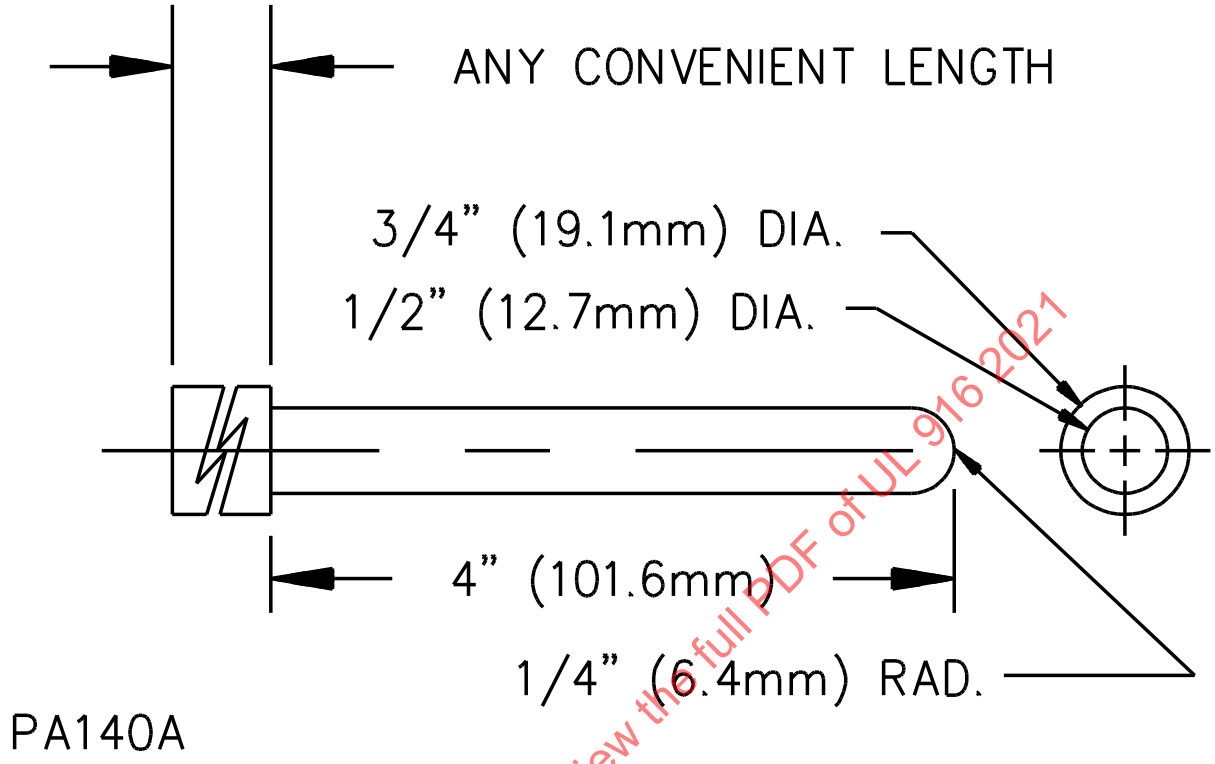


Figure 12.3

Probe for film-coated wire

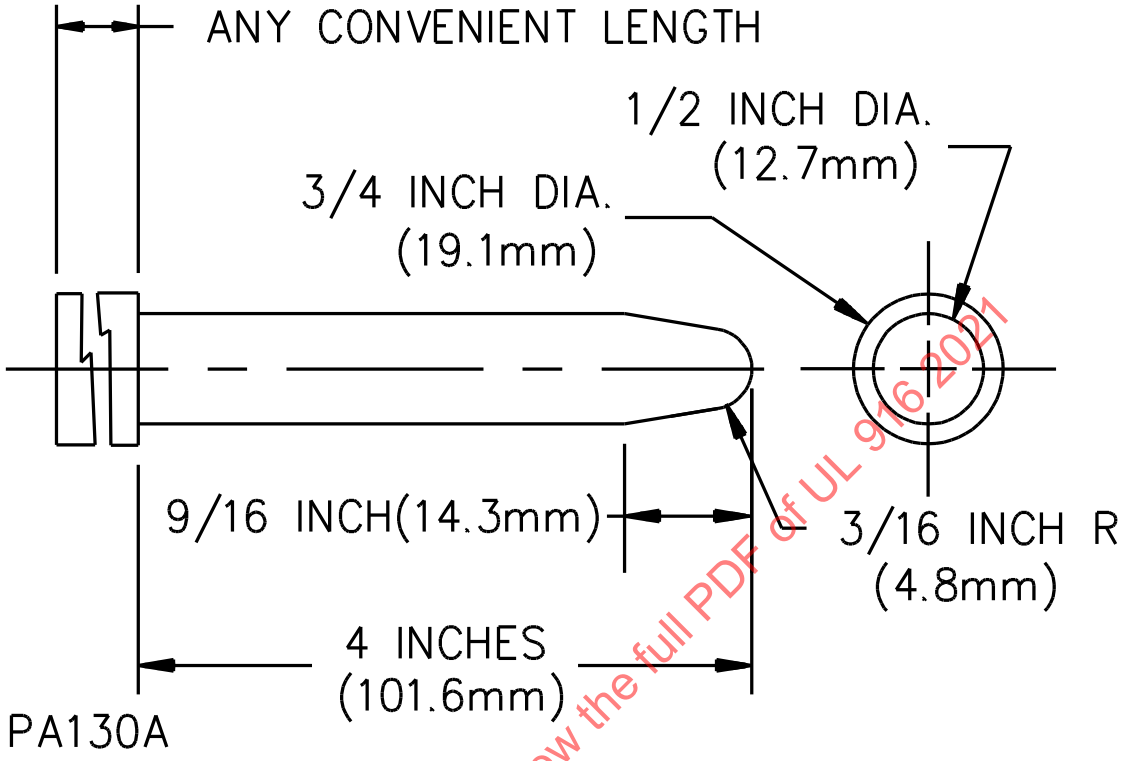
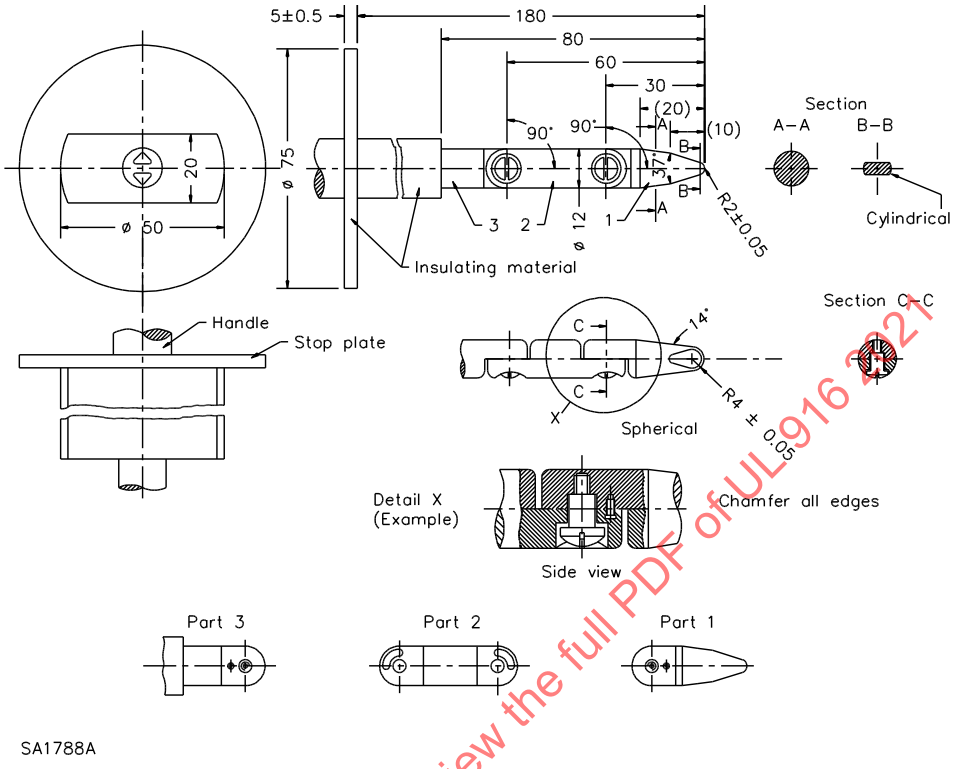


Figure 12.4

Articulate probe



12.3 The probes mentioned in 12.1 and 12.2 and illustrated in Figure 12.1 – Figure 12.4 are to be applied to any depth that the opening will permit, and are to be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the enclosure. The probes illustrated in Figure 12.1 and Figure 12.4 are to be applied in any possible configuration; and, if necessary, the configuration is to be changed after insertion through the opening.

12.4 The probes mentioned in 12.3 and 12.5 shall be used as measuring instruments to judge the accessibility provided by an opening, and not as instruments to judge the strength of a material; they shall be applied with the minimum force necessary to determine accessibility.

12.5 With reference to the requirements in 12.1 and 12.2, the minor dimension of an opening is the diameter of the largest cylindrical probe having a hemispherical tip that can be inserted through the opening.

12.6 With reference to the requirements in 12.2, an indirectly accessible motor is a motor that is:

a) Accessible only by opening or removing a part of the outer enclosure, such as a guard or panel, that can be opened or removed without using a tool or

b) Located at such a height or is otherwise guarded or enclosed so that it is unlikely to be contacted.

12.7 With reference to the requirements in 12.2, a directly accessible motor is a motor that can be contacted without opening or removing any part, or is located so as to be accessible to contact.

12.8 During the examination of a product to determine whether it complies with the requirements in 12.1 or 12.2, a part of the enclosure that may be opened or removed by the user without using a tool (to attach an accessory, to make an operating adjustment, or for other reasons) is to be opened or removed.

12.9 With reference to the requirements in 12.1 and 12.2, insulated brush caps are not required to be additionally enclosed.

13 Protection Against Corrosion

13.1 Iron and steel parts shall be protected against corrosion by:

a) Enameling;

b) Galvanizing;

c) Sherardizing;

d) Plating; or

e) Other equivalent means.

Exception No. 1: Bearings, thermal elements, or the like, if such protection is impracticable, need not be protected.

Exception No. 2: Small minor parts of iron or steel, such as washers, screws, bolts, and the like, that do not carry current need not be protected if corrosion of such unprotected parts would not be likely to result in a risk of fire, electric shock, or injury to persons.

Exception No. 3: Parts made of stainless steel, properly polished or treated if necessary, need not be protected.

13.2 The requirement in 13.1 applies to all enclosing cases whether of sheet steel or cast iron, and to all springs and other parts upon which proper mechanical operation may depend.

13.3 An enclosure designated either raintight or rainproof shall be protected against corrosion in accordance with the requirements in 13.4 – 13.18.

13.4 Metal shall be used in combinations that are galvanically compatible.

13.5 A hinge or other attachment shall be resistant to corrosion.

13.6 These requirements do not contemplate corrosion that might be caused by exposure to the earth or other corrosive agents.

13.7 The requirements in 13.8 – 13.18 do not apply to a part, such as a decorative grille, that is not a required part of an enclosure.

13.8 A nonmetallic enclosure is to be evaluated on the basis of the effect of exposure to ultraviolet light and water. See Component Evaluation, Section 66.

13.9 A metallic enclosure shall be protected against corrosion as specified in 13.10 – 13.18. See 7.3.1 – 7.5.4 for the required enclosure thickness.

13.10 Copper, bronze, brass containing not less than 80 percent copper, or stainless steel may be used without additional protection against corrosion. Sheet, extruded or cast aluminum, die-cast zinc, or other metal shall be of a grade or alloy having resistance to atmospheric corrosion equivalent to that specified for sheet steel of the required thickness, or shall be subjected to appropriate tests, or shall be additionally protected against corrosion.

13.11 An enclosure of cast iron or malleable iron at least 1/8 inch (3.2 mm) thick shall be protected against corrosion by:

a) A 0.00015-inch (0.0038-mm) thick coating of zinc, cadmium, or the equivalent on the outside surface and a visible coating of such metal on the inside surface or

b) One coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface.

13.12 Unless the paint can be determined to comply with these requirements by consideration of its composition, corrosion tests are required.

13.13 An enclosure of sheet steel less than 0.126 inch (3.20 mm) thick if zinc-coated or 0.123 inch (3.12 mm) thick if uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in 13.16.

a) Hot-dipped, mill-galvanized sheet steel conforming with the coating Designation G90 in Table I of the Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM designation. The weight of zinc coating may be determined by any appropriate method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight of Coating on Zinc Coated (Galvanized) Iron or Steel Articles of ASTM A90-87.

b) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00061 inch (0.0155 mm) on each surface with a minimum thickness of 0.00054 inch (0.0137 mm). The thickness of the coating shall be established by the Metallic Coating Thickness Test, Section 59. An annealed coating shall also comply with 13.18.

c) A zinc coating complying with 13.14 (a) or (b) with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface applied after forming. See 13.12.

d) A cadmium coating not less than 0.001 inch (0.03 mm) thick on both surfaces. The thickness of coating shall be established in accordance with the Metallic Coating Thickness Test, Section 59.

e) A cadmium coating not less than 0.00075 inch (0.0191 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.00051 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established in accordance with the Metallic Coating Thickness Test, Section 59, and the paint shall be as specified in (c).

13.14 An enclosure of sheet steel not less than 0.126 inch (3.20 mm) thick if zinc-coated or not less than 0.123 inch (3.12 mm) thick if uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been shown to give equivalent protection as described in 13.16.

a) Hot-dipped, mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in Table I of the Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, General Requirements, ASTM A653/A653M, with

not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM designation. The weight of zinc coating may be determined by any appropriate method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM A90-87.

b) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00041 inch (0.0104 mm) on each surface with a minimum thickness of 0.00034 inch (0.0086 mm). The thickness of the coating shall be established by the Metallic Coating Thickness Test, Section 59.

c) Two coats of an organic finish of the epoxy or alkyd resin or other outdoor paint on each surface. Compliance with these requirements is to be determined by consideration of the composition of the paint or by corrosion tests.

d) Any one of the means specified in 13.13.

13.15 The requirements in 13.14 also apply to an enclosure of zinc-coated sheet steel not less than 0.056 inch (1.42 mm) thick and an enclosure of uncoated sheet steel not less than 0.053 inch (1.35 mm) thick if the enclosure is intended to be mounted within and protected from direct exposure to weather by the enclosure of other equipment, such as an air conditioner. Such an enclosure shall not be marked rainproof or raintight.

13.16 With reference to 13.13 – 13.15, other finishes, including paints, metallic finishes and combinations of the two may be used when comparative tests with galvanized sheet steel – without annealing, wiping or other surface treatment – complying with 13.13(a) or 13.14(a), as applicable, indicate they provide equivalent protection. Among the factors that are to be taken into consideration when judging the compliance of such coating systems are exposure to salt spray, moist carbon dioxide-sulphur dioxide-air mixtures, moist hydrogen sulphide-air mixtures, ultraviolet light and water.

13.17 If tests are required, test specimens of a finish as described in 13.12, 13.13(c), 13.14(c), or 13.16, if the paint is tested, are to be consistent with the finish that is to be used in production with regard to the base metal, cleaning or pretreatment method, application method, number of coats, curing method, thickness, or the like.

13.18 A hot-dipped, mill-galvanized A60 (alloyed) coating or an annealed zinc coating that is bent or similarly formed after annealing and that is not otherwise required to be painted shall be painted in the bent or formed area if the bending or forming process damages the zinc coating, except that such areas on the inside surface of an enclosure that water does not enter during the rain test need not be painted. The zinc coating is considered to be damaged if flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 power magnification. Simple sheared or cut edges and punched holes are not considered to be formed.

14 Insulating Materials

14.1 A barrier or integral part, such as an insulating washer or bushing, and a base or a support for mounting live parts, shall be moisture-resistant material that will not be adversely affected by the temperature and stresses to which it will be subjected under conditions of use.

14.2 Insulating material shall be evaluated with regard to its use. Materials, such as mica, some molded compounds, and certain refractory materials usually comply with the requirements for sole support of live parts. When an investigation is required to determine whether a material complies, the investigation shall be conducted in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, with consideration given to:

a) The material's;

1) Mechanical strength;

2) Resistance to hot wire ignition;

3) Resistance to high-current-arc ignition;

4) Resistance to high-voltage-arc ignition;

5) Dielectric strength;

6) Insulation resistance; and

7) Heat-resistant qualities

in both the aged and unaged conditions;

b) The degree to which the material is enclosed; and

c) Any other feature affecting the risk of fire, electric shock, or injury to persons.

All factors are to be considered with regard to conditions of actual service.

14.3 Ordinary vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not as sole support for uninsulated live parts.

14.4 A sensor such as a current transformer, transducer, or the like, shall be provided with insulation that has been evaluated for the maximum voltage and temperature involved in its application, while taking into consideration the presence of other circuits.

14.5 All internal polymeric parts shall be classified at least HB in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

15 Field Connections

15.1 General

15.1.1 Compartments, raceways, and the like, for routing and stowage of conductors connected in the field shall not contain rough, sharp, or moving parts that may damage conductor insulation.

15.2 Equipment permanently connected electrically

15.2.1 For power circuit connections, permanently-connected equipment shall have provision for the connection of a wiring system.

15.2.2 Wiring terminals or leads shall be provided and shall comply with the requirements for the connection of conductors having an ampacity not less than the largest of the following ratings that are applicable:

a) One hundred twenty-five percent of the ampere rating of an electric space-heating equipment load that is to be permanently connected electrically.

b) One hundred twenty-five percent of a continuous duty load.

c) One hundred twenty-five percent of the full-load motor-current rating in accordance with 71.4 and 71.5. See Table 49.2 or Table 49.3 for the ampere rating corresponding to a horsepower rating.

d) For a combination load, 125 percent of the full-load motor current of the largest motor, plus 125 percent of the ampere rating of an electric space-heating equipment load that is to be permanently connected electrically, plus 125 percent of the continuous duty load, plus 100 percent of the sum of the current ratings of all other loads.

e) For direct-current motors intended to be operated from a rectified single-phase power supply unless marked in accordance with 73.18,

1) One hundred ninety percent if a half-wave rectifier is used.

2) One hundred fifty percent if a full-wave rectifier is used.

f) The ampere rating of the equipment for a load not specified in (a), (b), (c), (d), or (e).

15.2.3 With reference to 15.2.2, it is assumed that 75°C (167°F) conductors will be employed for currents of more than 100 amperes.

15.2.4 For equipment marked to indicate that it may be used with copper, copper-clad aluminum, or aluminum conductors, the field wiring terminals shall comply with the requirements for such devices and with the requirement in 15.2.2 for a wire of each metal for which it is marked. See 73.12.

15.2.5 A terminal box or compartment on equipment permanently connected electrically shall be located so that wire connections therein will be accessible for inspection, without disturbing either factory or field connected wiring, after the equipment is installed in the intended manner.

Exception No. 1: Wire connections to equipment intended to be mounted on an outlet box may be accessible upon removal of the equipment from the outlet box.

Exception No. 2: Factory supplied low-voltage, non-safety circuit wire connected to a hinged panel or cover may be flexed.

15.2.6 A field-wiring lead shall not be more than two standard wire sizes smaller than the copper conductor to which it will be connected, and shall not be smaller than 18 AWG (0.82 mm^2). For example, a 10 AWG (5.3 mm^2) or larger field-wiring lead is required for connection to a 6 AWG (13.3 mm^2) field-provided conductor. A field-wiring lead shall not be less than 6 inches (152.4 mm) long. Insulation on such a lead shall be:

a) At least 1/32-inch (0.8-mm) thick thermoplastic;

b) At least 1/64-inch (0.4-mm) thick rubber plus a braid cover for 300-volt or less applications; or

c) At least 1/32-inch thick rubber plus a braid cover for applications between 301 and 600 volts.

Exception No. 1: An 18 AWG size field-wiring lead may be provided for connection to a No. 12 (3.3 mm^2) size branch circuit conductor.

Exception No. 2: A lead may be more than two wire sizes smaller than the field-provided copper conductor to which it will be connected, but not smaller than 18 AWG, if more than one factory-provided copper lead is intended for connection to the same field-provided lead, and the construction complies with the following conditions:

a) A wire connector for connection of the field-provided wire is provided as part of the unit or remote-control assembly, and the wire connector can be used with the combination of wires that will be spliced;

b) The factory-provided leads are bunched or otherwise arranged so that stress does not result on an individual lead; and

c) The equipment is marked in accordance with 73.14.

15.2.7 A pigtail lead intended for field-wiring connection shall be subjected to the test specified in 57.1.2.

15.2.8 A lead provided for connection to an external line-voltage circuit shall not be connected to a wire-binding screw or pressure terminal connector located in the same compartment as the splice unless the screw or connector is rendered unusable for field-wiring connection or:

a) The lead is insulated at the unconnected end, and

b) A marking on the equipment clearly indicates the intended use of the lead.

15.2.9 The free end of field-wiring leads that will not be used in every installation – such as a tap for a multivoltage transformer or one free lead for a single-pole, double-throw switch – shall be insulated. For a grounding lead see 19.3.9.

15.2.10 Equipment that can be used with a fitting for only one type of wiring system shall be supplied with such a fitting.

15.2.11 An opening for the entry of a conductor or conductors of a circuit of limited power and voltage shall be provided with an insulating bushing. The bushing may be mounted in place in the opening or may be within the enclosure so that it shall be properly mounted when the equipment is installed.

15.2.12 The opening mentioned in 15.2.11 may be used for accommodating armored cable or conduit.

15.2.13 A bushing of rubber or rubber-like material provided in accordance with 15.2.11 shall be not less than 1/8 inch (3.2 mm) thick, except that it may be not less than 3/64 inch (1.2 mm) thick if the metal around the hole is eyeletted or similarly treated to provide smooth edges. A bushing shall be located so that it will not be exposed to oil, grease, oily vapors, or other substances having a deleterious effect on the material of the bushing. A hole in which such a bushing is mounted shall be free from sharp edges, burrs, projections, or the like, that might damage the bushing.

15.3 Terminals

15.3.1 Terminal parts by which supply connections are made shall comply with the requirements in 15.3.2 – 15.3.7 so as to provide good connections even under hard usage.

15.3.2 A wiring terminal shall be able to hold the next larger size conductor than that required in 15.2.2 if the terminal receives the larger size conductor, unless the equipment is marked in accordance with 73.15.

15.3.3 Soldering lugs or solderless (pressure) wire connectors shall be used. A solderless (pressure) connector intended for connection of a 14 AWG (2.1 mm^2) or smaller copper conductor shall comply with the Torque Test specified in the Standard for Wire Connectors, UL 486A-486B, or the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E, at a tightening torque of not less than 7 pound-inches (0.8 N·m).

Exception No. 1: For a 10 AWG (3.5 mm^2) or smaller wire, the parts to which connections are made may consist of clamps or binding screws with terminal plates having upturned lugs or the equivalent to hold the wires in position.

Exception No. 2: Quick-connect terminals may be used for field wiring connections of a Class 2 circuit, providing:

a) The circuit is not a safety control circuit;

b) A positive engaging detent or the equivalent is provided on the connector; and

c) For each such terminal, a mating connector is furnished together with instructions covering the proper method of installation.

15.3.4 A wire-binding screw used at a wiring terminal shall not be smaller than No. 8 (4.2 mm diameter).

Exception: A 6 (3.5 mm diameter) screw may be used for the connection of one 14, 16, or 18 AWG (2.1, 1.3, or 0.82 mm^2) conductor.

15.3.5 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 not be less than two full threads in the metal.

Exception: A low-voltage transformer may have terminal plates 0.030 inch (0.76 mm) thick for either primary or secondary connections.

15.3.6 A terminal plate formed from stock having the required thickness specified in 15.3.5 may have the metal extruded at a tapped hole for a binding screw so as to provide two full threads.

Exception: Two full threads are not required if fewer threads make a connection in which the threads do not strip when it is subjected to a 20-pound-inch (2.3-N·m) tightening torque.

15.3.7 A wire-binding screw shall not thread into material other than metal.

15.3.8 The surface of an insulated lead intended solely for the connection of an equipment-grounding conductor shall be green with or without one or more yellow stripes, and no other lead in a field-wiring compartment shall be so identified.

15.4 Outlet-box-mounted devices

15.4.1 Wiring terminals and other live parts and sharp-edged grounded or dead metal parts of a device intended for mounting on an outlet box or similar enclosure shall be located or protected so that they will not be forced against wiring in the box during installation.

15.4.2 With reference to the requirements in 15.4.1, back wiring terminals may be employed if they are recessed or are protected by close-fitting barriers of insulating material or the equivalent so that contact with wiring installed in the box will not occur.

15.4.3 Terminals that do not project into a box beyond the plane of the front edge of the box may be used.

15.4.4 With reference to 15.4.2, guards provided alongside terminals and extending at least 1/4 inch (6.4 mm) beyond the terminals before wiring, with a corresponding guard between double-pole switching mechanisms, may be used.

15.4.5 To determine whether a construction other than that described in 15.4.4 is such that wiring in the box cannot be forced against live parts or sharp edges, a trial installation using only ordinary care is to be made on an appropriately sized outlet box, employing both copper and aluminum Type TW wire having ampacities in accordance with the rating of the device. The wire is to extend 6 inches (152 mm) inside the box from its point of entrance into the box.

15.5 Portable equipment

15.5.1 Portable equipment shall be provided with a length of flexible cord and an attachment plug for connection to the supply circuit. The type of cord shall comply with the requirements for the application, and the rating of the plug and the ampacity of the cord shall be as specified in 15.2.2.

15.5.2 The attachment plug shall be of the polarized type if the product is not provided with a grounding type attachment plug. See 19.1.1.

15.5.3 All external connection to the equipment shall be by means of a cord and attachment plug.

15.6 Stationary equipment

15.6.1 In determining the compliance of cord and plug connection for stationary equipment, the decision should include consideration of

a) Whether:

1) The cord connection of the equipment facilitates frequent interchange,

2) Reduction of the transmission of noise or vibration is accomplished,

3) The fastening means or mechanical connections are intended to permit removal for maintenance and repair, or

4) All external connections to the equipment are by means of cord and attachment plug, and

b) Whether the equipment is to be connected at the end of the run.

15.6.2 The cord on stationary equipment shall be Type SJ or an equivalent hard-usage cord, not more than 3 feet (914 mm) long, directly connected to the equipment and terminate in an attachment plug. The rating of the plug and the ampacity of the cord shall be as specified in 15.2.2.

15.7 Polarity

15.7.1 Equipment permanently connected electrically and intended to be connected to a supply circuit rated at 125 or 125/250 volts or less and using an Edison screw-shell lampholder or a single-pole switch or overcurrent-protective device other than an automatic control, shall have one terminal or lead identified for connection to the grounded conductor of the supply circuit.

15.7.2 A terminal, lead, or a blade of an attachment plug identified for connection to the grounded supply conductor shall be electrically connected to the screw shell of a lampholder, if provided, and shall not be connected to a single-pole switch or a single-pole overcurrent-protective device.

15.8 Strain relief

15.8.1 Strain relief shall be provided so that mechanical stress on a flexible supply cord will not be transmitted to terminals, splices, or interior wiring.

15.8.2 A strain-relief device shall be subjected to the test described in 57.1.1.

15.8.3 A surface against which a knot in a flexible cord that serves as strain relief may bear or which it may contact shall be free from:

a) Projections,

b) Sharp edges,

c) Burrs,

d) Fins, and

e) Similar features

that may abrade the insulation or conductors.

15.9 Bushings

15.9.1 Where a flexible cord passes or is intended to pass through an opening in a wall, barrier, or enclosing case, there shall be a substantial bushing or the equivalent that is reliably secured in place, and has a smoothly rounded surface against which the cord may bear. An insulating bushing shall be provided for a cord lighter than Type SJ that passes through a wall or barrier of metal if the construction is such that the cord may be subjected to stress or motion.

15.9.2 A cord hole with a smoothly rounded surface through wood, porcelain, phenolic composition, or other acceptable nonconductive material, is considered to be the equivalent of a bushing.

15.9.3 Ceramic materials and some molded compositions may be used for insulating bushings, but a separate bushing of wood or so-called hot-molded shellac and tar composition shall not be used.

15.9.4 A fiber bushing shall not be less than 3/64 inch (1.2 mm) thick, shall be formed and secured in place so that it will not be adversely affected by conditions of ordinary moisture, and shall not be used where it will be subjected to a temperature higher than 90°C (194°F) under normal operating conditions.

15.9.5 A soft-rubber bushing shall not be less than 3/64 inch (1.2 mm) thick and shall be located so that it will not be exposed to oil, grease, oily vapor, or other substance having a deleterious effect on rubber. Such a bushing may be used only in the frame of a motor or for a cord connected to a supply circuit of limited voltage and power. A hole in metal in which a soft-rubber bushing is used shall be free from sharp edges, burrs, projections, and the like, that may cut into the rubber.

15.9.6 Insulating material in an insulated metal grommet used in lieu of an insulating bushing shall not be less than 1/32 inch (0.8 mm) thick and shall completely fill the space between the grommet and the metal in which it is mounted.

16 Current-Carrying Parts

16.1 A current-carrying part shall have the necessary mechanical strength and ampacity for the service, and shall be of metal that complies with the requirements for the application.

16.2 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 is prevented from turning or shifting in position if such motion may result in reduction of spacings to less than those required by this standard. The security of a contact assembly shall provide for the continued alignment of contacts.

Exception: A pressure terminal connector need not be prevented from turning provided spacings not less than those required result when the terminals are turned 30 degrees toward each other, toward other uninsulated parts of opposite polarity, or toward grounded metal parts.

17 Switches

17.1 A switch provided as part of a product intended to be connected to a power-supply circuit having a potential to ground of more than 150 volts shall be rated for the maximum potential to ground of the circuit.

17.2 A nominal 208-volt, single or 3-phase or a 120/240-volt, single-phase product is considered to involve a potential to ground of less than 150 volts. A 2-wire, single-phase or a 3-wire, 3-phase product with a rating in the range of 220 – 240 volts is considered to involve a potential to ground in excess of 150 volts, unless it is marked in accordance with 75.10 or 75.11.

18 Internal Wiring

18.1 General

18.1.1 The internal wiring of the equipment shall consist of general-use wire or appliance wiring material that complies with the requirements for the application, when considered with regard to the temperature, voltage, and conditions of service to which the wiring is likely to be subjected.

18.1.2 All wiring harnesses, barriers, and channels shall be V-2 or less flammable. For the purposes of this requirement PVC, TFE, PTFE, FEP, and neoprene insulations on wiring are to be considered V-1.

18.1.3 Individual clamps, barriers, and channels, including helical wraps or other continuous forms, lacing tape, twine, and cable ties shall be HB or less flammable.

18.1.4 Appliance wiring material of one or more of the types specified in Table 18.1 may be used for internal wiring when considered with regard to the requirements in 18.1.1.

Table 18.1
Appliance-wiring material

Type of insulation	Nominal thickness of insulation, inch (mm)[a]	
	600-volt applications	300-volt applications
Thermoplastic	1/32 (0.8)	1/32[b,c]
Rubber	1/32 plus an impregnated-braid cover	1/64 (0.4) plus impregnated-braid cover
		1/32 without a braid cover
Neoprene	3/64 (1.2)	1/64 plus an impregnated-braid cover
		1/32 without a braid cover
Silicone Rubber	1/32 plus an impregnated-braid cover	1/64 plus an impregnated-braid cover
	1/32 without a braid cover[d]	1/32 without a braid cover[d]
Cross-linked synthetic polymer	1/64	1/64

[a] The minimum thickness is 0.028 inch (0.71 mm) for 1/32-inch-thick insulation; the minimum thickness is 0.013 inch (0.33 mm) for 1/64-inch-thick insulation.

[b] May be not less than 0.013 inch (0.33 mm) only for short, moving pigtails or coil leads in a small device, provided such leads make no more than casual contact with parts of opposite polarity and with ungrounded parts.

Table 18.1 Continued on Next Page

Table 18.1 Continued

Type of insulation	Nominal thickness of insulation, inch (mm)[a]	
	600-volt applications	300-volt applications
[c] May be not less than 0.007 inch (0.18 mm) only if routed away from live parts of opposite polarity and protected from mechanical damage both during installation of field wiring and while the equipment is in operation.		
[d] Only if routed away from live parts of opposite polarity and protected from mechanical damage both during installation of field wiring and while the equipment is in operation.		

18.1.5 Appliance wiring material having an insulation thickness other than those specified in Table 18.1 may be used provided the insulation, when considered with regard to temperature, voltage, and conditions of service, is equivalent to one of those specified in Table 18.1.

18.1.6 Line-voltage and secondary wiring in other than a limited energy circuit shall be 18 AWG (0.82 mm^2) or larger except for short integral leads of small electrical components, such as relay coils and clock motors. See Overcurrent Protection, Control-Circuit Conductors, Section 26.

18.1.7 The effects of vibration, impact, and exposure are to be considered for wires smaller than 404 circular mils or 0.205 square mm in cross-sectional area (24 AWG).

18.1.8 Wiring that extends from the cabinet to a hinged door or other part that is subject to movement in use other than installation and servicing, shall be stranded and the arrangement shall preclude twisting or stressing of conductors as a result of the movement. The wiring shall be routed or protected to reduce the risk of damage to the insulation. The conductors shall be of a jacketed type, such as Type SJ, SJO, or SJT and shall be provided with strain relief so that stress will not be transmitted to terminals or splices.

18.1.9 Wiring of a type other than those mentioned in 18.1.8 that is subject to motion, and any supplementary insulation provided on the wire, may be subjected to a flexing test to determine the acceptability for the application. See 57.2.1.

18.1.10 Impregnated or unimpregnated cotton- or asbestos-insulated wire shall not be used.

18.1.11 Metal clamps and guides used for routing stationary internal wiring shall be provided with smooth rounded edges.

18.1.12 Auxiliary mechanical protection that is not electrically conductive shall be provided:

a) Under a clamp at which pressure is exerted on a conductor having thermoplastic insulation less than 0.030 inch (0.76 mm) thick and no overall braid and

b) On any wire or wires that are subject to motion.

18.1.13 All internal wiring shall be of a flame-retardant type. Neoprene- and thermoplastic-insulated wiring are considered to be of such a type.

18.1.14 If the use of a short length of insulated conductor is not feasible – for example, a short coil lead or the like– electrical insulating tubing may be used.

18.1.15 Tubing shall not be subjected to sharp bends, tension, compression, or repeated flexing, and shall not contact sharp edges, projections, or corners. Tubing may be used in dry or damp locations but shall not be used in wet locations.

18.1.16 The wall thickness of electrical insulating tubing shall comply with the requirements for such tubing, except that the thickness at any point for the smaller sizes of polyvinyl chloride tubing shall not be

less than 0.017 inch (0.43 mm). Insulating tubing of other types shall have a wall thickness not less than that providing mechanical strength, dielectric properties, heat- and moisture-resistant characteristics, and the like, at least equal to those of 0.017-inch-thick polyvinyl chloride tubing.

Exception: Tubing having a thickness less than that specified may be used provided it is routed away from live parts of opposite polarity and protected from mechanical damage during installation of field wiring, user servicing, and while the equipment is in operation.

18.1.17 Rubber-insulated conductors shall not be exposed to oil, grease, oily vapor, or other substance having a deleterious effect on rubber, unless the insulation has been investigated and found to comply with the requirements for the application.

18.1.18 A wireway shall be smooth and free from sharp edges, burrs, fins, moving parts, and the like, that may abrade insulation on conductors.

18.1.19 Mounting screws and nuts shall be constructed or located so that sharp edges will not damage wiring. A screw shall have a flat or blunt end. The end of a screw shall have no burrs, fins, or sharp edges that might abrade wire insulation, and shall not project more than 3/16 inch (4.8 mm) into a wireway.

18.1.20 A hole in a sheet-metal wall through which insulated wires pass and on which they may bear shall be provided with a smoothly rounded bushing or shall have smooth, rounded surfaces upon which the wires may bear, to avoid abrasion of insulation.

18.1.21 A bushing used over other than smooth, rounded surfaces of a hole through which wires pass shall be of material that has mechanical and heat-resistant properties acceptable for the application, such as porcelain, phenolic, fiber at least 3/64 inch (1.2 mm) thick, or smooth, rounded metal. A soft-rubber bushing or the like shall not be used for other than low-voltage wiring – see 15.2.13 – unless the material has been evaluated and found to comply with the requirements for the purpose.

18.1.22 Insulated wires that are entirely enclosed within metal walls may be bunched and passed through a single opening.

18.1.23 A short length of rubber-insulated flexible cord may be exposed to a temperature in excess of the normal maximum allowable temperature for the compound involved in a location such as at a terminal if supplementary heat-resistant insulation of appropriate dielectric properties is used on individual conductors of the cord to reduce the risk of deterioration of the rubber. In any case, rubber insulation shall be of a type normally available that has a temperature limit as close as possible to or higher than the temperature involved.

18.1.24 A joint or connection shall be mechanically secure and shall provide reliable electrical contact without stress on a connection or a terminal.

18.1.25 A soldered connection shall be made mechanically secure before being soldered.

Exception: A connection need not be mechanically secured before soldering if:

a) A soldering or brazing material having a softening or melting point greater than 454°C (849°F) is used;

b) A hand-soldered lead is passed through a hole in a printed wiring board and bent 90 degrees to the board to make contact with the conductor before soldering;

c) Soldering on a printed wiring board is done by a machine process in which the soldering time and solder temperature are automatically controlled – bending over of leads is not required; or

d) The lead wire is strapped in place, or the equivalent, adjacent to the soldered connection so as to hold the lead end in place.

18.1.26 A joint shall be provided with insulation equivalent to that on the wires involved if permanence of spacing between the joint and uninsulated live parts of opposite polarity or grounded dead metal parts may not be maintained.

18.1.27 A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch wide quick-connect terminal shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310. Other sizes of quick-connect terminals shall be investigated with regard to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rises; all tests are to be conducted in accordance with UL 310.

18.2 Interconnecting cords and cables

18.2.1 Cable assemblies and flexible cords used for external interconnection between sections of a unit or between units of a system shall be of a type that comply with the requirements for the service use involved and shall be provided with bushings and strain relief in accordance with 15.8.1 – 15.9.6.

Exception: Cable assemblies used in nonsafety Class 2 circuits need not comply with 15.8.1 – 15.9.6.

18.2.2 A cable external to the equipment and supplied by the manufacturer for connection in a low-voltage Class 2 circuit shall comply with the requirements for the intended application as specified in Article 725 of the National Electrical Code, ANSI/NFPA 70.

18.2.3 Inserting a male connector in a female connector other than the one intended to receive it, misalignment of male and female connectors, and other manipulations of parts that are accessible to the operator shall not result in a risk of:

a) Fire,

b) Electric shock, or

c) Injury to persons.

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

18.2.5 To comply with the requirement in 18.2.4, an interlock circuit may be provided in the cable to de-energize the exposed contacts whenever an end of the cable is disconnected. If an interlock is not provided, compliance is to be determined by means of the procedure in 18.2.6.

18.2.6 While the interconnected units are operating normally, the cable connectors mentioned in 18.2.4 are to be disengaged from their receptacles one at a time. The open-circuit voltages are to be measured between each of the exposed contacts and earth-grounded metal. A 1500-ohm resistance is to be connected between each of the exposed contacts and earth-grounded metal, and the current – not to exceed 5 milliamperes – through the resistor is to be measured in each position.

18.3 Interconnection of units

18.3.1 Unless cable assemblies are provided, each unit in an energy management system shall be provided with field-wiring terminals (see 15.3.1 – 15.3.8) to facilitate interconnection by means of permanently installed wiring.

18.3.2 Units of an energy management system that are intended to be combined in field installations to form overall unified enclosures (modular constructions) may be used if the constructions provide complete enclosures or the equivalent that facilitate the routing or interconnecting cables or other wiring from one unit of the system to another. Such constructions shall provide substantially complete enclosures for all wiring.

18.3.3 If interconnection of units of a system involves Class 2 circuits, the Class 2 circuits may be terminated in field-wiring connections other than specified in 18.3.1, such as wire-wrap or crimp-on types, if the Class 2 circuits are permanently separated from all other circuits and if the mating parts and instructions for their method of attachment are provided.

19 Grounding

19.1 General

19.1.1 There shall be provision for grounding all dead metal parts of the following equipment that are exposed or that are likely to be touched by a person during normal operation or adjustment and that are likely to become energized through electrical malfunction:

a) Stationary equipment or equipment intended to be permanently connected electrically.

b) Equipment that is required to be grounded.

c) Portable equipment for use on a circuit involving a potential of more than 150 volts to ground.

d) Equipment provided with a grounding means, whether required or not.

19.1.2 To determine whether a part is likely to become energized, the following factors are to be evaluated:

a) Construction;

b) Proximity of wiring;

c) A dielectric voltage-withstand test conducted after the appropriate overload;

d) An endurance test; and

e) A burnout test.

19.2 Grounding means

19.2.1 An equipment-grounding terminal or lead-grounding point shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection.

19.2.2 A grounding connection shall reliably penetrate a nonconductive coating, such as paint or vitreous enamel.

19.2.3 A grounding point shall be located so that it is unlikely that the grounding means will be removed during normal servicing.

19.2.4 The following means may be used for grounding fixed equipment that is to be permanently connected electrically.

a) An equipment-grounding terminal or lead in:

1) A control intended for use in a residence,

2) A device intended to be connected to a nonmetal-enclosed wiring system; for example, a nonmetallic-sheathed cable, or

3) A device intended to be grounded by an isolated ground and intended to be connected to a metal-enclosed wiring system.

b) A knockout or equivalent opening in a metal enclosure of a nonresidential control intended to be connected to a metal-enclosed wiring system.

19.3 Terminals and leads

19.3.1 A wire-binding screw intended to connect an equipment-grounding conductor shall have a green-colored head that is hexagonal, slotted, or both.

19.3.2 A wire-binding screw or pressure wire connector intended to connect an equipment-grounding conductor shall be located so that it is unlikely to be removed during servicing.

19.3.3 A terminal for connection of an equipment-grounding conductor shall be capable of securing a conductor of the required size and shall be constructed as specified in 15.3.1– 15.3.5.

19.3.4 A grounding terminal for a 10 AWG (5.3 mm^2) or smaller wire may be a threaded stud welded to the enclosure or the equivalent. Such a terminal shall be of acceptable material, for example, it shall be plated if of steel; and shall also comply with 15.3.1 – 15.3.5 and 19.3.1 – 19.3.3.

19.3.5 A soldering lug, a push-in (screwless) connector, or a quick-connect or similar friction-fit connector shall not be used for a grounding terminal.

19.3.6 A lead intended for connection to an equipment-grounding conductor shall be of the size specified in 20.2.8, and shall have a free length of 6 inches (152 mm) or more.

19.3.7 The surface of an insulated lead intended solely to connect an equipment-grounding conductor shall be green with or without one or more yellow stripes, and no other lead visible in a field wiring compartment to the installer shall be so identified.

19.3.8 The color coding requirement in 19.3.7 does not apply to a low-voltage nonsafety circuit under the following conditions:

a) Leads or wiring to low-voltage terminals are remote from the location where the line-voltage connections are made and connectors and live parts are segregated in accordance with 33.7 and 33.8; or

b) Leads or low-voltage terminals are specifically marked with the intended use, such as "Thermostat," so that reference to a wiring diagram is not necessary.

19.3.9 The free end of an equipment-grounding conductor shall be insulated – for example, shall have the end folded back and taped to the lead – unless the conductor is located so that it cannot contact live parts in the event that the conductor is not used in the field.

19.3.10 A multiple-conductor cord with a grounding conductor connected to the frame or enclosure may be used as the grounding means for all cord-connected equipment. The line fitting of such a cord shall have a fixed contacting member for grounding.

19.3.11 The surface of an insulated grounding conductor of a flexible cord shall be green with or without one or more yellow stripes and no other lead shall be so identified.

19.3.12 The grounding conductor of a power-supply cord shall be attached to the grounding blade of an attachment plug and shall be connected within the frame or enclosure by means of a screw not likely to be removed during ordinary servicing not involving the power-supply cord. A grounding conductor shall be arranged so that an external pull on a power-supply cord will not transmit stress to the grounding connection on a frame or enclosure before line-voltage connections are broken.

19.3.13 Circuitry shall be arranged so that an equipment-grounding connection or conductor, an enclosure, a frame, a component mounting panel, and earth ground do not carry current except in the event of an electrical fault.

Exception: A single-point reference ground may be used in a low-voltage or isolated-limited-secondary circuit. An enclosure, frame, or panel, including bolted joints, may carry the current of a low-voltage circuit. Such current shall not be carried by a field-equipment grounding means, a metallic raceway or other power-supply grounding means, or earth ground in either case.

19.3.14 The grounded-circuit conductor shall not be grounded at or in conjunction with the equipment.

20 Bonding of Internal Parts

20.1 General

20.1.1 On equipment that is grounded, an exposed noncurrent-carrying metal part that is likely to become energized through electrical fault – see 19.1.2 – shall be reliably bonded to the point of connection of the field-equipment grounding means.

Exception No. 1: A metal part, such as an adhesive-attached metal-foil marking, a screw, or a handle that is:

a) Located on the outside of an enclosure or cabinet and isolated from electrical components and wiring by grounded metal parts so that it is not likely to become energized, or

b) Separated from wiring and spaced from uninsulated live parts as if it were a grounded part.

Exception No. 2: A small internal assembly screw, or other small fastener, such as a rivet, a handle for a pull-out disconnect switch, or a magnet or armature of a relay or contactor.

Exception No. 3: A metal panel or cover that:

a) Is insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or other moisture-resistant material not less than 1/32 inch (0.8 mm) thick and reliably secured in place;

b) Does not enclose uninsulated live parts, and wiring is positively separated from the panel or cover so that it is not likely to become energized; or

c) Is isolated from live parts and wiring by grounded or bonded interposing metal so that the interposing metal would be subject to an electrical fault before the isolated metal panel or cover.

20.1.2 A guard, baffle, or cover that can be removed without a tool is to be removed when determining whether a part is exposed to contact by the user. A part that can be contacted by a 3/8-inch (9.5-mm) diameter rod having a hemispherical end inserted through an opening in a permanently attached guard or baffle for a distance of 4 inches (102 mm) is considered exposed for the purposes of grounding.

Exception: A snap-on cover that complies with the requirements in the Cover Retention Test, Section 62, need not be removed.

20.1.3 Uninsulated metal parts, such as:

a) Cabinets;

b) Electrical enclosures and covers;

c) Motor frames and mounting brackets;

d) Controller mounting frames and brackets;

e) Capacitors and other electrical components;

f) Interconnecting tubing and piping;

g) Valves; and

h) Pneumatic accessories

shall be electrically bonded together if they may be contacted by a user or serviceperson. See 20.1.5 and Exceptions to 20.1.1 for parts to which this requirement does not apply.

20.1.4 Operations and adjustments that subject parts to contact by a user include actions taken at the time of installation and during normal use, such as seasonal adjustments, relamping, replacing fuses, resetting overload devices, and oiling motors. These procedures and those specified in Protection of Users and Service Personnel, Section 39, subject parts to contact by a serviceperson.

20.1.5 A part on the back side of a component mounting panel and a part located so as to require major disassembly by using tools are not considered to be exposed to the user; such parts are not considered to be exposed to a serviceperson unless it is likely that servicing will be performed while the equipment is energized after disassembly.

20.1.6 Uninsulated live parts and wiring shall be held away from moving parts, such as relay and contactor magnets and armatures, by clamping, routing, or equivalent means that will provide permanent separation.

20.1.7 If a component is likely to be separated from its grounding means after installation for the purposes of testing or adjustment while the equipment is energized, it shall be provided with a bonding terminal or with a bonding conductor so that it is not necessary to remove it from the component for such service.

20.2 Construction and connection

20.2.1 Parts shall be bonded by metal-to-metal contact or by a separate bonding jumper in accordance with 20.2.2 – 20.2.9.

20.2.2 A separate bonding conductor shall be:

a) Copper,

b) A copper alloy, or

c) Other material that may be used as an electrical conductor.

20.2.3 A ferrous metal part in a grounding path shall be protected against corrosion by:

a) Enameling,

b) Galvanizing,

c) Plating, or

d) Other equivalent means.

20.2.4 A separate bonding conductor or strap shall:

a) Be protected from mechanical damage or shall be located within an 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.

20.2.5 The ends of a bonding conductor shall be in metal-to-metal contact with the parts to be bonded.

20.2.6 A wire used for bonding purposes shall not be spliced.

20.2.7 An internal connection for bonding internal parts to an enclosure for grounding, but not for a field-installed grounding conductor or for the grounding wire in a supply cord, may use a quick-connect terminal provided:

a) The connector is not likely to be displaced;

b) The terminal has the dimensions specified in Table 20.1; and

c) The component is limited to use on a circuit having a branch-circuit protective device as specified in Table 20.1.

Table 20.1
Quick-connect terminals for grounding internal parts

Nominal size of terminal						Rating of branch-circuit protective device, amperes
Width,		Thickness,		Length,		
inch	(mm)	inch	(mm)	inch	(mm)	
0.187	(4.7)	0.020	(0.5)	1/4	(6.35)	20 or less
0.187	(4.7)	0.032	(0.8)	1/4	(6.35)	20 or less
0.205	(5.2)	0.032	(0.8)	1/4	(6.35)	20 or less
0.250	(6.4)	0.032	(0.8)	5/16	(8.00)	60 or less

20.2.8 A separate component-bonding conductor shall not be smaller than:

a) That specified in Table 20.2,

b) The conductor supplying the motor or component, whichever is the smaller, or

the bonding conductor shall comply with the performance requirements in the Bonding Conductor Tests, Section 63.

Table 20.2
Bonding conductor size

Rating or setting of automatic overcurrent device in circuit ahead of equipment, conduit, and the like, not exceeding, amperes	Minimum size of bonding conductor[a]					
	Copper wire,		Aluminum wire,		Rigid conduit or pipe, inch	Electrical metallic tubing, inches
	AWG	(mm^2)	AWG or kcmil	(mm^2)		
20[b]	12	(3.3)	10	(5.3)	1/2	1/2
30	10	(5.3)	8	(8.4)	1/2	1/2
40	10	(5.3)	8	(8.4)	1/2	1/2
60	10	(5.3)	8	(8.4)	1/2	1/2
100	8	(8.4)	6	(13.3)	1/2	1/2
200	6	(13.3)	4	(21.2)	1/2	1
400	3	(26.7)	1	(42.4)	3/4	1-1/4
600	1	(42.4)	00	(67.4)	3/4	1-1/4
800	0	(53.5)	000	(85.0)	1	2
1000	00	(67.4)	0000	(107.0)	1	2
1200	000	(85.0)	250	(127.0)	1	2

[a] Or equivalent cross-sectional area.

[b] For a cord-connected device, the grounding wire in the cord may be the same size as the current-carrying conductors.

20.2.9 If more than one size of branch-circuit overcurrent device is involved, the size of the bonding conductor is to be based on the rating of the overcurrent device intended to provide ground-fault protection for the component bonded by the conductor. For example, if a motor is individually protected by a branch-circuit overcurrent device smaller than other overcurrent devices used with the equipment, a bonding conductor for that motor is to be sized on the basis of the overcurrent device intended for ground-fault protection of the motor.

21 Motors

21.1 A motor shall comply with the requirements in the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1, and shall be capable of delivering its maximum normal load without introducing a risk of fire, electric shock, or injury to persons.

21.2 A motor shall incorporate overload protection and locked-rotor protection.

Exception: A motor intended to move air only by means of an air-moving fan that is integrally attached, keyed, or otherwise fixed to the motor shaft is not required to have overload protection.

21.3 The protection required by 21.2 shall consist of one of the following:

a) Thermal protection complying with the applicable requirements in the Standard for Overheating Protection for Motors, UL 2111.

b) Impedance protection complying with UL 2111.

c) Other protection that tests show is equivalent to the protection mentioned in (a).

22 Printed Wiring Boards

22.1 A printed-wiring board shall comply with the requirements in the Standard for Printed-Wiring Boards, UL 796.

Exception: A printed-wiring board in a nonsafety Class 2 circuit need not comply with the bonding requirements in UL 796 if it is separated from parts of other circuits so that loosening of the bond between the foil conductor and the base material does not result in the foil conductor contacting part of other circuits.

22.2 A printed-wiring board shall be classified at least V-2 as specified in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

22.3 A plastic coating used on the surface of a printed-wiring board and intended to be used because of reduced spacings as described in 29.2.4 – 29.2.6 shall comply with the requirements for the application by being investigated on the printed-wiring board material in accordance with the Standard for Polymeric Materials– Long Term Property Evaluations, UL 746B. A conformal coating shall also be subject to an investigation.

23 Transformers

23.1 A transformer that supplies a low-voltage circuit shall be of the two-coil or isolated type.

23.2 A transformer shall comply with the performance requirements outlined in this standard, including the Temperature and Dielectric Voltage-Withstand Tests.

24 Capacitors

24.1 General

24.1.1 A capacitor shall use such materials and shall be constructed so that it will not constitute a risk of fire. It shall not be adversely affected by the temperature it reaches under the most severe conditions of use.

24.1.2 A paper capacitor shall be impregnated or enclosed to exclude moisture.

24.1.3 An electrolytic capacitor and a capacitor intended for connection directly across the line shall comply with the requirements for the application.

24.1.4 Under both normal and abnormal conditions of use, a capacitor employing a liquid dielectric medium more combustible than askarel shall not result in a risk of fire or electric shock; and shall be constructed to reduce the risk of expelling the dielectric medium.

24.1.5 A capacitor complying with the requirements for protected oil-filled capacitors in the Standard for Capacitors, UL 810, is considered to be protected against the expulsion of the dielectric medium.

24.2 Signal coupling capacitors

24.2.1 A signal coupling or blocking capacitor shall comply with the requirements for line-bypass and antenna coupling capacitors if failure of the capacitor can result in a risk of fire, electric shock, or injury to persons.

Exception: A capacitor shall not be considered subject to fault if all of the following conditions are met:

a) The capacitor is of a type not likely to develop an internal short circuit, such as a hermetically sealed or ceramic capacitor. An electrolytic or tantalum capacitor is not considered to be of this type.

b) Two such capacitors are connected in series.

c) At least one-half of the spacing required between the two circuits is provided between the bare live parts of each of the capacitors.

d) Each capacitor is rated to withstand for 1 minute an alternating test voltage of twice the maximum circuit voltage plus 1000 volts rms.

e) Each capacitor can limit the current from one circuit to the other to less than 0.5 milliamperes if the parts of one of the circuits are accessible to a user or operator, and 5.0 milliamperes if the parts of the circuit are accessible to a service person only.

25 Fuseholders

25.1 A fuseholder shall be of either the cartridge-enclosed or plug-fuse type.

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

26 Overcurrent Protection, Control-Circuit Conductors

26.1 A conductor of a control circuit that is connected to the load side of the branch-circuit short-circuit protective device – common control – shall be protected against overcurrent in accordance with Table 26.1 by a protective device located within the controller. See 26.2 and 26.4.

Exception No. 1: If the rating or setting of the intended branch-circuit short-circuit protective device is not more than the applicable value specified in Table 26.2, and the equipment is marked in accordance with 72.15, additional protection is not required.

Exception No. 2: A limited-energy control circuit, such as a Class 2 circuit need not be so protected.

Exception No. 3: A control-circuit conductor that is the same size as or larger than the main circuit conductors need not be protected.

Table 26.1
Protective devices

Control-circuit wire size, AWG	Control-circuit wire size, (mm^2)	Maximum rating of protective device, amperes
22	(0.32)	6
20	(0.52)	10
18	(0.82)	20
16	(1.3)	20
14	(2.1)	20
12	(3.3)	25

Table 26.2
Branch-circuit protective devices

Control-circuit wire size,		Maximum rating of branch-circuit protective device, amperes	
AWG	(mm^2)	Conductors remaining within enclosure	Conductors going outside enclosure
22	(0.32)	12	9
20	(0.52)	20	15
18	(0.82)	25	20
16	(1.3)	40	20
14	(2.1)	80	45
12	(3.3)	100	60

26.2 The protective device specified in 26.1 shall be either a supplementary or a branch-circuit overcurrent-protective device. A fuse shall be factory installed in a supplementary fuseholder but may be omitted if a branch-circuit-type fuseholder is provided. The equipment shall be marked in accordance with 72.16.

26.3 Internal conductors of control circuits that are connected to a remote source of supply – not a common control – shall be provided with overcurrent protection in accordance with Table 26.2 or the device shall be marked in accordance with 72.17. The internal conductors shall not be smaller than 20 AWG (0.52 mm^2).

26.4 With reference to 26.1 and 26.3:

a) A short, direct lead – generally 12 inches (305 mm) long, such as transformer leads or a printed-wiring assembly having no connection external to the controller – need not be so protected.

b) A short, direct lead from a contact of a switching device, or the like, for connection within the enclosure to field wiring need not be protected in addition to the remote protective device that will be provided for the field wiring. See 15.2.6.

c) A lead or a strap or bus that withstands the applicable short-circuit test in accordance with the requirements in the Conductor Short-Circuit Test, Section 56, need not be so protected.

26.5 A control-circuit transformer shall be protected by an overcurrent device in each secondary circuit. The device shall be rated or set at not more than 200 percent of the rated secondary current of the transformer.

Exception No. 1: A transformer protected by other means in accordance with the National Electrical Code, ANSI/NFPA 70, need not be so protected.

Exception No. 2: A limited-energy transformer, such as a Class 2 transformer, need not be so protected.

27 Overload Relays, Thermal Protectors for Motors, and Impedance-Protected Motors

27.1 Overload relays, thermal protectors for motors, and impedance-protected motors are to be examined and tested in accordance with the requirements for such devices.

28 Coil Windings

28.1 A coil winding shall resist the absorption of moisture. This may be accomplished by:

a) Impregnating,

b) Dipping in or brushing with varnish, or

c) Other equivalent means.

Exception: Film-coated wire need not be additionally treated to resist moisture absorption.

29 Spacings

29.1 General

29.1.1 Other than as provided in Clearances and Creepage Distances, Section 30, the spacings in energy management equipment shall not be less than the applicable values specified in Table 29.1.

Table 29.1
Spacings for non-surge controlled circuits in a general environment

Potential involved in volts rms (peak)		Minimum spacing, inch (mm)						
		Equipment with a volt ampere rating that is not limited				Equipment having a limited volt ampere rating (see 29.2.2 and 29.2.3)		
		A. General equipment				B. Industrial and commercial		C. Residential[a]
		0 – 50 (0 – 70.7)	51 – 150 (72.1 – 212.1)	151 – 300 (213.5 – 424.3)	301 – 600 (425 – 848.5)	51 – 300 (72.1 – 424.3)	301 – 600 (425.7 – 848.5)	51 – 300 (72.1– 424.3)
Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[c,d]	Through air or oil	1/16[b](1.6)[b]	1/8[b](3.2)[b]	1/4 (6.4)	3/8 (9.6)	1/16[b] (1.6)[b]	3/16[b] (4.8)[b]	1/16[b](1.6)[b]
	Over Surface	1/16[b](1.6)[b]	1/4 (6.4)	3/8 (9.6)	1/2 (12.7)	1/8[b] (3.2)[b]	3/8 (9.6)	1/16[b] (1.6)[b]
Between any uninsulated live part and the walls of a metal enclosure including fittings for conduit or armored cable[e]	Shortest distance	1/4 (6.4)	1/2 (12.7)	1/2 (12.7)	1/2 (12.7)	1/4 (6.4)	1/2 (12.7)	1/4 (6.4)

[a] Equipment having spacings indicated in column C shall be marked in accordance with 72.9.

[b] The spacing between field-wiring terminals of opposite polarity and the spacing between a wiring terminal and a grounded dead metal part shall not be less than 1/4 inch (6.4 mm) if short-circuiting or grounding of such terminals results from projecting strands of wire.

[c] In a safety circuit the spacing between wiring terminals, regardless of polarity, and the spacing between a wiring terminal and a grounded dead metal part – including the enclosure – shall not be less than 1/4 inch.

[d] In a safety circuit the spacing between same polarity live parts on opposite sides of a switching mechanism, except at contact point, shall not be less than 1/32 inch (0.8 mm) through air and 1/16 inch over surface.

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

29.1.2 A live screw head or nut on the underside of a base shall be countersunk not less than 1/8 inch (3.2 mm) in the clear, and covered with a waterproof, insulating, sealing compound that will not melt at a temperature 15°C (27°F) higher than the normal operating temperature of the device, but not less than 65°C (149°F).

Exception: If such a part is staked, upset, or otherwise reliably secured, it need not be recessed, and may be insulated from the mounting surface by material other than sealing compound or by the provision of spacings through air and over surface as required in this standard.

29.1.3 A spacing at a wiring terminal is to be measured with appropriate wires connected to the terminals as in actual service.

29.1.4 The required spacing applies only to the sum of the spacings involved wherever an isolated dead metal part is interposed.

29.1.5 For the purpose of these requirements, the voltage and volt-ampere ratings are those measured with the equipment connected to a supply circuit as specified in Table 40.1.

29.1.6 Uninsulated live parts connected to different circuits shall be spaced from each other as if they were parts of opposite polarity, in accordance with the requirement in 29.2.1, and shall be evaluated on the basis of the highest voltage involved.

29.1.7 Safety circuits, such as interlock circuits, shall be evaluated as primary circuits with regard to spacings. Primary circuit spacings shall also apply to inherent spacings in component devices in such circuits.

Exception: Spacings between parts of the same polarity specified in footnote (a) to Table 29.1 do not apply to the protective component of a power source.

29.1.8 Opposite polarity spacings are not specified for a circuit beyond an impedance that limits the product of the current through and the voltage across this impedance to a value not exceeding

a) The wattage rating of the impedance, and

b) 15 watts, when a direct short is applied across the remainder of the circuit.

29.2 Line-voltage circuits

29.2.1 Unless otherwise noted and as provided in Clearances and Creepage Distances, Section 30, spacings shall not be less than those specified in Table 29.1. Greater spacings are required in an enclosure that because of its size, shape, or the material used, is not sufficiently rigid to maintain the minimum spacings.

29.2.2 The spacings specified in columns B and C of Table 29.1 are applicable to equipment or circuits rated 2000 volt-amperes or less. Those spacings are also applicable to equipment or circuits rated not more than 15 amperes at 51 – 150 volts, 10 amperes at 151 – 300 volts, or 5 amperes at 301 – 600 volts.

29.2.3 With reference to the requirements in 29.2.2, the spacings applicable to a device of the type described apply also to that device when controlling more than one load provided the total load connected to the line at one time does not exceed 2 horsepower (1492 watt output), 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.

29.2.4 To determine if the equipment is within the rating limitation specified in 29.2.2 and 29.2.3, the output rating of the equipment is to be added to the rating of the load that the equipment is intended to

control. The sum of the inputs to and the switch ratings of the equipment is the rating. This applies to equipment that does not contain a number of individual components as mentioned in 29.2.6, and also to individual components evaluated in accordance with that paragraph.

29.2.5 The volt-ampere equivalent of a horsepower rating is the product of the voltage and the full-load current as specified in Table 49.2 and Table 49.3 and for a polyphase device, the appropriate numerical multiplier.

29.2.6 In multicomponent equipment, spacings from one component to another, and from a component to the enclosure and to other uninsulated dead metal parts excluding the component mounting surface are based on the maximum voltage and total volt-ampere rating of the complete equipment; not on the individual component ratings. Spacings inherent in an individual component, such as a relay or a temperature controller, including spacings from a live part to a mounting surface other than the enclosure, are to be evaluated on the basis of the volt-amperes used and controlled by the individual component.

29.2.7 For a multipole, a double-throw, or a sequencing device or the like, the volt-ampere rating is the maximum sum of the consumption of the device and the simultaneously controlled load.

29.2.8 Where required in place of spacings between a magnet-coil winding and other uninsulated live parts or grounded dead metal parts, the type of insulation may differ from that required by 29.2.12. The type and thickness of crossover-lead insulation and insulation under coil terminals secured to the coil winding may be less than that specified in 29.2.12, if the coil withstands a dielectric voltage-withstand test between coil-end leads after the inner coil lead has been broken where it enters the layer, or an equivalent opposite polarity test as specified in 52.3.1 – 52.3.3. The test potential is to be applied in accordance with 52.1.1 – 52.1.5.

29.2.9 Spacings inherent in a component, such as a snap switch, a lampholder, a motor, or a clock motor, are evaluated under the requirements for the component. Spacings from such a component to another component and to the enclosure, and spacings at wiring terminals shall comply with the requirements in 29.2.1 and Table 29.1.

29.2.10 Spacings at a fuse and fuseholder are to be measured with a fuse that has the maximum standard dimensions for the rating in place and shall not be less than those specified in column B of Table 29.1.

29.2.11 An insulating barrier or liner that is used to provide spacings, including spacings in conjunction with the required over surface spacings, shall not be less than 0.028 inch (0.71 mm) thick. A barrier or liner that is used in conjunction with a spacing through air or oil not less than one-half the required spacing may be less than 0.028 inch but not less than 0.013 inch (0.33 mm) thick, provided the barrier or liner is an insulating material resistant to moisture and has the necessary mechanical strength if exposed or otherwise likely to be subject to mechanical damage, reliably held in place, and located so that it will not be adversely affected by operation of the equipment in service – particularly arcing.

Exception: As provided in 29.2.13.

29.2.12 An insulating barrier or liner used as the sole separation between live parts and grounded parts or between live parts of opposite polarity, shall be a material that may be used for mounting uninsulated live parts and is not less than 0.028 inch (0.71 mm) thick. Otherwise, a barrier shall be used in conjunction with at least a 1/32-inch (0.8-mm) air spacing.

Exception: As provided in 29.2.13.

29.2.13 Insulating and encapsulating materials and coatings having a thickness less than that specified in 29.2.11 and 29.2.12 may be used if, upon investigation, it is found to comply with the requirements for the application, and is equivalent in all regard to materials of the thicknesses specified in 29.2.11.

29.2.14 Film-coated wire is considered to be an uninsulated live part in determining the spacing requirements in this standard.

29.3 Magnet-coil windings

29.3.1 Insulation required in place of spacings between a magnet-coil winding and other uninsulated live parts or grounded dead metal parts, may differ in type and thickness from that required by 29.2.12. The type and thickness of crossover-lead insulation and insulation under coil terminals secured to the coil winding may be less than that specified in 29.2.12 if:

a) The insulation is at least 0.013 inch (0.33 mm) thick; or

b) The coil withstands the dielectric voltage-withstand test specified in either (1) or (2):

1) Application of the test potential in accordance with 52.1.1 – 52.1.4 between coil-end leads after breaking the inner coil lead where it enters the layer, or an equivalent opposite polarity test.

2) Application of the induced potential test described in 52.4.1 – 52.5.2.

29.3.2 A slot in a molded bobbin for guiding the crossover- or start-lead – unspliced at the windings – of a magnet-coil is to be filled with an insulating material unless

a) The slot provides a graduated spacing to the winding, increasing to the end turns, and

b) The magnet-coil winding withstands the induced potential test in 52.4.1 – 52.5.2.

29.4 Low-voltage class 2 circuits

29.4.1 Safety circuits

29.4.1.1 If a short circuit between the parts in a low-voltage, Class 2 safety control may result in a risk of fire, electric shock, or injury to persons, spacings shall be as specified in 29.4.1.2 – 29.4.1.4, and as provided in Clearances and Creepage Distances, Section 30.

Exception: A protective component of a power source need not have the spacings specified.

29.4.1.2 Spacing between an uninsulated live part and the wall of a metal enclosure, including fittings for connection of conduit or armored cable, shall not be less than 1/8 inch (3.2 mm). A greater spacing may be required if an enclosure is not sufficiently rigid to maintain the required spacing because of its:

a) Size,

b) Shape, or

c) The material used.

29.4.1.3 Spacing between wiring terminals, regardless of polarity, and between a wiring terminal and a dead metal part – including the enclosure – that may be grounded when the equipment is installed shall not be less than 1/4 inch (6.4 mm).

29.4.1.4 Spacing between uninsulated live parts, regardless of polarity, and between an uninsulated live part and a dead metal part, other than the enclosure, that may be grounded when the equipment is installed shall not be less than 1/32 inch (0.8 mm), provided that the construction is such that spacings will be permanently maintained.

29.4.2 Non-safety circuits

29.4.2.1 The spacings between bare live parts connected to separate low-voltage, Class 2 circuits shall be not less than 1/32 inch (0.8 mm) through air and over the surface of insulating material.

29.4.2.2 The spacings within a low-voltage Class 2 circuit, other than a safety circuit, are evaluated on the basis of a dielectric voltage-withstand test. See 52.1.2 and 52.1.3.

29.5 Isolated limited secondary circuits (100-volt-amperes or less)

29.5.1 If short-circuiting of parts in a safety circuit of an isolated-limited-secondary circuit may cause the controlled equipment to result in a risk of fire, electric shock, or injury to persons, then the spacings shall be as specified in Table 29.1, column A or B; otherwise Table 29.2 shall apply.

29.5.2 Spacing between uninsulated live parts of opposite polarity and between such parts and dead metal that may be grounded in service is not specified for an isolated limited secondary circuit. The spacing is based on the performance of applicable dielectric voltage-withstand and abnormal operation tests.

Table 29.2
Minimum spacings in safety circuits in isolated-limited-secondary circuits

Spacing between uninsulated live parts and		Potential involved, volts			
		0 – 600,		601 – 1000,	
		inch	(mm)	inch	(mm)
A. Exposed isolated (insulated) dead metal part	Through air	1/8	(3.2)	1/4	(6.4)
	Over surface	1/4	(6.4)	3/8	(9.5)
B. Grounded dead metal part other than the enclosure	Through air or over surface	1/16	(1.6)	3/16	(4.8)
C. Uninsulated live part of opposite polarity	Through air or over surface	1/16	(1.6)	3/16	(4.8)
D. Wall of metallic enclosure	Through air or over surface	1/4	(6.4)	1/2	(12.7)

29.6 Controlled environment circuits

29.6.1 The requirements in 29.6.2 – 29.6.5 apply to equipment that is:

a) Intended for use in a controlled environment and so marked in accordance with 75.9 or

b) Provided with a gasketed enclosure, a tight-fitting enclosure that has been investigated for the purpose, or a filter system that affords the same degree of protection from environmental contamination.

29.6.2 The spacings between field-wiring terminals of opposite polarity and the spacings between a field-wiring terminal and any other uninsulated metal part (dead or live) not of the same polarity shall not be less than the applicable value specified in Table 29.3.

Table 29.3
Minimum spacings at field-wiring terminals

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

[a] For a terminal in a safety circuit note (d) of Table 29.1 applies.

[b] See Table 29.4.

29.6.3 In primary circuits other than at field-wiring terminals, the spacings between uninsulated live parts of opposite polarity and between an uninsulated live part and any other uninsulated metal part (dead or live) not of the same polarity shall not be less than indicated in Table 29.4. See also 29.6.4. If an uninsulated live part is not rigidly fixed in position by a means other than friction between surfaces or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that the minimum acceptable spacings specified in Table 29.4 will be maintained regardless of the position of the movable part.

Table 29.4
Spacings in primary-circuits elsewhere than at field-wiring terminals and in motors

Potential involved,		Minimum spacings[a]			
		Over surface,		Through air,	
volts rms	(volts peak)	inch	(mm)	inch	(mm)
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 – 353.5)	3/32[b]	(2.4)	3/32[b]	(2.4)
251 – 600	(355 – 848)	1/2[b,c,d]	(12.7)	3/8[b,c,d]	(9.5)
601 – 3000	850 – 4242[e]	3/4[d,f,g]	(19.1)	3/4[d,f,g]	(19.1)
3001 – 5000	(4243 – 7070)[e]	1[f,g]	(25.4)	1[f,g]	(25.4)
5001 – 10000	(7071 – 14140)[e]	1-1/2[f]	(38.1)	1-1/2[f]	(38.1)
		1-1/8[g]	(28.6)	1-1/8[g]	(28.6)
10001 – 15000	(14141– 21210)[e]	1-1/2[f,g]	(38.1)	1-1/2[f,g]	(38.1)

[a] For additional spacing requirements in safety circuits up to 600 volts, refer to footnote (d) of Table 29.1. Spacing requirements for higher voltage safety circuits are under consideration.

[b] For equipment with a volt-ampere rating that is limited in accordance with 29.2.2 and 29.2.3, the spacings shall not be less than indicated in Table 29.1, column B or C as applicable.

[c] Film-coated wire is to be considered as if it were an uninsulated live part. However, 1/2-inch and greater spacings over the surface and through the air may be used between dead metal parts and film-coated wire that is rigidly supported and held in place on a coil.

[d] On printed-wiring boards and their connectors wired on the load side of line filters (or similar voltage-peak reduction networks and components), 3/32 inch plus 0.0002 inch (0.0051 mm) per volt peak above 353.5 volts peak [0.094 + 0.0002 (V_{pk} − 353.5)] spacings over the surface and through the air may be used between uninsulated live parts of opposite polarity, and between uninsulated live parts and any other conductive parts (live or dead) not of the same polarity.

Table 29.4 Continued on Next Page

Table 29.4 Continued

Potential involved,		Minimum spacings[a]			
		Over surface,		Through air,	
volts rms	(volts peak)	inch	(mm)	inch	(mm)
[e] Applies to internal circuitry.					
[f] Between uninsulated high-voltage parts and:					
1) Uninsulated high-voltage parts of opposite polarity or of different potentials,					
2) Grounded metal parts, and					
3) Uninsulated primary circuit parts.					
[g] Between uninsulated high-voltage parts and:					
1) Uninsulated primary-circuit parts, and					
2) Insulated high-voltage parts of opposite polarity or of different potentials.					

29.6.4 Primary-circuit spacings apply in all secondary circuits that are safety circuits and in all secondary circuits supplied by a transformer winding of a 200-volt-ampere or higher capacity (maximum available power) at a potential higher than 100 volts. Except as noted in Controlled-Environment Secondary Circuits, Section 31, the spacings in all other secondary circuits that are not safety circuits are evaluated on the basis of the dielectric voltage-withstand test described in 52.2.1 – 52.3.3.

29.6.5 With reference to 29.6.4, an isolated internal secondary circuit is considered to have less than a 200-volt-ampere capacity starting at any point beyond:

a) A reliable limiting impedance that limits the available power to less than 200 volt-amperes under all conditions or

b) A fuse or other overcurrent-protective device other than an automatically reset type having a current rating in amperes not exceeding:

$$\frac{200\ VA}{2.0\ V_{max}}$$

in which:

V_{max} is the open-circuit voltage of the secondary in question in volts rms with the primary connected to maximum rated voltage.

Maximum available power is to be measured using a variable resistor connected in place of the circuit in question. For a transformer having multiple secondary windings, all measurements on one secondary winding circuit are to be made with all other windings unloaded.

30 Clearances and Creepage Distances

30.1 As an alternative to the specified spacing requirements of Spacings, Section 29, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, may be used. The spacing requirements in UL 840 shall not be used for field wiring terminals and spacings to a dead metal enclosure. In determining the pollution degree and overvoltage category, the end-use application is to be considered and may modify those characteristics given in 30.2 – 30.5.

30.2 When applying specific requirements from the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, it is anticipated that the degree of pollution expected or controlled will be as indicated in Table 30.1.

Table 30.1
Degrees of pollution

Equipment	Pollution degree
Hermetically sealed or encapsulated equipment or printed wiring boards with a protective coating[a]	1
Equipment for ordinary locations and indoor use, such as:	2
a) Residential controls;	
b) Commercial controls for use in a clean environment; and	
c) Nonsafety controls for installation on or in appliances	
All safety or limit controls, equipment for outdoor use, and equipment influenced by surrounding environment, such as:	3
a) Industrial controls;	
b) Refrigeration controls; and	
c) Water heater controls	
[a] Tested in accordance with the protective coating test in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.	

30.3 When applying specific requirements from the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, it is anticipated that the equipment will be identified by overvoltage categories as indicated in Table 30.2.

Table 30.2
Overvoltage categories

Equipment	Overvoltage category
Intended for fixed wiring connection	III
Portable and stationary cord-connected	II
Power-limited and safety[a] low voltage	I
[a] Applicable to low-voltage circuits if a short circuit between the parts involved may result in operation of the controlled equipment that would increase the risk of fire or electric shock.	

30.4 In order to evaluate clearances where the levels of overvoltage are controlled, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product. The equipment shall be evaluated for the rated impulse withstand voltage specified in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

30.5 Printed wiring boards constructed of Types XXXP, XXXPC, G-10, FR-2, FR-3, FR-4, FR-5, CEM-1, CEM-3, GPO-2, or GPO-3 industrial laminates in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed-Wiring Boards, UL 746E, are considered to have a minimum comparative tracking index of 100 without further investigation.

31 Controlled-Environment Secondary Circuits

31.1 Secondary circuits – other than safety circuits – shall be evaluated in accordance with 31.2 – 31.9 if in equipment intended for installation in a controlled environment or provided with:

a) A gasketed enclosure,

b) A tight-fitting enclosure that has been investigated for the purpose, or

c) A filter system that provides the same degree of protection from environmental contamination.

31.2 Printed-wiring assemblies and subsequent circuitry used in secondary circuits that do not involve a risk of electric shock need not be investigated. However, power supplies and power-distribution components, such as bus bars, wiring connectors and similar parts up to and including printed-wiring receptacles and connectors shall be investigated. Printed-wiring boards and insulated wire used in such circuits shall comply with the requirements for the application.

31.3 Circuits supplied by a single source consisting of an isolating transformer, a power supply that includes an isolating transformer, or a battery need not be investigated if the open-circuit potential is not more than 42.4 volts peak and the energy available to the circuit is limited:

a) So that the current under any condition of load including short circuit is limited by:

1) Construction of the battery or isolating transformer, or

2) Construction or value of a fixed impedance or reliable regulating network to not more than 8 amperes measured after 1 minute of operation; or

b) By a fuse or a nonadjustable manually reset circuit-protective device that is rated or set at not more than the values specified in Table 31.1.

Table 31.1
Rating for fuse or circuit protector

Open-circuit potential, peak volts	Current rating, amperes
0 – 21.2	5
21.3 – 42.4	3.2

31.4 The voltage limit specified in 31.3 is to be measured with the equipment, the power supply, or the transformer primary connected to the voltage specified in 31.3 and all load circuits disconnected from the battery, transformer, or the power supply under test. The measurement may be made at the output terminals of the battery, transformer, or power supply. If a tapped transformer winding is used to supply a full-wave rectifier, the voltage measurement is to be made from each end of the winding to the tap.

31.5 If the performance of a regulating network used to limit the voltage or current in accordance with 31.3(a) may be adversely affected by either a short-circuit or open-circuit of any single component in the network, the risk of such an occurrence shall be determined by investigation of that component.

31.6 In a circuit of the type described in 31.3, the secondary winding of the transformer, the fuse or circuit-protective device, or the regulating network and all wiring up to the point at which the current and voltage are limited are to be evaluated under the applicable requirements of this standard.

31.7 Secondary circuits may be connected to the frame of the unit.

31.8 If the frame is used as a current-carrying part of a secondary circuit, a hinge or other movable part shall not be relied upon as a current-carrying means.

31.9 A circuit supplied from a Class 2 transformer rated at 30 volts rms sinusoidal or less need not be investigated.

32 Wiring Space

32.1 Except as noted in 32.2 and 32.3, the space within an enclosure shall provide ample room for the distribution of wires and cables to be connected in the field as specified in Table 32.1.

Table 32.1
Field wiring space

Conductor size,		Minimum usable volume per conductor,	
AWG	(mm^2)	cubic inches	(cm^3)
14 and smaller	(2.1 and smaller)	2	(33)
12	(3.3)	2.25	(37)
10	(5.3)	2.5	(41)
8	(8.3)	3	(49)
6	(13.3)	5	(82)

32.2 In lieu of the volume specified in Table 32.1, a trial installation may be made to determine that ample room is provided for the distribution of wires and cables required for the proper wiring of the equipment. However, wire-bending space shall be provided in accordance with 32.4 and 32.5.

32.3 To determine whether the equipment complies with 32.2, it is to be wired as it would be in service, and in so doing, a reasonable amount of slack is to be left in each conductor. No more than average care is to be exercised in stowing this slack into the wiring compartment. The wiring shall not bear against sharp projections or edges that may damage the insulation.

32.4 The wire-bending space within the enclosure of a controller shall be in accordance with Table 32.2. Bending space is to be measured in a straight line from the end of the lug, connector, or terminal to the wall or barrier, in the direction the wire leaves the terminal.

32.5 Any supplementary terminal supplied with the controller shall be of a type identified by the manufacturer for use with the product, and shall not reduce the minimum wire-bending space.

Table 32.2
Minimum field wire-bending space at terminals of enclosed controllers

Conductor size,		Bending space, inches (mm)			
		Wires per terminal			
AWG or kcmil	(mm^2)	1		2	
14 – 10	(2.1 – 5.3)	Not specified		–	
8 – 6	(8.4 – 13.3)	1-1/2	(38.1)	–	
4 – 3	(21.2 – 26.7)	2	(50.8)	–	

Table 32.2 Continued on Next Page

Table 32.2 Continued

Conductor size,		Bending space, inches (mm)			
		Wires per terminal			
AWG or kcmil	(mm^2)	1		2	
2	(33.6)	2-1/2	(63.5)	–	
1	(42.4)	3	(76.2)	–	
1/0	(53.5)	5	(127)	5	(127)
2/0	(67.4)	6	(152)	6	(152)
3/0 – 4/0	(85.0 – 107.2)	7	(178)	7	(178)
250	(127)	8	(203)	8	(203)
300	(152)	10	(254)	10	(254)
350 – 500	(177 – 253)	12	(305)	12	(305)
600 – 700	(304 – 355)	14	(356)	16	(406)
750 – 900	(380 – 456)	18	(457)	19	(483)

NOTE – If provision for three or more wires per terminal exists, the minimum wire-bending space shall be in accordance with the National Electrical Code, ANSI/NFPA 70.

33 Separation of Circuits

33.1 Insulated conductors shall be segregated or separated by barriers from:

a) Each other if used in different internal wiring circuits and

Exception: Conductors provided with insulation rated for the highest voltage involved need not be separated or segregated.

b) Uninsulated live parts connected to different circuits.

33.2 With reference to 33.1, the segregation is in compliance with 33.1 when it is accomplished by clamping, routing, or equivalent means that provides a minimum permanent 1/4 inch (6.35 mm) separation from an insulated conductor or an uninsulated live part of a different circuit.

33.3 The equipment shall be constructed so that a field-installed conductor of any circuit shall be segregated – see 33.7 – or separated by a barrier from a field-installed conductor connected to any other circuit.

Exception No. 1: Separation and segregation are not required when both circuits are Class 2 or Class 3 and both circuits are insulated for the maximum voltage of either circuit.

Exception No. 2: Separation and segregation are not required when both circuits are other than Class 2 or Class 3 and both circuits are insulated for the maximum voltage of either circuit.

Exception No. 3: Separation and segregation are not required between a limited energy (Class 2 or Class 3) circuit and an unlimited energy (Class 1, Electric Light, Power) circuit as long as:

a) The unlimited energy circuit is of a potential of 150 V ac or less to ground;

b) The product is marked to indicate that the limited energy circuit conductors are to be wired with Types CL3, CL3P, CL3R, or equivalent conductors as shown in Table 33.1. See 73.20; and

c) Types CL3, CL3P, CL3R, or equivalent conductors are used for the Class 2 and Class 3 conductors, provided that the bare conductors from the Class 3 cable are separated from the other conductors by:

1) Spacing not less than 1/4 inch (6.35 mm);

2) A non-conductive barrier; or

3) A non-conductive sleeving wrapped around the conductors.

Exception No. 4: Separation and segregation is not required between a limited energy (Class 2 or Class 3) circuit and an unlimited energy (Class 1, Electric Light, Power) circuit as long as:

a) The unlimited energy circuit is of a potential of 150 V ac or less to ground and

b) The product is marked to indicate that the limited energy circuit conductors are to be wired with conductors suitable for Class 1, Electric Light or Power circuits. See 73.21.

Table 33.1
Cable substitutes for Types CL3, CL3P, and CL3R cables

Cable type	Cable substitutes
CL3	CL3P, CL3R, CM, CMG, CMP, CMR, FPL, FPLP, FPLR, MP, MPG, MPP, MPR, and PLTC
CL3P	CMP, FPLP, and MPP
CL3R	CL3P, CMP, CMR, FPLP, FPLR, MPP, and MPR

33.4 The equipment shall be constructed so that field-installed conductors of any circuit shall be segregated – see 33.7 – or separated by barriers from uninsulated live parts of any other circuit of the device.

Exception No. 1: Field-installed Type RH, T, RFH-2 or equivalent conductors are not prohibited from contacting wiring terminals.

Exception No. 2: Field-installed conductors of a limited energy circuit are not prohibited from contacting terminals of a separate limited energy circuit provided that the short circuiting of such terminals does not result in a risk of fire or electric shock.

33.5 The equipment shall be constructed so that field-installed conductors of any circuit shall be segregated – see 33.7 – or separated by barriers from factory-installed conductors connected to any other circuit, unless the conductors of both circuits are insulated for the maximum voltage of either circuit.

33.6 With respect to 33.3, 33.4, and 33.5, when 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 is not prohibited. Instructions for the use of such a barrier are to be a permanent part of the device. Complete instructions in conjunction with a wiring diagram is not prohibited from being used in lieu of a barrier when, upon investigation, the combination is determined to comply with these requirements.

33.7 When field-installed conductors are segregated in accordance with 33.4, the segregation of the conductors complies with 33.4 when the segregation is from each other, from uninsulated live parts and from factory-installed conductors by locating openings in an enclosure for the various conductors – with respect to the terminals or other uninsulated live parts – so that a minimum permanent 1/4 inch (6.35 mm) separation is provided.

33.8 With reference to 33.7, when the number of openings in the enclosure does not exceed the minimum required for the proper wiring of the device, and when each opening is located opposite a set of terminals, it is to be assumed that a conductor entering an opening shall be connected to the terminal opposite that opening. When more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than the one opposite the terminal to which it is intended to be connected and the possibility of it contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit is to be investigated.

33.9 To determine whether the equipment complies with the requirement of 33.3, 33.4 and 33.5, it is to be wired as intended for service with:

a) 6 – 12 inches (152.4 – 305 mm) of slack left in each conductor and

b) No more than average care exercised in stowing the slack into the wiring compartment.

33.10 Conductors from an unlimited energy (Class 1, Electric Light, Power) field-wired circuit and from a limited energy (Class 2 or Class 3) field-wired circuit that are routed through a single opening in an enclosure of a permanently-connected appliance comply with the intent of 33.3 when the limited energy conductors are separated from the unlimited energy conductors by flexible tubing. The tubing shall be rated not less than the maximum voltage rating of the unlimited energy conductors. The tubing shall be provided as part of an installation kit with the equipment. See 73.22.

34 Isolation Devices

34.1 All devices that are necessary to provide electrical isolation, such as optical isolators, pulse transformers, and the like, shall comply with the requirements for such devices and with the requirements in 34.2 – 34.5.

34.2 An isolation device shall be provided if it reduces a risk of fire, electric shock, or injury to persons, or if isolation is required by this standard in specific circuits.

34.3 Equipment that incorporates Class 2 outputs and isolates these Class 2 outputs from circuits involving a risk of electric shock shall be subjected to tests to determine the effects on the insulating properties of the isolating medium. The testing shall include subjecting the insulation to the tests described in 47.4.1 – 47.4.3.

34.4 Resistors employed to obtain isolation shall comply with requirements for such devices. See Isolating Resistor Evaluation, Section 67. In addition, each line in a circuit that contains such resistors and that is exposed during user servicing shall be provided with an impedance that satisfies the following equation:

$$\frac{V}{Z} \leq 0.5\ mA$$

in which:

V is the open-circuit voltage of the line circuit and

Z is the minimum impedance, including tolerances.

Exception: The value in the equation is 5.0 milliamperes for circuits exposed only during servicing by qualified personnel.

34.5 The power rating of a resistor used to obtain isolation shall be at least three times the power it dissipates in normal operation.

34.6 Other types of impedances used in accordance with 34.2 are to be subjected to a special investigation.

35 Connections to Separate Equipment

35.1 General

35.1.1 If the combination of the equipment is investigated together, the connections in the combination may be evaluated to determined compliance with these requirements.

35.2 Fuel-control circuit

35.2.1 The interconnections of equipment or controller to the fuel control circuit of a separate gas, oil, or electric furnace or boiler, or air-cooling equipment, or the like, shall not:

a) Result in bypassing or defeating a safety control or protective device,

b) Require rewiring,

c) Introduce a new power supply to the separate equipment,

d) Add a load to the existing components which may interfere with proper operation of the controlled equipment, or

e) Interpose in the control circuit other controls, the malfunction of which may result in a condition that the control is intended to prevent.

Also see Separation of Circuits, Section 33 and Interconnection of Class 2 Circuits, Section 36.

35.2.2 Compliance with the requirement in 35.2.1 may be accomplished by

a) Connection of the controller ahead of the power-supply terminals of the separate equipment,

b) Connection of isolated contacts ahead of the control,

c) Connection of isolated contacts to thermostat terminals or to the water-temperature-regulating control terminals of the separate equipment, or

d) Equivalent connection that meets the intent of in 35.2.1.

35.2.3 The controller shall not furnish power or be connected to the circuit of a thermopile-powered furnace or boiler.

Exception: The controller may furnish power or be connected to the circuit:

a) Through an isolated contact connected in a separate compartment or

b) If the control is marked to specify use of an isolating relay.

35.3 Circulator or auxiliary-control circuit

35.3.1 The interconnection of a controller to a separate furnace fan, boiler pump, or the like, shall be by means of an isolated contact that is to be connected only to the fan or pump controls so as not to require rewiring or adding a power supply to the separate equipment. The controller shall be marked accordingly.

36 Interconnection of Class 2 Circuits

36.1 The output of a transformer supplying a Class 2, low-voltage circuit and provided as a part of the equipment shall not be interconnected with the output of another such transformer. See 73.6.

Exception: The output of two or more transformers provided as a part of the equipment may be interconnected if the voltage and current measurements at the output terminals are within the values for a single Class 2, 30-volt or less transformer.

36.2 The outputs of two or more transformers, all of which are evaluated as Class 2 in accordance with 6.2 and that are not interconnected, are to be considered as separate circuits.

36.3 If the wiring terminals or leads for two or more Class 2 circuits are located in the same wiring compartment, the compartment shall be such that ample room is provided for proper wiring without crowding, and such that the stowed wiring of one circuit will not be forced against terminals or live parts of another circuit. The equipment shall be marked in accordance with 75.8.

37 Barriers

37.1 A barrier used to provide separation between the wiring of different circuits shall be of metal or of insulating material having the necessary mechanical strength if exposed or otherwise likely to be subjected to mechanical damage, and shall be held in place.

37.2 Unclosed openings in a barrier for the passage of conductors shall not be larger than 1/4 inch (6.4 mm) in diameter and the number of openings shall not be more than the number of conductors that will need to pass through the barrier. The closure for any other opening shall have a smooth surface wherever an insulated wire may contact it and the area of any such opening, with the closure removed, shall not be larger than required for the passage of the necessary wires. See 18.1.20.

37.3 A barrier used to provide separation between the field wiring of one circuit and the wiring or uninsulated live parts of another shall not be spaced more than 1/16 inch (1.6 mm) from the enclosure walls and from interior mechanisms and component-mounting panels, or the like, that serve to provide segregated compartments.

37.4 A metal barrier used to provide segregation shall have the necessary strength and rigidity, and shall be at least the thickness specified under the column in Table 7.1 titled "With supporting frame or equivalent reinforcing," for the dimensions of the barrier.

37.5 A barrier of insulating material shall be of such thickness and be so supported that it cannot be readily deformed so as to defeat its purpose; in any case, the thickness shall not be less than 0.028 inch (0.71 mm).

37.6 A barrier between uninsulated live parts connected to different circuits, and a barrier between uninsulated live parts of one circuit and the wiring of another circuit shall also comply with the requirement in 29.2.11 and 29.2.12.

PROTECTION AGAINST INJURY TO PERSONS

38 General

38.1 Scope

38.1.1 The requirements in 38.2.1 – 38.7.8 apply to equipment, the normal operation of which may involve a risk of injury to persons.

38.1.2 There are risks of injury to persons inherent in some equipment that, if completely eliminated, would defeat the utility of the equipment. The requirements in this section are intended to reduce such risks, while retaining the intended function of the equipment.

38.2 Sharp corners and edges

38.2.1 An enclosure, a frame, a guard, a handle, or the like, shall not be sufficiently sharp to constitute a risk of injury to persons in normal maintenance and use.

Exception: This requirement does not apply to a part or portion of a part needed to perform a working function.

38.3 Moving parts

38.3.1 A hinged or pivoted panel or cover shall be positioned or arranged so that it is not subject to falling or swinging due to gravity or normal vibration in such a manner as to cause injury to persons by the panel or cover, by other moving parts capable of causing injury to persons, or by uninsulated live parts.

38.4 Enclosures and guards

38.4.1 The rotor of a:

a) Motor,

b) Pulley,

c) Belt,

d) Gear,

e) Chain,

f) Fan, or

g) Other moving part

that could cause injury to persons, shall be enclosed or guarded to reduce the risk of unintentional contact with the moving part.

38.4.2 A moving part that may involve a risk of injury to persons shall comply with the requirements specified in Table 12.1, and shall be considered with regard to:

a) The degree of exposure,

b) The sharpness of the moving part,

c) The risk of unintentional contact with the moving part,

d) The speed of the moving part, and

e) The risk that:

1) A part of the body could be endangered by the moving part or

2) Clothing could be entangled, resulting in a risk of injury to persons.

38.4.3 Unless it complies with 50.1, a guard or enclosure for a moving part capable of causing injury to persons shall be secured to the equipment so that it cannot be removed without using a tool.

38.5 Surface temperatures

38.5.1 During the Temperature Test, Section 42, the maximum temperature of a handle, lever, button, or knob that is contacted by a user during normal operation shall not exceed 60°C (140°F) for a metal surface or 85°C (185°F) for a nonmetallic surface.

38.5.2 With reference to 38.5.1, a handle, a lever, a button, a knob, or the like, made of a material other than metal, that is plated or clad with metal 0.005 inch (0.13 mm) thick or less shall be evaluated as a nonmetallic part.

38.5.3 The maximum temperatures specified in 38.5.1 do not apply to equipment intended specifically for use in an ambient temperature exceeding 85°C (185°F).

38.6 Mounting devices

38.6.1 Equipment weighing more than 5 pounds (2.3 kg) and relying on a mounting means other than its own enclosure, if malfunction of the mounting means will result in a risk of injury to persons, shall withstand for 1 minute, without dislocation of the mounting means or evidence of damage, a force as described in 38.6.2.

38.6.2 With the equipment mounted in accordance with the manufacturer's instructions, a force equal to three times the weight of the equipment but not less than 20 pounds-force (89 N) is to be applied through the approximate center of gravity of the equipment. The force is to be increased gradually to reach the required value in 5 – 10 seconds and is to be maintained at that value for 1 minute.

38.7 Strength of parts

38.7.1 A device that is actuated by an external source of pressure and that employs a Bourdon tube, a flexible metal bellows, a diaphragm, or the like, rated 300 psig (2068 kPa) or more and not contained within an enclosure, shall withstand for 1 minute the hydrostatic pressure specified in 38.7.2 without bursting, leakage, or rupture.

Exception: Certain leakage conditions may occur only as indicated in 38.7.3 – 38.7.7.

38.7.2 To determine whether a part complies with the requirement in 38.7.1, a sample shall be subjected to a hydrostatic pressure test. The sample is to be filled with water to exclude air and is to be connected to a hydraulic pump. The pressure is to be raised gradually to four times the maximum rated operating pressure of the device.

38.7.3 Leakage at a gasket or fitting during the hydrostatic pressure test may occur unless it occurs at a pressure 50 percent or less of the required test pressure.

38.7.4 If leakage occurs during the test, the test is to be continued to four times the maximum rated operating pressure of the device, test equipment permitting. If the leakage is due to external fittings, modifications may be made to permit completion of the test.

38.7.5 A Bourdon tube, a flexible metal bellows, a diaphragm, or the like that is contained within an enclosure shall comply with the requirement in 38.7.1 or shall:

a) Withstand for 1 minute without visible leakage a hydraulic pressure in accordance with the second column of Table 38.1; and

b) Except as indicated in 38.7.7, withstand a hydraulic pressure for 1 minute equal to four times the maximum rated operating pressure of the device without rupture that may present a risk of injury to persons.

Table 38.1
Test pressures for devices with enclosures

Marked maximum operating-pressure rating, psig (kPa)	Test pressure for	
	38.7.5(a)	38.7.7(a)
300 – 2000 (2068 – 137,900)	2 times maximum rated operating pressure	3 times maximum rated operating pressure

38.7.6 With reference to 38.7.5(b), a Bourdon tube, diaphragm, or bellows may split if no part is released outside the enclosure; a joint or a gasket may leak if the required pressure value is reached and maintained for 1 minute, a leaking gasket or flexible member may be replaced by a heavier disc to permit the required pressure value to be reached.

38.7.7 With reference to 38.7.6, if leakage becomes excessive so that the four-times pressure cannot reasonably be reached – that is, if the part functions as if it has a rupture disc – the part complies if:

a) A pressure in accordance with the third column in Table 38.1 is reached;

b) No part capable of causing injury to persons is released outside the enclosure; and

c) It can be demonstrated by test – which may be at a low pressure – or otherwise, that the outer enclosure can either relieve a pressure equal to the maximum rated operating pressure of the device without rupture that presents a risk of injury to persons, or can withstand a pressure equal to the maximum rated operating pressure.

38.7.8 A pressure vessel, a compressed 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.

39 Protection of Users and Service Personnel

39.1 General

39.1.1 The requirements in this section do not apply to live parts in low-voltage circuits as defined in 5.6.

39.1.2 Live parts shall be arranged and covers located so that persons are not likely to be exposed to a risk of electric shock while removing and replacing a cover.

39.1.3 Live parts shall be:

a) Recessed at least 1/8 inch (3.2 mm) from the plane of the front of the fixed portion of an enclosure;

b) Recessed at least 1/8 inch from the front edge of a wiring compartment, in the case of equipment mounted to the face of a wiring compartment; or

c) Provided with equivalent protection by projections or guards.

39.1.4 To determine whether live parts recessed or protected in accordance with 39.1.3 comply with the requirement in 39.1.2, the cover is to be removed and replaced. Contact of either a person or a conductive cover with a live part shall not occur.

39.1.5 Unless a cover complies with the requirements for hinged covers in 7.2.4 and 7.2.7, and unless all live parts are protected as specified in 39.1.6, a handle, a knob, or other manual operating means shall be arranged so that it can be operated from outside the enclosure. The position of such an operating means shall be marked, if necessary, as a guide for proper operation.

Exception: Equipment that involves manual operations that may be performed by a user only at the time of installation, during a servicing procedure, or seasonally, need not comply provided that it complies with the requirements in 39.1.6, 39.2.3, 39.2.5, 39.3.2, and 39.3.3. The requirements in Bonding of Internal Parts, Section 20, apply in any case.

39.1.6 An uninsulated live part or a moving part capable of causing injury to persons shall be located, guarded, or enclosed so as to reduce the risk of contact with such part by a person while changing a lamp or fuse, lubricating a motor, adjusting a control, or during other normal operations, including those performed only at the time of installation, during a servicing procedure, or seasonally.

39.1.7 A live heat sink for a solid-state component, a live relay frame, and the like, shall comply with 39.1.6, 39.2.2, and 39.3.2, and unless the equipment is marked in accordance with 75.6, shall also be guarded to reduce the risk of contact by persons, regardless of the location of the parts.

Exception: As provided in 39.1.9 and 39.1.10.

39.1.8 With reference to 39.1.7, the size, shape, material, and color give a heat sink or relay-frame the appearance of a dead metal part. Other live parts that can be mistaken as being dead parts are to be evaluated similarly.

39.1.9 A guard, baffle, or cover that can be removed without a tool is to be removed when determining whether a part is exposed to contact by a user. A part that can be contacted by a 3/8-inch (9.5-mm) diameter rod having a hemispherical end inserted through an opening in a permanently attached guard or baffle for a distance of 4 inches (102 mm) is considered to be exposed for the purpose of protecting persons.

Exception: A snap-on cover that complies with the requirements in the Cover Retention Test, Section 62, need not be removed.

39.1.10 A part on the back side of a component mounting panel or located so that major disassembly by using a tool is necessary to expose it is not considered to be exposed to a user; such a part is not considered to be exposed to service personnel unless it is likely that servicing will be performed while the part is energized after disassembly.

39.1.11 If a marking or an operating instruction refers a user to a hole or opening in an enclosure through which a tool is to be inserted for adjustment or a similar purpose, it shall not be possible to contact an uninsulated live part through the hole or opening with a 1/16-inch (1.6-mm) diameter rod.

39.2 Mechanical servicing

39.2.1 The requirements in 39.2.2 are intended to provide a reasonable degree of protection to service personnel performing a mechanical function on energized equipment. Such a service function does not in itself cause exposure to live parts or moving parts capable of causing injury to persons, but it is commonly necessary to perform the function with the equipment energized.

39.2.2 An uninsulated live part or a moving part capable of causing injury to persons shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact by service personnel adjusting or resetting a control, or performing a mechanical service function that may have to be performed with equipment energized.

39.2.3 Mechanical service functions that may have to be performed with equipment energized include operating a valve or connecting a fitting that may be necessary during charging or adjusting a pneumatic system, adjusting the setting of a temperature or pressure control with or without marked dial settings, resetting a control trip mechanism, operating a manual switch, or lubricating a motor. A control that has the set point sealed at the factory and that does not have marking or instructions for adjustment is not considered to be adjustable.

39.2.4 The requirements in 39.2.2 do not apply to a mechanical service function that is not normally performed with equipment energized.

39.2.5 An adjustable or resettable electric control or manual-switching device may be located or oriented with regard to uninsulated live parts so that manipulation of the mechanism for adjustment, resetting, or operation can be accomplished in the normal direction of access if uninsulated live parts are not located:

a) In front (in the direction of access) of the mechanism and

b) Near any side or behind the mechanism, unless guarded.

39.3 Electrical servicing

39.3.1 The requirements in 39.3.2 require that certain electrical components within an overall assembly be located so that the necessary space is provided for working on the components while the equipment is energized.

39.3.2 An electrical component that may need to be examined, adjusted, serviced, or maintained while the equipment is energized shall be located and mounted with regard to other components and with regard to grounded metal parts so that it is accessible for electrical servicing without subjecting service personnel to a risk of electric shock or to a risk of injury to persons by adjacent moving parts. Access to a component shall not be impeded by other components or by wiring.

39.3.3 Compliance with 39.3.2 may be obtained by mounting control components in an assembly so that unimpeded access to each component is provided through an access cover or panel in the outer cabinet, if provided, and the cover of the control assembly enclosure.

39.3.4 Electrical components to which 39.3.2 and 39.3.3 apply include:

a) Fuses;

b) Adjustable or resettable overload relays;

c) Manual or magnetic motor controllers;

d) Magnetically operated relays;

e) Adjustable or resettable pressure or temperature controllers;

f) Manual switching devices;

g) Clock timers; and

h) Incremental-voltage tap and motor-speed tap terminals for variable-speed motors.

Such components in a limited-energy circuit of 30 volts or less shall comply with 39.3.2 in their relation to bare live parts in a circuit of greater energy level and to moving parts capable of causing injury to persons.

39.3.5 The following are not considered to be uninsulated live parts:

a) Coils of controllers, relays and solenoids, and transformer windings, if the coils and windings are provided with insulating overwraps at least 1/32 inch (0.8 mm) thick, or the equivalent, in accordance with 29.2.6;

b) Enclosed motor windings;

c) Terminals and splices with insulation that complies with the applicable requirements; and

d) Insulated wire.

39.3.6 A device having exposed Class 2 outputs that:

a) May be contacted during normal operation or servicing and

b) Have clearances between the Class 2 circuit and an overvoltage protected line-voltage circuit that have been evaluated in accordance with Clearance B requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840,

shall be provided with a mechanism to indicate the failure of the overvoltage protective device or system. For example, the provision of a detection circuit that would indicate a transient voltage surge suppressor is no longer functional due to the absorption of an excessive amount of energy.

PERFORMANCE

40 General

40.1 The performance of energy management equipment shall be investigated by subjecting a representative sample or samples in commercial form to the tests described in Sections 41 – 67. Consideration shall be given to heat-sink construction, solid-state-device ratings, and other construction criteria in selecting samples for testing that are representative of a line of similarly constructed equipment.

40.2 Unless otherwise noted, tests shall be conducted at rated frequency and at the test potential specified in Table 40.1.

Table 40.1
Values of voltage for tests

Voltage rating of equipment and corresponding test potential, volts[a]				
110 – 120	220 – 240	254 – 277	440 – 480	550 – 600
120	240	277	480	600
[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.				

41 Power Input Test

41.1 The power input to the equipment shall not exceed the marked rating by more than 10 percent when it is operated under the conditions of normal use while connected to a supply circuit as specified in Table 40.1.

42 Temperature Test

42.1 When tested as described in this section, the equipment shall not attain a temperature at any point sufficiently high to constitute a risk of fire, to damage any materials employed in the equipment, or to exceed the temperature rises specified in Table 42.1.

Table 42.1
Maximum temperature rises

Materials and components	°C	(°F)
A. INSULATION SYSTEMS		
1. Insulation systems on coil windings of an AC motor having a frame diameter[a] of 7 inches (178 mm) or less, but not including a universal motor; and on vibrator coils:[b,c]		
(a) Class A Insulation Systems		
In an open motor:		
Thermocouple or resistance method	75	(135)
In a totally enclosed motor:		
Thermocouple or resistance method	80	(144)
(b) Class B Insulation System		
In an open motor and on vibrator coils:		
Thermocouple or resistance method	95	(171)
In a totally enclosed motor:		
Thermocouple or resistance method	100	(180)
2. Insulation systems on coil windings of an AC motor having a frame diameter[a] of more than 7 inches (178 mm), of a DC motor, and of a universal motor:[b]		
(a) Class A Insulation Systems		
In an open motor:		
Thermocouple method	65	(117)
Resistance method	75	(135)
In a totally enclosed motor:		
Thermocouple method	70	(126)
Resistance method	80	(144)

Table 42.1 Continued on Next Page

Table 42.1 Continued

Materials and components	°C	(°F)
(b) Class B Insulation Systems		
In an open motor:		
Thermocouple method	85	(152)
Resistance method	95	(171)
In a totally enclosed motor:		
Thermocouple method	90	(162)
Resistance method	100	(180)
B. COMPONENTS		
1. Capacitors:		
(a) Electrolytic[d]	40	(72)
(b) Other Types[d]	65	(117)
2. Field-wiring terminal[e]	50	(90)
3. Solid contacts, busses, and connecting bars[f]	65	(117)
4. Fuse clip	65	(117)
5. Printed-wiring board[g]		
6. Power-switching semiconductor (triac, SCR, or the like)[h]	–	–
7. Rectifier:		
(a) Selenium[i]	50	(90)
(b) Silicon[i]	75	(135)
8. Windings of a relay, solenoid, and coil (except motor coil windings and transformers) with:		
(a) Class 105 insulation systems:		
Thermocouple method[b]	65	(117)
Resistance method	85	(153)
(b) Class 130 insulation systems:[b,c]		
Thermocouple method	85	(153)
Resistance method	105	(189)
9. Sealing compound[j]	–	–
10. Epoxy[i]	65	(117)
11. Transformer:		
(a) Class 105 insulated systems:		
Thermocouple method	65	(117)
Resistance method	75	(135)
(b) Class 130 insulation systems:[c]		
Thermocouple method	85	(153)
Resistance method	95	(171)
12. Rubber- or thermoplastic-insulated wire and cord[i,k]	35	(63)
C. ELECTRICAL INSULATION – GENERAL		
1. Fiber employed as electrical insulation	65	(117)
2. Phenolic composition employed as electrical insulation or as a part the deterioration of which may result in a risk of fire or electric shock:		
(a) Laminated[i]	100	(180)

Table 42.1 Continued on Next Page

Table 42.1 Continued

Materials and components	°C	(°F)
(b) Molded[i]	125	(225)
3. Varnished-cloth insulation	60	(108)
4. Other insulating materials[l]	–	–
D. SURFACES		
1. A surface upon which a unit may be placed or mounted in service, and surfaces that may be adjacent to the unit when it is so placed or mounted	65	(117)
2. Any point on or within a terminal box or wiring compartment of permanently connected equipment in which power-supply conductors are to be connected, including such conductors themselves, unless the equipment is marked in accordance with 74.2.	35	(63)

[a] This is the diameter, measured in the plane of the laminations of the circle circumscribing the stator frame, excluding lugs, boxes, and the like, used solely for motor mounting, assembly, or connection.

[b] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature measured by means of a thermocouple may be 15°C (27°F) higher than that specified, provided that the temperature rise by the resistance method is not more than that specified.

[c] Insulation systems operating at a temperature greater than their limits shall comply with the thermal aging requirements for such insulation systems.

[d] A capacitor that operates at a temperature rise of more than 40°C (72°F) for electrolytic and more than 65°C (117°F) for other types may be evaluated on the basis of its marked temperature limit. However, the measured temperature shall not exceed the temperature rating of the capacitor based on a 25°C (77°F) ambient temperature.

[e] 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.

[f] If contacts of any metal and their supporting blades, busses, and connecting bars attain a temperature greater than 90°C (194°F) where a higher than nominal room ambient temperature or other external temperature prevails, or where affected by a bimetal heater or other heat source in the assembly, the control shall perform acceptably when subjected to overload and endurance tests conducted at the high temperatures involved.

Exception: Contacts of silver or a silver alloy that do not attain a temperature higher than 100°C (212°F) need not be subjected to overload and endurance tests conducted at the higher temperature.

[g] For a printed wiring board, the maximum temperature rise is the specified limit of the board minus an assumed ambient of 25°C (77°F).

[h] For a power-switching semiconductor and the like, the maximum temperature rise on the case is the maximum case temperature recommended by the semiconductor manufacturer minus an assumed ambient of 25°C (77°F) for open devices.

[i] These limitations do not apply to compounds and components that have been investigated and found for a higher temperature and determined to comply with the requirements.

[j] The maximum sealing-compound temperature, when corrected to a 25°C (77°F) ambient temperature, shall be 15°C (27°F) less than the softening point of the compound as determined in accordance with the Test for Softening Point by the Ball-and-Ring Apparatus, ASTM E28-82.

[k] Rubber-insulated conductors within a motor having a Class A system, rubber-insulated motor leads, and a rubber-insulated flexible cord entering a motor may be subjected to a temperature rise of more than 35°C (63°F) if braid is used on each individual conductor. This does not apply to thermoplastic-insulated wires or cords.

[l] The compliance of insulating materials other than those covered in Table 42.1 is to be determined with regard to properties, such as flammability, arc-resistance, and the like, based on an operating temperature equal to the measured temperature rise plus 25°C (77°F).

42.2 To determine if the equipment complies with the temperature test requirements, it is to be operated under normal conditions and is to carry its rated current continuously at the test potential specified in Table 40.1 until temperatures are constant.

Exception: The test on parts other than coils and transformer windings may be conducted at a potential between 90 and 110 percent of the potential specified if the ampere load is adjusted to produce the maximum normal heating.

42.3 A protective device shall not trip during the temperature test.

42.4 Permanently-connected equipment is to be tested with 4 feet (1.22 m) of wire attached to each field-wiring terminal. The wire is to be of the smallest size having an ampacity of at least 125 percent of the test current for motor loads, continuous duty loads, and combination loads, and at least 100 percent for other loads. Wire size is to be determined in accordance with Table 310-16 of the National Electrical Code, ANSI/NFPA 70. The size is to be based upon wire that is rated for a temperature of 60°C (140°F) for a rating of 100 amperes or less, and upon wire that is rated for 75°C (167°F) for a rating greater than 100 amperes. The type of insulation is not specified.

42.5 Permanently-connected equipment is to be installed so that it is located as close to the wall or corner as the construction will permit. Cord-connected equipment is to be placed on a horizontal supporting surface and spaced 1 inch (25 mm) from a vertical wall surface of wood or comparable material, unless the arrangement of ventilation and similar cooling factors is such that operation against a wall, as compared with operation in the open, will not increase operating temperatures, or unless the construction of the equipment is such that a spacing greater than 1 inch is maintained. Doors and covers that may be closed during operation of the equipment are to be closed during the test.

42.6 All values in Table 42.1 are based on an assumed ambient temperature of 25°C (77°F), but a test may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F). However, if the operation of an automatic thermal control during the test limits the temperatures under observation, no temperature shall exceed 25°C plus the specified maximum rise.

42.7 A short length of rubber- or thermoplastic-insulated flexible cord exposed to a temperature higher than that for which it is rated, such as at terminals, may be used if supplementary heat-resistant insulation having the necessary dielectric strength is provided on the individual conductors of the cord to reduce the risk of deterioration of the conductor insulation.

42.8 Open-type equipment is to be tested in a 40°C (104°F) ambient, and temperature corrections as specified in 42.9 are to be made.

42.9 Equipment intended specifically for use with a prevailing ambient temperature constantly more than 25°C (77°F) is to be tested at such higher ambient temperature, and the allowable temperature rises specified in Table 42.1 are to be reduced by the amount of the difference between the higher ambient temperature and 25°C.

42.10 A low-potential supply source may be used for conducting temperature tests on parts other than coils or transformer windings. Unless otherwise noted, the tests on all parts are to be conducted simultaneously, as the heating of one part may affect the heating of another part. Equipment intended to be mounted to a duct or the like is to be mounted during the heating test so that actual service conditions will be approximated. The temperature of the test chamber is to be the highest temperature at which the equipment is intended to function.

42.11 If the equipment is obviously not intended for continuous operation, the heating test may be conducted so that probable intermittent or short-time operation is considered.

42.12 If stalling of a motor on a timer or the like is part of the normal operation of the equipment while connected to a supply circuit as specified in Table 40.1, the temperature rise shall not exceed the limits specified in Table 42.1 with the motor stalled.

42.13 If stalling of a motor as described in 42.12 is not part of the normal operation, the values specified in Table 42.1 do not apply; but the motor shall be provided with impedance, thermal, or overload protection that complies with requirements for the application.

42.14 Equipment provided with a fuseholder is to be tested with an unplated copper bar, unplated copper tubing, or an equivalent material with negligible impedance instead of a regular fuse.

42.15 Other than at coils, temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2). See 42.20.

42.16 When thermocouples are used to determine temperatures in electrical equipment, it is common practice to use thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a potentiometer-type instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary.

42.17 The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to comply with the requirements for thermocouples as specified in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

42.18 A temperature is considered to be constant when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 5-minute intervals, indicate no change.

42.19 A thermocouple junction and adjacent thermocouple lead wire are to be securely held in good thermal contact with the surface of the material under test. In most cases, good thermal contact results from securely taping or cementing the thermocouple in place. If a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

42.20 The preferred method of measuring temperatures on coils is the resistance method, but temperature measurements may be used by either the thermocouple or resistance method, except that the thermocouple method is not to be used for a temperature measurement at a point where supplementary heat insulation is used.

42.21 The thermocouple method consists of the determination of temperature by the application of thermocouples to the hottest accessible parts.

42.22 When the resistance method is used, the temperature rise (Δt) of a winding is to be calculated by the following equation:

$$\Delta t = \frac{R_2}{R_1}(k + t_1) - (k + t_2)$$

in which:

R_2 is the resistance of the coil at the end of test in ohms;

R_1 is the resistance of the coil at the beginning 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;

t_1 is the room temperature in °C at the beginning of the test; and

t_2 is the room temperature in °C at the end of the test.

As it is generally necessary to de-energize the winding before measuring R_2, the 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. Instruments capable of measuring the winding resistance while the equipment is energized may be used.

43 Overvoltage and Undervoltage Tests

43.1 An electromagnet used on a relay or solenoid shall operate as intended when tested as described in 43.2 at the test voltages specified in Table 43.1.

Exception: If limits of operating voltage that may be marked on the unit nameplate in addition to the rated voltage extend beyond the overvoltage and undervoltage values of Table 43.1, the test potential for the overvoltage and undervoltage test is to be the marked value.

Table 43.1
Values of voltage for tests

Test	Voltage rating of equipment and corresponding test potential, volts[a]				
	110 – 120	220 – 240	254 – 277	440 – 480	550 – 600
Overvoltage, AC or DC	132	264	305	528	660
Undervoltage, AC	102	204	235	408	510
Undervoltage, DC	96	192	222	384	480

[a] If the rating of the equipment does not fall within any of the indicated voltage ranges, the equipment is to be tested at 110 percent of rated voltage during the overvoltage test, 85 percent of rated AC voltage, and 80 percent of rated DC voltage during the undervoltage test.

43.2 Each relay and solenoid is to be connected to a supply source maintained at the overvoltage until the coils reach a constant temperature. The potential is then to be reduced to the normal test voltage. Each relay and solenoid is to operate as intended at this test voltage. The potential is to be maintained at the normal test voltage until the coils reach constant temperatures. The potential is then to be reduced to the undervoltage condition. Each relay and solenoid is to operate as intended under this test condition. A relay or solenoid that will not be subject to continuous operation is to be energized at the overvoltage and at the normal test voltage for the maximum time permitted by its duty cycle, or until it reaches constant temperature, whichever occurs first.

43.3 If a relay and a solenoid are energized through a transformer, the voltage adjustments described are to be made at the transformer primary.

44 Leakage Current Test

44.1 The leakage current of cord-and-plug-connected equipment rated for a nominal 120-, 208-, or 240-volt supply when tested in accordance with 44.3 – 44.8 shall not be more than:

a) 0.5 milliampere for ungrounded (2-wire) portable equipment;

b) 0.5 milliampere for grounded (3-wire) portable equipment; and

c) 0.75 milliampere for grounded (3-wire) stationary equipment employing a standard attachment plug rated 20 amperes or less.

44.2 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.

44.3 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. A part is considered to be exposed unless it is guarded by an enclosure that complies with the requirements 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.

44.4 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 4 by 8 inches (10 by 20 cm) in contact with the surface. If the surface is less than 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.

44.5 The measurement circuit for leakage current is to be as illustrated in Figure 44.1. 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 kilohertz, 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 0.5 or 0.75 milliampere, the measurement is to have an error of not more than 5 percent of 60 hertz.

44.6 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.

44.7 A sample of the equipment is to be tested for leakage current starting with the as-received condition – the as-received condition 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 40.1. The test sequence, with reference to the measuring circuit, Figure 44.1, 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.

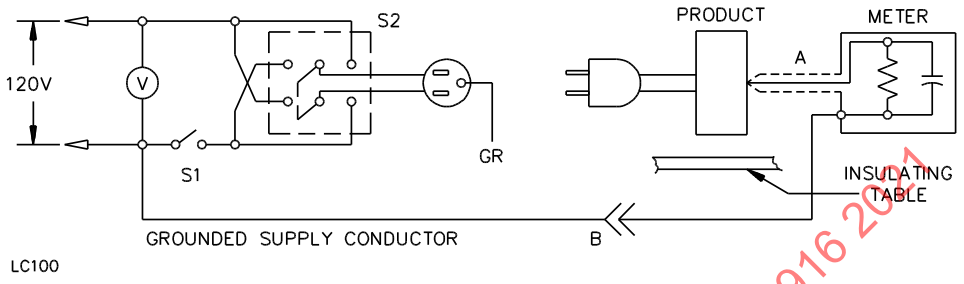
b) Switch S1 is then to be closed energizing the appliance and within 5 seconds the leakage current is to be measured using both positions of switch S2, and with the equipment switching devices in all their normal operating positions.

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 Temperature Test, Section 42.

44.8 Normally, the complete leakage current test program as described in 44.7 is to be conducted without interruption for other tests. However, with the concurrence of those concerned, the leakage current test may be interrupted to conduct other nondestructive tests.

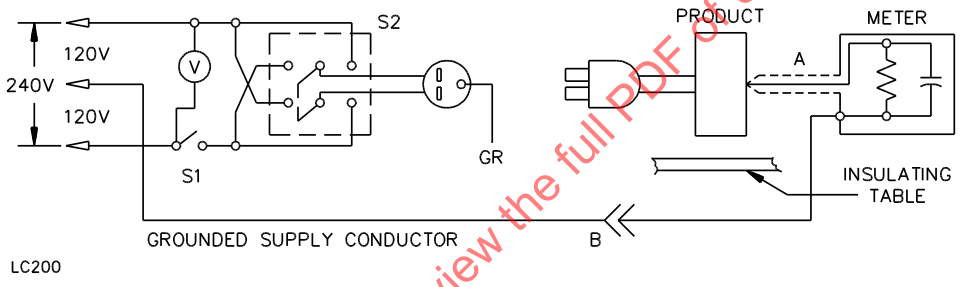
Figure 44.1

Leakage-current measurement circuits



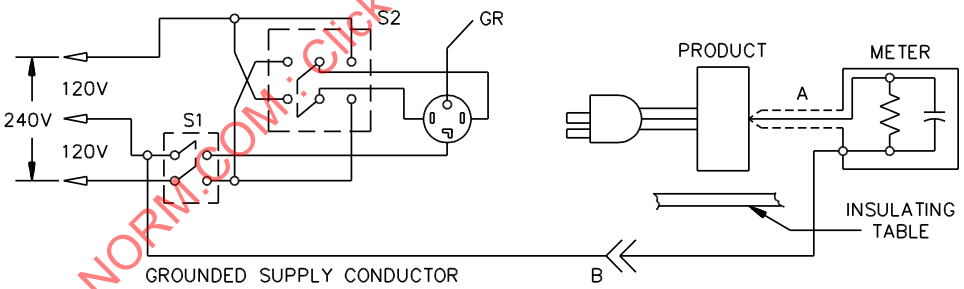
LC100

Equipment intended for connection to a 120-volt power supply.



LC200

Equipment intended for connection to a 3-wire, grounded neutral power supply, as illustrated above.



LC300

Equipment intended for connection to a 3-wire, grounded neutral power supply, as illustrated above.

A – Probe with shielded lead.

B – Separated and used as clip when measuring currents from one part of equipment to another.

45 Leakage Current Test Following Humidity Conditioning

45.1 Cord-and-plug-connected equipment rated for a nominal 120-, 208- or 240-volt supply shall comply with the requirements in the Leakage Current Test, Section 44, following exposure for 48 hours to air having a relative humidity of 88 ±2 percent at a room temperature of 32.0 ±2.0°C (89.6 ±3.6°F).

45.2 To determine whether equipment complies with 45.1, a sample of the equipment is to be heated to a temperature just above 34°C (93°F) to reduce the risk of condensation of moisture during conditioning. The heated sample is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 45.1. Following the conditioning, the sample is to be tested unenergized as described in 44.7(a). The sample is then to be energized and tested as described in 44.7 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

46 Normal Operation Test

46.1 Equipment utilizing a rheostat, a potentiometer, or a similar device intended for operator control or operating adjustment shall, after 100 operations under the most severe normal conditions for which the control is intended, show no serious faults, and the equipment shall be operable without risk of fire or electric shock during and after the test.

46.2 The requirements in 46.1 are intended to demonstrate the ability of the equipment to control and sequence the circuit under normal conditions of operation. For motor loads, this includes starting and running with the motor loaded to full load at normal speed.

47 Abnormal Operation Test

47.1 General

47.1.1 While operating at stabilized temperatures as in the Temperature Test, Section 42, there shall be no emission of flame or molten metal when the abnormal conditions described in 47.1.3 – 47.1.5 are imposed and maintained until ultimate results are obtained. Temperature- or current-sensitive devices or systems that cause termination of the test shall comply with the requirements for such devices. Opening or shorting of one or more output-power semiconductor devices may occur as a result of this test.

47.1.2 With reference to 47.1.1, the investigation of electronic current-limiting circuits will involve conducting a component evaluation study. See Component Evaluation, Section 66.

47.1.3 Three-phase equipment is to be operated with one line disconnected at the input. The line determined to be the one to which any protective devices are the least responsive is to be disconnected. The test is to be conducted by disconnecting one line with the equipment operating at maximum normal load and is to be repeated by energizing the equipment after one lead is disconnected.

47.1.4 Equipment having formed ventilation is to be operated with the rotor of a blower motor or motors locked until temperatures stabilize.

47.1.5 Enclosed equipment 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, which is intended to represent the most severe blockage; the test is then to be repeated under a full-blocked condition.

47.2 Rectifier – capacitor combinations

47.2.1 If a combination of a rectifier and a capacitor is connected directly across the branch circuit, a risk of fire, electric shock, or injury to persons shall not result from short-circuiting the capacitor or one or more sections of the rectifier. Operation of an overcurrent device is considered to comply with this requirement.

47.2.2 If a semiconductor rectifier is provided, three samples are to be tested with the rectifier terminals short-circuited. Three additional samples are to be tested with the terminals of the electrolytic capacitor connected together.

47.2.3 Three complete tests are to be conducted under each of the conditions described in 47.2.2, using new components in each test. The equipment to be tested is to be connected as indicated in Table 40.1.

47.2.4 The equipment is not considered to comply if flame is emitted from the overall enclosure of the equipment, or if a permanent path is established between live parts and exposed metal.

47.2.5 The tests described in 47.2.1 – 47.2.3 need not be conducted if one or both of the following conditions exist:

a) If there is 10,000 ohms or more of additional series impedance in a circuit in which the voltage is 125 volts or less or

b) If there is 20,000 ohms or more of additional series impedance in a circuit in which the voltage is higher than 125 volts but is not higher than 250 volts.

47.3 Feedback sensing devices

47.3.1 A current transformer, tachometer, transducer, or similar feedback device that is isolated from line-voltage circuits is considered to be a power-supplying source and shall be subjected to an investigation.

47.4 Isolation devices

47.4.1 A device used to provide isolation between circuits shall be subjected to the following tests:

a) Components incorporated within circuitry where isolation is necessary shall be open- or short-circuited to determine whether the isolation feature is maintained under this condition.

b) Each winding (or pair of circuit terminals) of isolation devices shall be short-circuited to determine if the isolation feature is still maintained.

47.4.2 As a result of the tests described in 47.4.1, there shall be no emission of flame or molten metal and the assembly shall withstand for 1 minute the following dielectric strength values between different circuits:

a) Twice the maximum rated voltage plus 1000 volts between primary and secondary circuits, and between line-voltage parts and grounded metal.

b) Five hundred volts between the low-voltage secondary circuits and grounded metal.

47.4.3 A resistor employed to obtain isolation shall not dissipate more than its rated wattage with the other components in the circuit short-circuited.

47.5 Abnormal switching test

47.5.1 Controls incorporating electronic circuitry to trigger the switching device during a more advantageous electrical condition, such as at zero crossing, shall be subjected to this abnormal switching test. This test is applicable when:

a) Loads and circuits are non-safety.

b) Switching components are used beyond their evaluated ratings. These evaluated ratings of switching devices are typically determined without electronic triggering techniques, such as zero cross switching.

47.5.2 Two test samples are prepared and connected as follows:

a) The trigger circuit of the switching device is to be removed or modified to allow random switching.

b) A ground arc indicating fuse is connected to accessible dead metal of the control. The ground arc detection fuse shall be rated not greater than 3A and not less than the working voltage.

c) The control is to be supported on a softwood surface, and is to be covered with a double layer of cheesecloth conforming to the outline of the control. The cheesecloth requirements shall be according to 48.1.2.

d) The rated supply shall be connected through a branch circuit protection device sized according to installation code requirements.

e) The control is connected to it's rated electrical load.

47.5.3 The prepared test samples shall be operated in accordance with the endurance test requirements specifying the number of operating cycles and on/off periods using random switching. The test samples shall be operated until either the required number of endurance test cycles are achieved or until ultimate results are demonstrated for 1h stabilized duration.

47.5.4 Immediately after each abnormal switching test, each control shall be subjected to the Dielectric Voltage-Withstand Test, Section 52.

47.5.5 The control shall either operate as intended in accordance with the endurance test requirements, or demonstrate an end-of-life fail safe condition with no evidence of an imminent electrical shock, fire or injury to persons. There shall be:

a) No opening of the ground arc detection fuse.

b) No emission of the flame or molten metal, or ignition of the cheesecloth.

c) No opening of the branch circuit protection device.

d) No breakdown during the post-dielectric withstand testing.

48 Component Breakdown Test

48.1 Effects on equipment

48.1.1 There shall be no emission of flame or molten metal, or ignition of a double layer of cheesecloth when the equipment is tested as described in 48.1.2.

48.1.2 Cheesecloth is to be loosely placed over all openings of ventilated equipment or totally around open equipment. Power circuit components, such as capacitors, diodes, or other solid-state components are to be short- or open-circuited, one at a time. The cheesecloth is to be untreated cotton cloth running 14 – 15 yards per pound (26 – 28 m^2/kg) and for any square inch, a count of 32 threads in one direction and 28 in the other direction.

48.1.3 With reference to 48.1.1, 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- or short-circuiting of another component.

b) For components in Class 2 circuits, or other circuits that need not be investigated in accordance with this standard.

c) On power semiconductor devices, if equivalent testing is accomplished during other tests.

d) On devices that have been subjected to the Component Evaluation, Section 66.

e) If the circuit components are contained in a complete enclosure without ventilating openings.

48.2 Effects on controlled load

48.2.1 With reference to 11.2, the effects of component short circuits and open circuits on the controlled load such as half wave condition or chattering of electromagnets, shall be determined by introducing specific short circuits and open circuits in the electronic control when the actual load is connected. For equipment incorporating safety circuits, see Component Evaluation, Section 66.

48.2.2 The likelihood of specific short circuits and open circuits may be determined by Component Evaluation, Section 66.

49 Overload Test

49.1 General

49.1.1 An ampere-rated switching device not intended for controlling a motor shall be subjected to an overload test consisting of making and breaking for 50 cycles of operation, at a rate of six cycles per minute, a current of 150 percent of the rated value, at the voltage specified in Table 40.1. There shall be no electrical or mechanical breakdown or malfunction of the device, nor undue burning, pitting, or welding of the contacts. For a device having a tungsten-filament-lamp load rating, the load characteristics are to be in accordance with 49.2.1 – 49.2.11 and the operating cycle is to be in accordance with 49.2.7.

49.1.2 Other than as noted in 49.1.6 and 49.1.8, a switching device intended for full-voltage motor starting shall be subjected to a locked-rotor test consisting of making and breaking for 50 cycles of operation, at a rate of six cycles per minute, a current as described in 49.1.3 and Table 49.1, at the voltage specified in Table 40.1. There shall be no electrical or mechanical breakdown or malfunction of the device, nor undue burning, pitting, or welding of the contacts.

Table 49.1
Method of determining currents for overload tests

Device rated in	Current in amperes and power factor (PF)	
	Locked-rotor, 49.1.2, 49.1.6, and 49.1.8	150-percent-current, 49.1.6 and 49.1.8
Horsepower	AC: Six times the full-load current specified in Table 49.3 , PF .40 – .50	AC: 1.5 times the full-load current specified in Table 49.3 , PF .75 – .80
	DC: Ten times the full-load current specified in Table 49.2 , non-inductive	DC: 1.5 times the full-load current specified in Table 49.2 , non-inductive
Full-load and locked-rotor amperes	Rated locked-rotor amperes, PF – same as above	1.5 times rated full-load amperes, PF – same as above

49.1.3 The current for the overload tests mentioned in 49.1.2, 49.1.6, and 49.1.8 is to be as specified in Table 49.1.

49.1.4 A switching device with a pilot duty rating and intended to control an electromagnet shall be subjected to an overload test consisting of 50 operations, making and breaking a circuit of rated frequency and 110 percent of the voltage specified in Table 40.1, at intervals of 10 seconds, with the contacts closed for approximately 1 second each cycle. The load is to consist of an electromagnet representative of the magnet-coil load that the device is intended to control – the normal current to be determined from the voltage and volt-ampere rating of the device. The test coils shall be those described in 50.3. The test is to be conducted with the contactor free to operate; for example, not blocked in either the open or closed position. There shall be no electrical or mechanical breakdown or malfunction of the device nor undue burning, pitting, or welding of the contacts.

49.1.5 A device that has been investigated and determined to comply with the requirements for controlling an alternating-current motor may be used for alternating-current pilot duty without further overload or endurance tests if:

a) During the locked-rotor motor-controller test, the contacts were caused to make and break, for 50 cycles of operation at a rate of six cycles per minute, a current having a value as specified in the second column of Table 49.1 at a power factor of 0.5 or less; and

b) The pilot-duty inrush current at the same voltage is not more than 67 percent of:

1) The rated locked-rotor motor current of the device; or

2) The locked-rotor current corresponding to the horsepower rating, depending on the basis on which the device is rated.

49.1.6 A switch that is not intended primarily to make and break motor current under locked-rotor conditions, but that has a manual adjusting or regulating means that may cause it to be so used, shall comply with the requirements in 49.1.2 for a locked-rotor test.

49.1.7 For a switch intended for operation on direct current, five operations are to be conducted at intervals of 30 seconds. The device shall also comply with the requirements in 49.1.9 pertaining to the 150-percent overload test.

49.1.8 A switch that may make a motor circuit under locked-rotor conditions, but that will never be required to break the circuit under such conditions, shall be subjected to an overload test consisting of 50 cycles of making and breaking, at a rate of six cycles per minute, a current as specified in the third column of Table 49.1. For an alternating-current device, the voltage of the test circuit is to be as specified in Table 40.1. For a direct-current device it is to be 50 percent of the value. The switch shall also be subjected to the locked-rotor test described in 49.1.2, except that it is to make – not break – the circuit only. A safety control that is subjected to the test of making – but not breaking – locked-rotor current shall open the

circuit under no-load conditions without more than a 20 percent change in its calibration. There shall be no electrical or mechanical malfunction of the device, nor undue burning, pitting, or welding of the contacts.

49.1.9 The test cycle is to be one second on and nine seconds off, if the construction of the device permits the test to be so conducted.

49.1.10 If an ampere-rated device has the same ampere rating at more than one voltage, a test at the highest voltage is considered to be representative of tests at the lower voltages, but if the device has a higher ampere rating at the lower voltage than at the higher ones, tests are to be conducted at the highest and lowest voltages.

49.1.11 An alternating-current device that does not have a frequency rating is to be tested on a circuit having a frequency of 60 hertz, except that a circuit having a lower frequency may be used with the concurrence of those concerned.

49.1.12 A multiple-pole, a sequencing, a double-throw, or a double-pole, single-throw (normally open, normally closed – sometimes called double-pole, opposite-throw) control, and the like are to be tested with a load on each pole. The loads on a double-pole or multiple-pole control are to be connected so that opposite polarity on the poles results unless the same polarity rating is assigned to the control.

49.1.13 If an electronic control for controlling a contactor, a relay, or other magnetically operated device is integral within a system the test is to be conducted with the actual electromagnet as the load.

49.1.14 If a horsepower-rated device has more than one voltage rating, the overload test or tests are to cover the conditions of maximum voltage, power, and current.

49.1.15 Other than as noted in 49.1.4 and 50.3, a current-interrupting device for use on direct current shall be tested with a noninductive resistance load. A current-interrupting device for use on alternating current shall be tested with an inductive load.

49.1.16 The power factor of an inductive load shall be 0.75 – 0.80, except that it shall be 0.40 – 0.50 for a load simulating locked-rotor conditions in a motor, and shall not be more than 0.35 for a pilot-duty load.

49.1.17 Table 49.2 and Table 49.3 give full-load currents corresponding to motor horsepower ratings, and are to be used in determining loads for the various tests specified for horsepower-rated equipment.

Table 49.2
Full-load motor-running currents in amperes corresponding to various DC horsepower ratings

Horsepower (watts output)		90 volts	110 – 120 volts	180 volts	220 – 240 volts	500 volts	550 – 600 volts
1/10	(75)	–	2.0	–	1.0	–	–
1/8	(93)	–	2.2	–	1.1	–	–
1/6	(124)	–	2.4	–	1.2	–	–
1/4[a]	(187)	4.0	3.1	2.0	1.6	–	–
1/3	(249)	5.2	4.1	2.6	2.0	–	–
1/2	(373)	6.8	5.4	3.4	2.7	–	–
3/4	(560)	9.6	7.6	4.8	3.8	–	1.6
1	(746)	12.2	9.5	6.1	4.7	–	2.0

Table 49.2 Continued on Next Page

Table 49.2 Continued

Horsepower (watts output)		90 volts	110 – 120 volts	180 volts	220 – 240 volts	500 volts	550 – 600 volts
1-1/2	(1.1 kW)	–	13.2	8.3	6.6	–	2.7
2	(1.5 kW)	–	17.0	10.8	8.5	–	3.6
3	(2.2 kW)	–	25.0	16.0	12.2	–	5.2
5	(3.7 kW)	–	40.0	27.0	20.0	–	8.3
7-1/2	(5.6 kW)	–	58.0	–	29.0	13.6	12.2
10	(7.5 kW)	–	76.0	–	38.0	18.0	16.0
15	(11 kW)	–	110.0	–	55.0	27.0	24.0
20	(15 kW)	–	148.0	–	72.0	34.0	31.0
25	(18.7 kW)	–	184.0	–	89.0	43.0	38.0
30	(22.4 kW)	–	220.0	–	106.0	51.0	46.0
40	(30 kW)	–	292.0	–	140.0	67.0	61.0
50	(37.3 kW)	–	360.0	–	173.0	83.0	75.0
60	(45 kW)	–	–	–	206.0	99.0	90.0
75	(60 kW)	–	–	–	255.0	123.0	111.0
100	(75 kW)	–	–	–	341.0	164.0	148.0
125	(93.3 kW)	–	–	–	425.0	205.0	185.0
150	(112 kW)	–	–	–	506.0	246.0	222.0
200	(150 kW)	–	–	–	675.0	330.0	294.0

[a] The full-load current for a 1/4-horsepower, 32-volt DC motor is 8.6 amperes.

Table 49.3
Full-load motor-running currents in amperes corresponding to various AC horsepower ratings

Horsepower (watts output)		110 – 120 volts		220 – 240 volts[a]		440 – 480 volts		550 – 600 volts	
		Single phase	Three phase	Single phase	Three phase	Single phase	Three phase	Single phase	Three phase
1/10	(75)	3.0	–	1.5	–	–	–	–	–
1/8	(93)	3.8	–	1.9	–	–	–	–	–
1/6	(124)	4.4	–	2.2	–	–	–	–	–
1/4	(187)	5.8	–	2.9	–	–	–	–	–
1/3	(249)	7.2	–	3.6	–	–	–	–	–
1/2	(373)	9.8	4.0	4.9	2.0	2.5	1.0	2.0	0.8
3/4	(560)	13.8	5.6	6.9	2.8	3.5	1.4	2.8	1.1
1	(746)	16.0	7.2	8.0	3.6	4.0	1.8	3.2	1.4
1-1/2	(1.1 kW)	20.0	10.4	10.0	5.2	5.0	2.6	4.0	2.1
2	(1.5 kW)	24.0	13.6	12.0	6.8	6.0	3.4	4.8	2.7
3	(2.2 kW)	34.0	19.2	17.0	9.6	8.5	4.8	6.8	3.9
5	(3.7 kW)	56.0	30.4	28.0	15.2	14.0	7.6	11.2	6.1
7-1/2	(5.6 kW)	80.0	44.0	40.0	22.0	21.0	11.0	16.0	9.0
10	(7.5 kW)	100.0	56.0	50.0	28.0	26.0	14.0	20.0	11.0

Table 49.3 Continued on Next Page

Table 49.3 Continued

Horsepower (watts output)		110 – 120 volts		220 – 240 volts[a]		440 – 480 volts		550 – 600 volts	
		Single phase	Three phase	Single phase	Three phase	Single phase	Three phase	Single phase	Three phase
15	(11 kW)	135.0	84.0	68.0	42.0	34.0	21.0	27.0	17.0
20	(15 kW)	–	118.0	88.0	54.0	44.0	27.0	35.0	22.0
25	(19 kW)	–	136.0	110.0	68.0	55.0	34.0	44.0	27.0
30	(22 kW)	–	160.0	136.0	80.0	68.0	40.0	54.0	32.0
40	(30 kW)	–	208.0	176.0	104.0	88.0	52.0	70.0	41.0
50	(37 kW)	–	260.0	216.0	130.0	108.0	65.0	86.0	52.0
60	(45 kW)	–	–	–	154.0	–	77.0	–	62.0
75	(50 kW)	–	–	–	192.0	–	96.0	–	77.0
100	(75 kW)	–	–	–	248.0	–	124.0	–	99.0
125	(94 kW)	–	–	–	–	–	156.0	–	125.0
150	(112 kW)	–	–	–	–	–	180.0	–	144.0
200	(150 kW)	–	–	–	–	–	240.0	–	192.0

[a] To obtain full-load currents for 200 and 208 volt motors, increase corresponding 220 – 240 volt-currents by 15 and 10 percent, respectively, for single-and 3-phase motors. To obtain full-load currents for 265- and 277-volt motors, decrease the corresponding 220 – 240 volt currents by 13 and 17 percent respectively. The 265- and 277-volt ratings are applicable for equipment rated 2 horsepower or less, single-phase only.

49.1.18 Current-interrupting tests for an alternating current device are to be conducted at the voltage specified in Table 40.1. For a direct-current device, current-interrupting tests are to be conducted at 50 percent of the voltage specified in Table 40.1 in accordance with 49.1.8 and 50.1.

49.1.19 A circuit in which the closed-circuit voltage is 100 – 110 percent of the test potential specified in Table 40.1 may be used for the tests mentioned in 49.1.18.

Exception: For a device rated more than 25 horsepower (18.7 kW output) or more than 100 amperes, the open-circuit voltage is to be 110 percent of the value specified in Table 40.1, or as much above that value as the closed-circuit voltage is below it, whichever is less.

49.1.20 Alternating-current interrupting tests are to be conducted on a circuit having a frequency of 60 hertz. Tests at 25 – 60 hertz may, however, be considered to be representative.

49.1.21 A 2-pole or 4-pole device is to be tested on a single-phase or direct-current circuit. In a 4-pole device, adjacent poles are to be used, one pole being that nearest the enclosure. If the pole spacing varies, an additional test is to be conducted between the poles with the smallest spacing, to cover use on 2-phase interconnected systems.

49.1.22 A 3-pole device for polyphase use is to be tested on a 3-phase circuit. A 3-pole device for use on a direct-current or single-phase system with a grounded neutral is to be tested with rated voltage applied to the outside poles and with the middle pole electrically connected to the line and to the midpoint of a balanced load.

49.1.23 For a device that is intended for connection to a grounded-neutral system and is marked in accordance with 75.10 or 75.11, the enclosure is to be connected during the test through a 3-ampere cartridge fuse to the grounded conductor of the circuit. For any other system the enclosure is to be connected through such a fuse to the live pole least likely to arc to ground.

49.2 Tungsten-filament-lamp load characteristics

49.2.1 The test circuit, including the generator or other source of supply for a device with a tungsten-filament-lamp load rating for use on direct current, is to provide a current inrush through the switch and load of not less than eight times the normal current when the circuit is closed on a 20-ampere load. The circuit is to be such that the peak value of the inrush current will be reached within 1/240 of a second after the circuit is closed. If a synthetic load is used, its characteristics are to, in addition, be such that the current-inrush factor is not less than:

a) 9 with a 15-ampere load;

b) 10 with a 10-ampere load;

c) 11 with a 5 ampere load;

d) 12 with a 3-ampere load;

e) 12-1/2 with a 2-ampere load; and

f) 13 with a 1-ampere load

Exception: If the required inrush is available for a lower current rating with testing limited to such rating, a tungsten-filament-lamp load and the supply circuit need not be sufficient for the 20 ampere load test.

49.2.2 The test circuit, including the generator or other source of supply for a device with a tungsten-filament-lamp load rating used on alternating current, shall provide a peak current inrush through the switch and load not less than the value given in Table 49.4 when the circuit is closed on a load corresponding to a rating equal to or greater than the rating of the device. The circuit shall be such that the highest value of the inrush current will be reached within 1/240 of a second after the circuit is closed.

Exception: If the required inrush is available for a lower current rating with testing limited to such rating, a tungsten-filament-lamp load and the supply circuit need not be sufficient for the 20 ampere load test described above.

Table 49.4
Tungsten-filament-lamp load test circuit characteristics

Steady-state current (rms), amperes	Minimum inrush current (Peak), amperes
10	141
15	191
20	226

49.2.3 A synthetic load and a combination synthetic and tungsten-filament-lamp load, used to simulate a tungsten-filament-lamp load for testing on alternating current, is to be tested as described in 49.2.4 and 49.2.9, and also with regard to special conditions which are introduced by use on alternating current.

49.2.4 Oscillograph studies are to be used to determine compliance of a test circuit, including the generator or other source of supply, for testing with a tungsten-filament-lamp. If the circuit is tested at a normal (steady state) current flow of 20 amperes and inrush currents as indicated in 49.2.1 and Table 49.4 are recorded, the test circuit is considered to have a capacity for testing switches rated up to and including 60 amperes. With reference to a 60-hertz timing wave, the peak values of inrush current as shown by oscillograms are to be reached within 1/4 cycle.

49.2.5 The characteristics of a direct-current test circuit shall be determined from 12 or more oscillograms, and testing equipment may be used if not less than half the oscillograms show at least the minimum current-inrush factor.

49.2.6 The characteristics of an alternating-current test circuit shall also be determined from 12 or more oscillograms. Those which indicate that the current is decreasing (that the part of the sine wave in question is approaching the zero point) shall be disregarded. Twelve or more oscillograms taken at other points on the sine wave should indicate whether the capacity of the test circuit can produce the minimum current-inrush factor based on observed peak values.

49.2.7 If tungsten-filament-lamps are used as the load for a device designed for use with such lamps, the load shall be made up of the smallest possible number of lamps having standard ratings. In determining the smallest number of lamps necessary, the maximum lamp size required to be used is 500 watts. Larger lamps may be used if desired. The operating cycle shall be such that the lamps are off for at least 55 seconds of each test cycle. If a device is operated at the rate of 10 cycles per minute, at least ten banks of lamps controlled by a commutator are necessary for each switch under test.

49.2.8 A synthetic load may be used instead of tungsten-filament-lamps and may consist of noninductive resistors if they are so connected and controlled that a portion of the resistance is shunted during the closing of the switch under test or if a portion of the load is cut out prior to opening the switch. A synthetic load may also consist of a noninductive resistor or resistors and a capacitor in parallel, in which case the load is to be calibrated immediately after the capacitor has been charged and discharged in the usual manner. A combination load consisting of tungsten-filament-lamps and resistors and/or capacitor shall be considered a synthetic load.

49.2.9 A test circuit (including the generator or other source of supply) for testing with a synthetic load shall be determined to comply in a manner similar to that described in 49.2.6, consideration being given to the provision of higher current-inrush factors with the lower current loads, as required in 49.2.1.

49.2.10 A synthetic load is to be calibrated against and equivalent to a tungsten-filament-lamp load in the test circuit. The calibration of a synthetic load is to be checked at intervals to determine that none of the constants of the circuit or load change with time or use.

49.2.11 The characteristics of a synthetic load are to be such that the inrush current will be as specified in 49.2.1 – 49.2.3. In addition, the current in the capacitor/resistance load or the combination load mentioned in 49.2.8 shall not be less than half the required inrush current at 1/60 second and not less than twice the steady-state current at 7/120 second after the circuit is closed. The current in a straight resistance load shall be the full inrush value for at least 15 milliseconds after the circuit is closed.

50 Endurance Test

50.1 A switch is to be operated manually, by means of a machine, or by automatic means for the number of cycles specified in Table 50.1, and at the rate specified unless the device requires a longer time to complete a cycle of operation. If an electrical load is involved, and except as otherwise noted, a switch shall make and break its rated current at the voltage specified in Table 40.1. Switch contacts for control of a motor are to be tested with full-load motor current; if the switch is rated in horsepower instead of full-load motor current, the latter value shall be determined from Table 49.2 or Table 49.3, as applicable. If the switch contacts control a direct-current motor, and the switch normally will make but not break the motor circuit under locked-rotor conditions, the potential of the test circuit is to be 50 percent of the value specified in Table 40.1. For a device having electronic ballast, self-ballasted LED and CFL, or LED driver load rating, the load characteristics are to be in accordance with Section 51. There shall be no electrical or mechanical breakdown of the device, nor undue burning, pitting, or welding of the contacts.

Table 50.1
Number of cycles for endurance test

Types of devices	Number of cycles of operation[a]					
	With current	Without current	First	Maximum cycles per minute	Last	Maximum cycles per minute
Safety controls	100,000	–	75,000	6	25,000	1[b]
Refrigeration controls	30,000	–	24,000	6	6,000	1[b]
Water-heater controls	30,000	–	30,000	1[b]	–	–
Manually operated switches	6,000	–	6,000	6	–	–
Protective switches not normally required to make and break a circuit, such as manually reset safety controls, high-pressure and high-temperature cutouts used in addition to the regular operating control, and the like, but not including automatically-reset controls	1,000	5,000	1,000	1[b]	5,000	c
Motor controllers and ampere-rated devices not mentioned above, and timing mechanisms	6,000	–	6,000	1[b]	–	–
Electronic ballast, self ballasted LED and Compact Fluorescent Lamps, LED drivers and similar loads with capacitive load characteristics	6,000	–	6,000	6	–	–

[a] Magnetic, manual and motor-operated switches, or the like, and switches that snap with lost motion and do not creep, may be tested at the rate of 6 cycles per minute.

[b] For all controls, the test is to be conducted with 50 ±20 percent on time. A temperature- or pressure-operated control is to be so tested, using a slow rate of change.

[c] When no current is used, the switch may be operated at any convenient speed.

50.2 The conditions for the endurance test shall be as described in 49.1.10 – 49.1.23.

50.3 A contact device designated for pilot duty is to be operated for the number of cycles specified in Table 50.1, making and breaking a circuit of rated frequency at the voltage specified in Table 40.1. Unless the design of the device requires a longer time to complete a cycle of operation, the rate of operation for the test shall be as follows: for a manually operable device, the first 1000 cycles shall be at the rate of 1 cycle per second – except that the first 10 or 12 cycles shall be made as rapidly as possible – and the remaining cycles shall be at the rate of 6 cycles per minute, with the device closed for approximately 1 second each cycle; and for a self-actuated device the cycle rate shall be as specified in Table 50.1. The load shall consist of an electromagnet representative of the magnet-coil load that the device is intended to control. The normal current shall be determined from the voltage and volt-ampere rating of the device. The test current is to be the normal current; and for an alternating-current device, the power factor shall be 0.35 or less and the inrush current shall be ten times the normal current, unless marked in accordance with 72.12. The test is to be conducted with the contactor free to operate, that is, not blocked either open or closed. There shall be no electrical or mechanical breakdown of the device nor undue pitting or burning of contacts.

50.4 If a device requiring an endurance test of 100,000 cycles has two or more electrical ratings – for example, different currents at different voltages – it may be tested for not less than 25,000 cycles at each rating, but the total number of cycles on any one sample is not to be more than 100,000. At least one sample is to be tested for 100,000 operations.

50.5 If a device requiring an endurance test of 30,000 cycles has two or more electrical ratings, it may be tested for not less than 7,500 cycles at each rating, but the total number of cycles on any one sample is not to be more than 30,000. At least one sample is to be tested for 30,000 operations.

50.6 With reference to 50.4 and 50.5, the volt-amperes of the smallest rating shall be at least 75 percent of the volt-amperes of the largest rating.

51 Electronic Ballast, CFLs and LED Driver Rated Controls

51.1 A control intended for use with electronic ballasts, self ballasted LED and Compact Fluorescent Lamps, LED drivers and similar loads with capacitive load characteristics, having a rated current (steady state current) and rated voltage in accordance with Table 51.1 and/or Table 51.2 shall be marked in accordance with 72.20.

Table 51.1
Peak current requirements with pulse width less than or equal to 2 ms for endurance test

Steady state current (A)	Peak current (A), 120 V AC	Pulse width 120 V AC (mS). See Note 2	I^2t (A^2 sec) 120 V AC. See Note 1	Peak current (A), 277 V AC	Pulse width 277 V AC (mS). See Note 2	I^2t (A^2 sec) 277 V AC. 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 and pulse duration of 2 mS (t).

2 – Pulse widths shown will provide adequate performance with electronic ballasts having pulse widths up to 2 ms, in accordance with the Standard for Lamp Ballasts – High Frequency Fluorescent Lamp Ballasts , ANSI_ANSLG C82.11, or the Standard for Lamp Ballasts Low-Frequency Square Wave Electronic Ballasts – for Metal Halide Lamps, ANSI_ANSLG C82.14.

Table 51.2
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

Table 51.2 Continued on Next Page

Table 51.2 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
5	450	1.15	476
8	492	1.5	569
10	508	1.67	606
12	529	1.86	658
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).

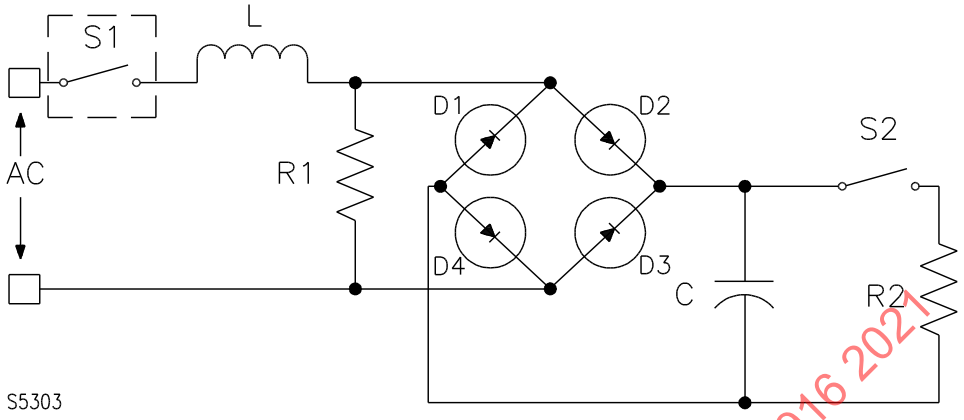
2 – Pulse widths shown will provide adequate performance with electronic ballasts having pulse widths up to 2.35 ms, in accordance with the Standard for Lamp Ballasts – High Frequency Fluorescent Lamp Ballasts, ANSI_ANSLG C82.11, or the Standard for Lamp Ballasts Low-Frequency Square Wave Electronic Ballasts – for Metal Halide Lamps, ANSI_ANSLG C82.14.

51.2 The synthetic load described in 51.3 and 51.4 shall be used as the load for testing. The endurance test shall be completed with that load.

51.3 The series coil values must be adjusted based on the input line characteristics to achieve the peak currents listed in Table 51.1 or Table 51.2. 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 51.2.

Figure 51.1

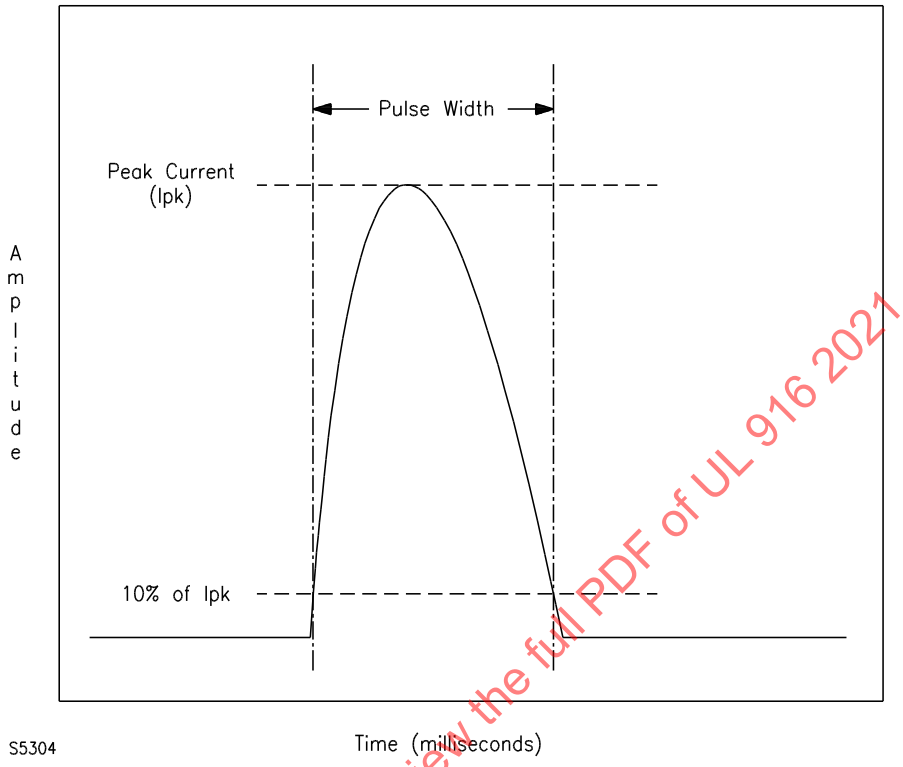
Typical test circuit diagram



Reference	Description
AC	Test voltage is either 277 Vac, 347 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., 5A, 8A... 16A)
D1 – 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 or 347 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

Figure 51.2

Waveform per synthetic measurement of pulse width and peak current



51.4 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 51.1. 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.

51.5 For products rated in excess of 347 Vac, the controls shall be tested with the specific model of electronic ballast(s) they are intended to control. The manufacturer's name and model number of the electronic ballast(s) with which the control is intended to be used shall be marked either on the product or provided with the control on the packaging or stuffer sheet.

51.6 The characteristics of the waveform (peak currents and pulse width) shall be recorded using an oscilloscope.

52 Dielectric Voltage-Withstand Test

52.1 General

52.1.1 The equipment shall withstand for 1 minute without breakdown the application of an alternating potential of 1000 volts plus twice maximum rated voltage between:

a) Line-voltage live parts and grounded or exposed metal parts or the enclosure with the contacts open and closed,

b) Line-voltage live parts of opposite polarity with the contacts closed,

c) Live parts of line- and low-voltage circuits, line-voltage and isolated-limited-power secondary circuits, and different line-voltage circuits, and

d) Live parts of different secondary circuits.

52.1.2 Equipment using a low-voltage circuit shall withstand for 1 minute without breakdown the application of an alternating potential of 500 volts applied between low-voltage live parts of opposite polarity with contacts, if any, closed, and between low-voltage live parts and the enclosure and grounded dead metal parts.

52.1.3 The opposite polarity dielectric voltage-withstand test may be omitted for a portion of a low-voltage, nonsafety circuit that is beyond any fixed impedance.

52.1.4 A transformer shall withstand for 1 minute without breakdown the application of an alternating potential of 1000 volts plus twice the maximum rated primary voltage, at rated frequency, between primary and secondary windings and between the primary winding and the core or enclosure.

52.1.5 If the equipment involves a meter or meters, such instruments are to be disconnected from the circuit and the complete equipment subjected to a dielectric voltage-withstand test as described in 52.1.1 – 52.1.4. The meter or meters is then to be tested separately in accordance with the tests outlined in 52.1.1 or 52.1.2 – whichever is applicable– except that an ammeter in a line-voltage circuit shall be tested at 1000 volts.

52.1.6 To determine whether the equipment complies with the requirements in 52.1.1 – 52.1.5, it is to be tested using 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 until the required test level is reached, and is to be held at that level for 1 minute. The increase in the applied potential is to be at a substantially uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter.

52.1.7 If the charging current through a capacitor or capacitor-type filter connected across the line, or from line to earth ground, is large enough to make it impossible to maintain the required alternating-current test potential, the capacitors and capacitor-type filters may be tested as described in 52.1.8.

52.1.8 The capacitors and capacitor-type filters mentioned in 52.1.7 are to be subjected to a direct-current test potential of 1414 volts for equipment rated 250 volts or less or 1414 volts plus 2.828 times the rated circuit voltage for equipment rated at more than 250 volts. The direct-current test potential is to be maintained for 1 minute without breakdown.

52.1.9 The test potential may be obtained from any convenient source of sufficient capacity to maintain the potential specified in Table 52.1, except in case of breakdown. The output voltage of the test apparatus is to be monitored. Starting at zero, the applied potential is to be increased at a rate of approximately 200 volts per second until the required test value is reached and is to be held at that value for 1 minute. A direct-current source is to be used for testing a direct-current circuit.

Table 52.1
Magnitude of test potential

Maximum voltage (rms) in the circuit[a]	Test potential
30 or less (42.4 peak)	No test
More than 30 (42.4 peak) but not more than 333.3 (471.3 peak)	Ten times maximum voltage in circuit (maximum of 1,000 V rms)
More than 333.3 (471.3 peak) but not more than 1,000 (1,414 peak)	Three times maximum voltage in circuit
More than 1,000 (1,414 peak)	1,750 V plus 1.25 times voltage in circuit
[a] If the peak voltage is greater than 120 percent of 1.414 times the rms voltage, the circuit shall be tested as if the voltage were peak voltage divided by 1.414.	

52.1.10 Printed-wiring assemblies and other electronic-circuit components that can be damaged by application of the test potential or that would short-circuit the test potential are to be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand tests are conducted. A representative subassembly may be tested instead of an entire unit. Rectifier diodes in the power supply may be individually shunted before the test is made to protect them in the case of a fault elsewhere in the secondary circuits.

52.2 Secondary circuits (controlled environment)

52.2.1 Secondary circuits other than those with a voltage of 42.4 volts peak (30 volts rms) or less shall withstand for 1 minute the test potential specified in Table 52.1 applied:

a) Between primary and secondary circuits and

b) Successively between secondary circuits and earth ground with all chassis-connected components (earth grounded) disconnected at the chassis-to-earth-ground connection.

52.3 Power transformers

52.3.1 Each power transformer shall operate without breakdown while the potential specified in Table 52.1 is induced for 1 minute in each secondary winding that furnishes power at a higher potential than the primary windings. Windings of special transformers that do not serve a prime power-supply function, such as the resonant winding of a constant-voltage transformer, are excluded from this requirement.

52.3.2 A power transformer shall withstand for 1 minute without breakdown the application of an alternating potential of 1000 volts plus twice the maximum rated primary or secondary voltage, at rated frequency, between primary and secondary windings, and shall withstand under the same conditions the application of an alternating potential of 1000 volts plus twice the rated voltage of each winding, at rated frequency, between each winding and the core or enclosure, except that the test between primary and secondary windings is omitted for an autotransformer.

52.3.3 Primary- and secondary-circuit wiring connected to a transformer is to be disconnected for the test mentioned in 52.3.1. An essentially sinusoidal source is to be used, and the frequency of the source may be in the range of 180 – 1000 hertz if necessary to prevent saturation of the core.

52.4 Induced potential (crossover lead)

52.4.1 Each of three separate magnet-coil-winding samples shall withstand without breakdown the test specified in 29.3.1(b)(2) after constant temperatures have been reached as the result of operation under the conditions specified in the Temperature Test, Section 42. While still heated, the coil winding shall be subjected to an alternating potential of twice the rated voltage at any acceptable frequency – typically 120

hertz or higher – for 7200 electrical cycles or for 60 seconds, whichever is less. The required test voltage is to be obtained by starting at one-quarter or less of the full value and increasing to the full value in not more than 15 seconds. After being held for the time specified, the voltage is to be reduced within 5 seconds to one-quarter or less of the maximum value, and the circuit is to be opened.

52.5 Induced potential repeated

52.5.1 While heated following operation at 110 percent of rated voltage as specified in the Overvoltage and Undervoltage Tests, Section 43, each of three samples shall withstand without breakdown a repeated induced potential test at 65 percent of the potential applied in accordance with 52.4.1.

52.5.2 If the temperature that a coil winding reaches in the tests described in 52.4.1 and 52.5.1 is known, an oven may be set at the required temperature and used to condition the sample to that temperature before conducting the test.

52.6 Dead-case-mounted semiconductors

52.6.1 A power-switching semiconductor that has not previously been investigated and determined to comply with the requirements shall be subjected to the tests specified in 52.6.2 – 52.6.5.

52.6.2 Six samples in the as-received condition are to be subjected to 2500 volts rms between all live parts and all dead metal parts for 1 minute. The as-received condition is without prior energization, except as may occur as part of the production-line testing.

52.6.3 The same samples used for the test in 52.6.2 are to be conditioned in a 0°C (32°F) ambient for 3 hours and then subjected to the same dielectric voltage-withstand test as described in 52.6.2.

52.6.4 Six additional samples are to be conditioned for 7 hours in an air-circulating oven the temperature of which is to be set at the maximum operating junction temperature of the thyristor. The samples are then to be removed and immediately subjected to the dielectric voltage-withstand test described in 52.6.2.

52.6.5 Six additional samples are to be exposed for 24 hours to an environment of 85 percent relative humidity at 32°C (89.6°F). The samples are then to be removed and immediately subjected to the dielectric voltage-withstand test described in 52.6.2.

53 Volt-Ampere Capacity

53.1 An isolated limited-secondary circuit shall have a continuous-use capacity of 100 volt-amperes or less when energized from a circuit of rated frequency at the voltage specified in Table 40.1.

53.2 A single-wound secondary transformer is to attain a temperature rise on the enclosure, core, or coil of at least 50°C (90°F) when the secondary is loaded to the maximum output obtainable or 100 volt-amperes, whichever is less.

Exception: If the product of the open-circuit voltage and the short-circuit current is 100 volt-amperes or less, the 50°C (90°F) temperature rise need not be obtained.

53.3 Each secondary winding of a multi-secondary transformer is to be loaded in turn with a variable resistor. Starting with a cold transformer for each part of the test, the load resistance is to be decreased from open- to short-circuit in such a manner that the elapsed time is between 1-1/2 and 2-1/2 minutes. Depending upon the open-circuit voltage of the winding, the maximum outputs obtained by this method are to be as follows:

a) 350 volt-amperes for 0 – 15 volts.

b) 250 volt-amperes for 15.1 – 30 volts.

c) 200 volt-amperes for 30.1 – 1000 volts.

54 Burnout Test

54.1 A continuous-duty resistor shall not burn out or be adversely affected by carrying the full normal current on any step continuously. A resistor intended for intermittent use shall carry its rated current on any step for as long a time as the apparatus that it controls will permit.

54.2 When a power transformer, other than a transformer supplying a low-voltage, electronic, or isolated-limited-secondary circuit is operated as described in 54.3, there shall be no damage to the enclosure or emission of flame or molten metal.

54.3 The device is to be operated continuously at the voltage and frequency specified in Table 40.1 and 49.1.11 with the enclosure grounded. The load connected to the output terminals is to be a resistance of such value that three times full rated current will be drawn from the secondary winding of the device, and operation is to be continued until constant temperatures are attained on the enclosure or until burnout occurs.

54.4 A circuit on which a transformer is tested is to be protected by fuses rated at least ten times the primary current rating of the transformer. Opening of the fuses may occur. The test is to be conducted with the output terminals short-circuited, if such a condition results in less than three times full-rated current being drawn from the secondary. If other means of limiting the load to less than three times normal is inherent in or provided as part of the device, these features are to be given consideration and the burnout test conducted at the maximum load permitted by the limiting features.

54.5 A transformer supplying a low-voltage circuit is to be tested in the same manner as a standard Class 2 transformer, with low-voltage wiring terminals short-circuited, and wiring not complying with 18.1.4 short-circuited. A transformer supplying an isolated-limited-secondary circuit or an electronic circuit is to be tested in accordance with 54.2 – 54.4, except all secondary windings are to be directly short-circuited. If a portion of an isolated-limited-secondary or electronic circuit is connected to low-voltage field-wiring terminals, separate samples are to be subjected to the standard Class 2 test and the shorted-secondary test.

55 Limited Short-Circuit Test

55.1 General

55.1.1 A device such as a dead-case solid-state switch and a bonding conductor shall be subjected to the tests described in this section. After the test the equipment shall be examined with regard to the following results:

a) Damage to equipment such as welding of contacts and short-circuiting or opening of power semiconductor devices of the equipment may occur, but the test shall not result in damage to other parts of the equipment that would impair its function.

b) The cotton indicator shall not ignite.

c) The fuse connected between the live pole and the enclosure shall not open.

d) The test shall not result in damage to any conductor, its insulation, or termination.

Exception: A power-switching semiconductor that has been previously investigated and determined to comply with requirements for the application need not be subjected to additional testing.

55.1.2 A number of units considered to be representative of the line are to be subjected to short-circuit tests as specified in 55.1.3 – 55.2.2 when protected by the appropriate branch-circuit overcurrent protective device. Representative samples are to be selected on the basis of configuration, component construction, and ratings.

55.1.3 Open-type equipment is to be tested in an enclosure representative of that likely to be encountered in service except that tests may be conducted in the open and considered representative of enclosed tests if agreeable to those concerned. If tests are conducted in the open, 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.

55.1.4 The enclosure or grounded dead metal parts of an open-type unit are to be connected through a nontime delay, 30-ampere cartridge fuse to the live pole least likely to arc to ground. The fuse is to have an interrupting rating at least equal to the short-circuit test current in Table 55.1. The connection is to be made to the load side of the limiting impedance by a 10 AWG (5.3 mm^2) copper wire 4 – 6 feet (1.2 – 1.8 m) long.

Table 55.1
Circuit capacity for short-circuit test

Combined rating of device			Horsepower	Volts	Circuit capacity in amperes
Volt-amperes, single-phase	Volt-amperes, 3-phase	Volt-amperes, direct-current			
0 – 1176	0 – 832	0 – 648	1/2 maximum	0 – 250	200
0 – 1176	0 – 832	0 – 648	1/2 maximum	251 – 600	1000
1177 – 1920	833 – 1496	649 – 1140	over 1/2 to 1 maximum	0 – 600	1000
1921 – 4080	1497 – 3990	1141 – 3000	1 to 3	0 – 250	2000
4081 – 9600	3991 – 9145	3001 – 6960	3 to 7-1/2	0 – 250	3500
9601 or more	9146 or more	6961 or more	over 7-1/2	0 – 250	5000
1921 or more	1497 or more	1141 or more	above 1	251 – 600	5000

55.1.5 During the test, surgical cotton is to be located at all openings, handles, flanges, joints, and the like, on the outside of the enclosure. Also see 55.1.3.

55.1.6 A solid-state protective circuit that has not been subjected to a component evaluation is to be short- or open-circuited during the test.

55.1.7 The equipment is to be tested with 4 feet (1.2 m) of wire attached to each terminal and with the wires routed through a 10 – 12 inch (254 – 305 mm) length of conduit installed in the enclosure with each end of the conduit plugged with cotton. Wire size is to be determined in accordance with Field Connections, Section 15.

55.2 Test circuit

55.2.1 Equipment with an alternating-current input is to be tested on a 60 hertz essentially sinusoidal current. The open-circuit voltage of the test circuit is not to be less than 100 percent nor more than 105 percent of the voltage rating of the equipment, except that a voltage more than 105 percent ofthe rated voltage may be used if agreeable to those concerned. The test circuit is to be capable of delivering the current specified in Table 55.1 for a given horsepower rating when the system is short-circuited at the test terminals to which the device under test is to be connected, and this is to be verified by means of an oscillograph.

55.2.2 Reactive components of the impedance in the line employed as specified in 55.2.1 may be paralleled if of the air-core type, but no reactance shall be connected in parallel with resistance except that an air-core reactor in any phase may be shunted by resistance, the volt-ampere loss of which is approximately 0.6 percent of the reactive volt-ampere in the air-core reactor in that phase. The shunting resistance used with an air-core reactor having negligible resistance may be calculated from the formula:

$$R = \frac{167E}{I}$$

in which:

E is the voltage across the air-core reactor with current I flowing as determined by oscillographic measurement during the short-circuit calibration or by proportion from meter measurements at some lower current.

55.2.3 A dead-case semiconductor in contact with the enclosure shall be subjected to the Dielectric Voltage-Withstand Test, Section 52, after the short-circuit test.

Exception: A device that has been previously investigated and determined to comply with the applicable requirements need not be subjected to the dielectric voltage-withstand test.

56 Conductor Short-Circuit Test

56.1 If required – see 26.4 – there shall be no damage to any conductor, its insulation, or termination as a result of the test described in 56.2 – 56.5.

56.2 Two sets of three samples are to be subjected to the test. For one set, the samples are to consist of two conductors each; for the other set, the samples are to consist of one conductor each – a total of nine conductors. The conductors are to be of the type, size, length, and the like used in the equipment with terminations as used in the equipment at each end. For each sample the conductor or conductors are to be routed within a length of conduit, if so used in the equipment, or they are to be placed on a metal plate.

56.3 The conduit or metal plate is to be connected to the unfused pole of the supply circuit. For the tests on one set, the two conductors of each sample are to be connected to the power supply and the terminals at the load end are to be connected together. For the tests on the other set, the conductor is to be connected across the supply circuit.

56.4 The test circuit is to be a 2-wire circuit having a power factor of 0.9 – 1.0, and available current as specified in Table 55.1, at the voltage specified for the limited short-circuit test in Table 55.1. The open-circuit voltage of the test circuit is to be 100 – 105 percent of the specified voltage in Table 55.1.

56.5 A nonrenewable fuse that will not open in less than 12 seconds when carrying twice its rated current is to be connected to one pole of the supply circuit. The fuse is to have a current rating equal to that of the branch-circuit overcurrent-protective device to which the equipment will be connected, but not less than 20 amperes.

57 Strain Relief and Flexing Test

57.1 Strain relief

57.1.1 A strain-relief device 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.

57.1.2 A pigtail lead intended for field-wiring connection shall withstand without damage or displacement a direct pull of:

a) 20 pounds (89 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.

57.2 Flexing

57.2.1 With reference to 18.1.9, wiring that is subjected to movement at times other than installation and servicing is to be tested by cycling the moving part through the maximum travel permitted by the construction. The duration of the test is to be 500 cycles. Following this, the equipment is to be subjected to the Dielectric Voltage-Withstand Test, Section 52, and the wiring is to be examined for damage to determine if any conductors are broken or if individual strands have penetrated the insulation.

58 Accelerated Aging Tests

58.1 General

58.1.1 The requirements in 58.2.2 – 58.3.2 apply to gaskets and sealing compounds used to make an enclosure raintight or rainproof as determined in accordance with the requirements in the Rain Test, Section 60. With requirements in 58.4.1 and 58.4.2 apply to adhesives required to secure such gaskets to an enclosure or cover.

58.2 Gaskets

58.2.1 The temperature rises mentioned in this section correspond to the maximum temperature rise measured on the gasket during the temperature test. Materials other than those mentioned in this section shall be nonabsorptive and they, and any materials having higher temperature rises, shall provide equivalent resistance to aging and temperatures.

58.2.2 Neoprene or rubber compounds, except foamed materials, used for gaskets to seal an enclosure shall have physical properties as specified in Table 58.1 before and after accelerated aging under the conditions specified in Table 58.2.

Table 58.1
Physical properties for gaskets

	Neoprene or rubber compound		Polyvinyl chloride materials	
	Before test	After test	Before test	After test
Recovery – Maximum set when 1-inch (25.4-mm) gage marks are stretched to 2-1/2 inches (63.5 mm), held for 2 minutes and measured 2 minutes after release.	1/4 inch (6.4 mm)	–	Not specified	
Elongation – Minimum increase in distance between 1-inch gage marks at break.	250 percent, 1 – 3-1/2 inches (25.4 – 88.9 mm)	65 percent of original	250 percent, 1 – 3-1/2 inches	75 percent of original
Tensile Strength – Minimum force at breaking point.	850 psi (5.9 MPa)	75 percent of original	1200 psi (8.3 MPa)	90 percent of original

Table 58.2
Accelerated aging conditions

Measured temperature rise,		Test program	
°C	(°F)	Rubber or neoprene	Thermoplastic
35	(63)	Aged in air oven for 70 hours at 100 ±2°C (212 ±3.6°F)	Aged in full-draft, air-circulating oven for 168 hours at 87.0 ±1.0°C (188.6 ±1.8°F)
50	(90)	Aged in air oven for 70 hours at 100 ±2°C (212 ±3.6°F)	Aged in full-draft, air-circulating oven for 240 hours at 100.0 ±1.0 °C (212.0 ±1.8°F)
55	(99)	Aged in full-draft, air-circulating oven for 168 hours at 113.0 ±1.0°C (235.4 ±1.8°F)	Aged in full-draft, air circulating oven for 168 hours at 113.0 ±1.0°C (235.4 ±1.8°F)
65	(117)	Aged in full-draft, air-circulating oven for 240 hours at 121.0 ±1.0°C (249.8 ±1.8°F)	Aged in full-draft, air-circulating oven for 168 hours at 121.0 ±1.0°C (249.8 ±1.8°F) or 1440 hours at 97.0 ±1.0°C (206.6 ±1.8°F)
80	(144)	Aged in full-draft, air-circulating oven for 168 hours at 136.0 ±1.0°C (276.8 ±1.8°F)	Aged in full-draft, air-circulating oven for 168 hours at 136.0 ±1.0°C (276.8 ±1.8°F)

58.2.3 Foamed neoprene or rubber compounds used for gaskets to seal an enclosure are to be subjected to accelerated aging under the conditions specified in Table 58.2. The compounds shall not harden or otherwise deteriorate to a degree that will affect their sealing properties.

58.2.4 Thermoplastic materials used for gaskets to seal an enclosure shall be subjected to accelerated aging under the conditions specified in Table 58.2. Thermoplastic material shall not deform, melt, or otherwise deteriorate to a degree that will affect its sealing properties. Solid polyvinyl-chloride gasket material shall have physical properties as specified in Table 58.1 before and after the accelerated aging.

58.2.5 Tensile strength and elongation are to be determined using the test methods and apparatus described in Test Methods for Rubber Properties in Tension, ASTM D412-80.

58.3 Sealing compound

58.3.1 A sealing compound, when tested as described in 58.3.2, 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.

58.3.2 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).

58.4 Adhesives

58.4.1 The force required to peel a gasket that is secured by an adhesive from its mounting surface after conditioning as described in 58.4.2 shall not be less than 75 percent of the value determined on as-received samples.

58.4.2 For the conditioning described in 58.4.1 samples of the gasket, adhesive, and mounting surface are to be exposed for 72 hours to each of the following conditions, for a temperature rise not exceeding 35°C (63°F):

a) A temperature of 100°C (212°F);

b) Immersion in distilled water; and

c) A temperature of minus 10°C (minus 14°F).

59 Metallic Coating Thickness Test

59.1 The method of determining the thickness of a zinc or cadmium coating on enclosures for outdoor use is described in 59.2 – 59.9.

59.2 The solution used for the test is to be made from distilled water and is to contain 200 grams per liter of American Chemical Society (ACS) reagent grade chromic acid (CrO_3); and 50 grams per liter of ACS reagent grade concentrated sulphuric acid (H_2SO_4). The latter is equivalent to 27 milliliters per liter of ACS reagent grade concentrated sulphuric acid, specific gravity 1.84, containing 96 percent of H_2SO_4.

59.3 The test solution is to be contained in a glass vessel, such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube having an inside bore of 0.025 inch (0.64 mm) and a length of 5.5 inches (140 mm). The lower end of the capillary tube is to be tapered to form a tip, the drops from which are about 0.025 milliliter each. To preserve an effectively constant level, a small glass tube is to be inserted in the top of the funnel through a rubber stopper and its position is to be adjusted so that, when the stopcock is open, the rate of dropping is 100 ±5 drops per minute. If desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

59.4 The sample and the test solution are to be kept in the test room long enough to acquire the temperature of the room, which is to be noted and recorded. The test is to be conducted at an ambient temperature of 21.1 – 32.2°C (70 – 90°F).

59.5 Each sample is to be cleaned before testing. All grease, lacquer, paint, and other nonmetallic coatings are to be removed using solvents. Samples are then to be thoroughly rinsed in water and dried with clean cheesecloth. Care is to be exercised to avoid contact of the cleaned surface with the hands or any foreign material.

59.6 The sample to be tested is to be supported from 0.7 – 1.0 inch (17.8 – 25.4 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested is to be inclined about 45 degrees from horizontal.

59.7 The stopcock is to be opened and the time in seconds until the dropping solution dissolves the protective metallic coating, exposing the base metal, is to be measured. The end point is the first appearance of the base metal recognizable by a change in color.

59.8 Each sample of a test lot is to be subjected to test at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface and at an equal number of points on the outside surface, at places where the metallic coating may be expected to be the thinnest. On an enclosure made from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.

59.9 To calculate the thickness of the coating being tested, select from Table 59.1 the thickness factor appropriate for the temperature at which the test was conducted and multiply by the time in seconds required to expose base metal as noted in 59.7.

Table 59.1
Thickness of coatings

Temperature,		Thickness factors, 0.00001 inches (0.00025 mm) per second	
°F	(°C)	Cadmium platings	Zinc platings
70	(21.1)	1.331	0.980
71	(21.7)	1.340	0.990
72	(22.2)	1.352	1.000
73	(22.8)	1.362	1.010
74	(23.3)	1.372	1.015
75	(23.9)	1.383	1.025
76	(24.4)	1.395	1.033
77	(25.0)	1.405	1.042
78	(25.6)	1.416	1.050
79	(26.1)	1.427	1.060
80	(26.7)	1.438	1.070
81	(27.2)	1.450	1.080
82	(27.8)	1.460	1.085
83	(28.3)	1.470	1.095
84	(28.9)	1.480	1.100
85	(29.4)	1.490	1.110
86	(30.0)	1.501	1.120
87	(30.6)	1.513	1.130
88	(31.1)	1.524	1.141
89	(31.7)	1.534	1.150
90	(32.2)	1.546	1.160

60 Rain Test

60.1 Raintight or rainproof equipment shall be exposed to a water spray as described in 60.2– 60.5. The exposure shall not result in entrance of water:

a) Into a raintight enclosure or

b) Above the lowest live part or wetting of live parts in a rainproof enclosure.

Exception: Water may enter a rainproof enclosure above live parts if the construction is such that no water is visible on live parts, insulating materials, or mechanism parts and no water has entered any space above live parts within the enclosure in which wiring may be present under any proper installation conditions.

60.2 A raintight or rainproof enclosure is to be mounted as in actual service. Unspecified lengths of conduit are to be attached with normal torque and without a pipe thread compound. At each unthreaded wiring opening, a locknut and bushing are to be used. The unattached end of each conduit is to be covered to prevent entry of water during the test. Openings intended for the entry of Class 2 wiring in a low-voltage circuit are not to be sealed, and openings in the enclosure bottom need not be closed.

60.3 The equipment is to be operated so that it is tested under the normal conditions evaluated most likely to cause the entrance of water. It may be necessary:

a) To operate the equipment under various modes of operation and in different mounting or operating handle positions (if applicable) or

b) To energize the equipment if more adverse conditions could result.

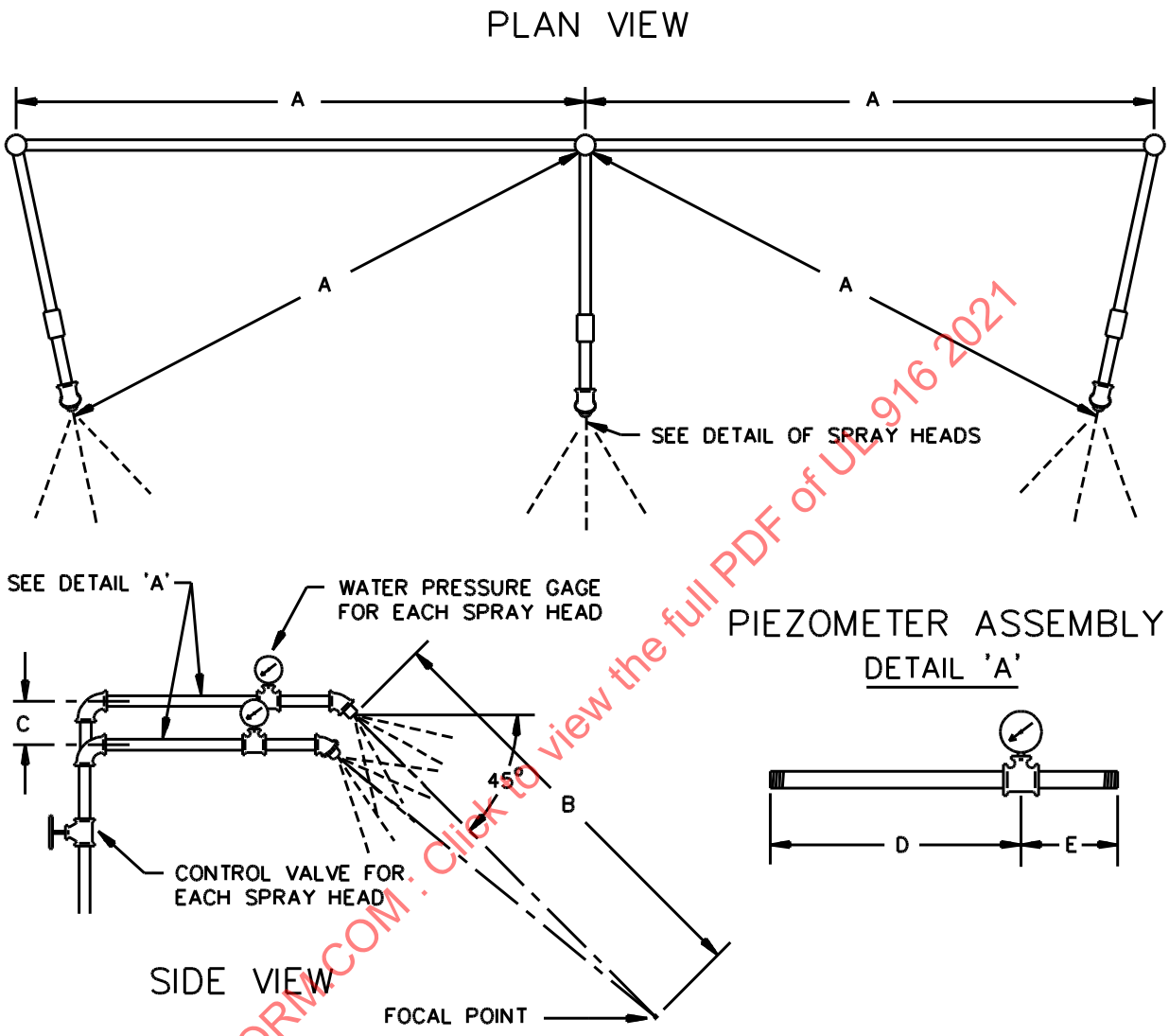
Each exposure is to be for 1 hour. If more than one exposure is required, the equipment is to be reconditioned, if necessary, prior to the second and each subsequent exposure so that the results of the test will not be adversely affected by prior exposures.

60.4 At the conclusion of each test, the outside of the enclosure is to be wiped dry. The enclosure is then to be opened for inspection.

60.5 The water spray apparatus is to consist of three spray heads mounted in a water supply pipe rack as illustrated in Figure 60.1. Spray heads are to be constructed in accordance with Figure 60.2. The water pressure for all tests is to be maintained at 5 psi (34.5 kPa) at each spray head. The equipment is to be brought into the focal area of the three spray heads in such position and under such conditions that the greatest quantity of water will enter the equipment. The spray is to be directed at an angle of 45 degrees to the vertical toward the device.

Figure 60.1

Spray head

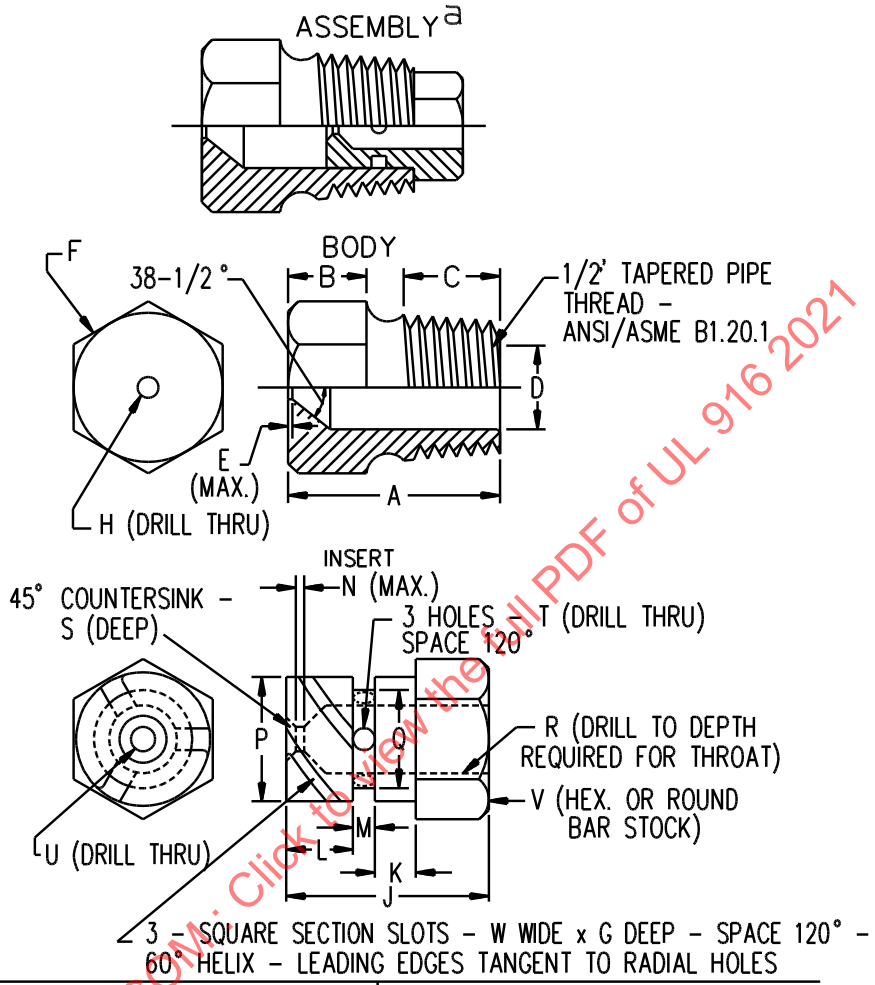


Item	inch	mm
A	28	710
B	55	1400
C	2–1/4	55
D	9	230
E	3	75

RT101D

Figure 60.2

Rain-test spray-head piping



Item	inch	mm	Item	inch	mm
A	1-7/32	31.0	N	1/32	0.80
B	7/16	11.0	P	.575	14.61
C	9/16	14.0		.576	14.63
D	.578	14.68	Q	.453	11.51
	.580	14.73		.454	11.53
E	1/64	0.40	R	1/4	6.35
F	c	c	S	1/32	0.80
G	.06	1.52	T	(No. 35)[b]	2.80
H	(No.9)[b]	5.0	U	(No. 40)[b]	2.50
J	23/32	18.3	V	5/8	16.0
K	5/32	3.97	W	0.06	1.52
L	1/4	6.35			
M	3/32	2.38			

[a] Nylon Rain-Test Spray Heads are available from Underwriters Laboratories

[b] ANSI B94.11M Drill Size

[c] Optional - To serve as a wrench grip.

RT100E

61 Conduit Entries Strength Test

61.1 Polymeric enclosures

61.1.1 A polymeric enclosure having a threaded conduit entry intended for connection to a rigid conduit system shall withstand, without pulling apart or damage such as cracking and breaking, the pullout, torque, and bending tests described in 61.1.2 – 61.1.4.

Exception: An enclosure that is provided with a separate hub assembly and that has instructions stating that the hub is to be connected to the conduit before being connected to the enclosure need not be subjected to the torque test.

61.1.2 The enclosure is to be suspended by a length of rigid conduit installed in one wall of the enclosure and a direct pull of 200 pounds-force (890 N) is to be applied for 5 minutes to a length of conduit installed in the opposite wall.

61.1.3 The enclosure is to be securely mounted as intended in service. A torque of 800 pound-inches (90.4 N·m) is to be applied to a length of installed conduit in a direction tending to tighten the connection. The lever arm is to be measured from the center of the conduit. The torque is to be applied for 5 minutes.

61.1.4 A length of conduit – at least 1 foot (305 mm) long – of the proper size is to be installed in:

a) The center of the largest unreinforced surface, or

b) A hub or an opening if provided as part of the enclosure.

The enclosure is to be securely mounted as intended in service, but positioned so that the installed conduit extends in a horizontal plane. A bending moment of 300 pound-inches (33.9 N·m) is to be applied for 5 minutes. The test may be terminated prior to attaining the bending moment if the deflection of the conduit exceeds 10 inches (254 mm) for a 10 foot (3.1 m) length of conduit. The weight necessary to produce the bending moment when suspended from the end of the conduit is to be determined from the formula:

$$W = \frac{M - 0.5\,CL}{L}$$

in which:

W is the weight, in pounds (kg), to be hung at the end of the conduit;

M is the bending moment required in pound-inches (N·m);

C is the weight of the conduit, in pounds (kg); and

L is the length of the conduit, in inches (mm), from the wall of the enclosure to the point at which the weight is suspended.

61.1.5 A nonmetallic enclosure that is intended to be connected at the end of a run of conduit that has only one 1/2 or 3/4 inch (12.7 or 19.0 mm) opening for conduit connection shall be subjected to the pullout, torque, and bending tests described in 61.1.2 – 61.1.4, except that the torque value for the test described in 61.1.3 shall be 200 pound-inches (22.6 N·m), and the bending moment for the test described in 61.1.4 shall be 150 pound-inches (17.0 N·m).

61.1.6 For a nonmetallic enclosure having a conduit nipple for direct connection to an outlet box or other electrical enclosure and no other mounting means, the acceptability of the nipple is to be determined by a