UL 1994

STANDARD FOR SAFETY

Luminous Egress Path Marking Systems

UL Standard for Safety for Luminous Egress Path Marking Systems, UL 1994

Fourth Edition, Dated May 29, 2015

Summary of Topics

This revision of ANSI/UL 1994 dated November 20, 2023 includes the following changes in requirements:

– Markings location; 41.1.2 and 41.1.3.

– Use of website and QR code markings for instructions; 44.3.

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

The revised requirements are substantially in accordance with Proposal(s) on this subject dated July 21, 2023.

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MAY 29, 2015
(Title Page Reprinted: November 20, 2023)

ANSI/UL 1994-2023

UL 1994

Standard for Luminous Egress Path Marking Systems

Prior to the February 14, 2005 revisions, this standard was titled Low Level Path Marking and Lighting Systems.

First Edition – May, 1991
Second Edition – January, 1997
Third Edition – January, 2004

Fourth Edition

May 29, 2015

This ANSI/UL Standard for Safety consists of the Fourth Edition including revisions through November 20, 2023.

The most recent designation of ANSI/UL 1994 as an American National Standard (ANSI) occurred on November 20, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover floor proximity and other egress path marking and lighting systems that provide a visual delineation of the path of egress. These systems are also used to identify significant egress path features such as doors, door hardware, door frames, stairs, stair landings, stair banisters, obstacles, egress symbols, information placards, and similar elements of the egress path.

1.2 These systems are intended for installation and use as required by building and fire safety codes such as the Life Safety Code, NFPA 101; the Building Construction and Safety Code, NFPA 5000, and the International Building Code sponsored by the International Code Council.

1.3 These requirements cover photoluminescent egress path marking system materials such as sheeting and adhesive-backed laminates. They also cover paints, pigments or inks pre-applied to a substrate. They are intended for installation where the facility illumination is sufficient to activate the photoluminescent material.

1.4 These requirements do not address the mounting integrity of path markers intended to be secured by adhesive to a building element. The suitability of this form of mounting for any given application is outside the scope of this Standard.

1.5 Self-luminous systems include constructions as defined in 5.13.

1.6 Externally powered lighting systems include varying designs of electric lamps that may be intended for connection to any combination of normal power supply, emergency power supply, and battery backup.

1.7 These requirements do not cover egress signs and lighting to be used independent from a path marking system, such as EXIT signs or other legally required legends or graphical symbols that are within the scope of the Standard for Emergency Lighting and Power Equipment, UL 924.

1.8 These requirements do not address the text or graphical symbol content, or the configuration of path marker signs.

1.9 The term "product" as used in these requirements refers to egress path marking and lighting systems or any part thereof covered by these requirements unless specifically noted otherwise.

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

4 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 purposes of this Standard the following definitions apply.

5.2 DIRECTIONAL MARKER – A photoluminescent, self-luminous, or externally powered marker that is provided with a means of identifying the direction of emergency egress. A directional marker is intended only for use with and as part of a path marking and lighting system. See 1.7 for other limitations.

5.3 FLOOR PROXIMITY – A mounting location within 18 inches (45.7 cm) of grade. For stairs, the mounting location is measured relative to a line connecting the stair nosings.

5.4 HIGH-VOLTAGE CIRCUIT – A circuit involving a potential of more than 30 volts ac, 42.4 volts peak or dc, but not more than 600 volts.

5.5 HORIZONTAL LUMINOUS LENGTH – The length of the luminous segment parallel to the direction of travel in the path of egress, that is, the length a person would have to traverse to pass the luminous segment.

5.6 LOW-VOLTAGE CIRCUIT – A circuit involving a potential of not more than 30 volts ac, 42.4 volts peak or dc, and supplied by:

a) An energy limiting battery circuit,

b) A Class 2 transformer, or

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

(See also Low-Voltage, Power-Limited Circuits, Section 31.)

5.7 LUMINOUS SEGMENT – The portion of the path marking system that is intended to be illuminated after activation of the system.

5.8 PATH MARKER – A luminous strip or sign intended only for use with a luminous egress path marking system to assist building occupants in finding an exit.

5.9 PATH MARKER SIGN – A path marker that includes text and/or one or more graphical symbols intended to provide information related to egress features or procedures.

5.10 PATH MARKER STRIP – A path marker without text or graphical symbols.

5.11 PATH MARKER SYSTEM – An integrated collection of path marker strips and/or path marker signs intended to assist building occupants and/or first responders to deal effectively with evacuation scenarios.

5.12 PHOTOLUMINESCENT – Having the property of emitting light that continues for a length of time after excitation by visible or invisible light has been removed.

5.13 SELF-LUMINOUS – Illuminated by a self-contained power source (other than batteries) and operated independently of external power sources.

5.14 VISUAL DELINEATION – The use of visual cues to identify the path of egress accurately.

CONSTRUCTION

6 General

6.1 Product assembly

6.1.1 Systems shall include all components necessary for intended function when installed as specified in the manufacturer's instructions.

6.1.2 A product or system that is not assembled by the manufacturer as a complete unit shall include a list identifying all parts needed to form a complete system. All parts shall be marked or otherwise identified in the instructions. Any special tools required to complete the assembly shall be provided.

6.2 Mechanical protection

6.2.1 Louvers and other openings in the ultimate enclosure shall be constructed and located to reduce the risk of unintentional contact with hot surfaces or with moving parts that may cause a risk of injury to persons. In determining compliance with this requirement, parts such as covers, panels, or grilles used as part of the enclosure are to be removed unless tools are required for their removal.

6.2.2 The degree of protection required by 6.2.1 depends upon the general design and the intended use of the product. The location where the product ordinarily will be used is considered when judging the acceptable degree of exposure of moving parts. Other factors taken into consideration in judging the acceptability of exposed moving parts are:

a) The degree of exposure;

b) The sharpness of the moving parts;

c) The likelihood of unintentional contact with the moving parts; and

d) The speed of movement of those parts.

6.2.3 Moving parts that may cause injury to persons, such as fan blades or blower wheels, shall be guarded or enclosed so that the minor dimension of any opening does not exceed the values in 6.2.4 and 6.2.6. Parts required for guarding shall be secured by means dependent upon tools for their removal unless the guard is required to be in place in order for the product to function.

6.2.4 The distance from an opening to the moving part shall be in accordance with Table 6.1, but the minor dimension of the opening shall not, in any case, exceed 1 inch (25.4 mm). For an opening having a minor dimension intermediate between two of the values included in the table, the distance from the opening to the moving part shall be not less than that found by appropriate interpolation between the corresponding values in the table. The minor dimension of the opening is determined by the largest

hemispherically tipped cylindrical probe that can be inserted through the opening with a force of 5 pounds (22.3 N). See 6.2.6 for round holes and slots.

Table 6.1
Dimensions of opening

Minor dimensions of opening[a]		Minimum distance from opening to moving part[c]	
inches	(mm)	inches	(mm)
1/4	(6.4)	1/2	(12.7)
3/8	(9.5)	1-1/2	(38.1)
1/2	(12.7)	2-1/2	(63.5)
3/4	(19.1)	4-1/2	(114.0)
1	(25.4)	6-1/2	(165.0)
1-1/2	(38.1)	10-1/2	(267.0)
2	(50.8)	14-1/2	(368.0)
2-1/4[b]	(57.2)	16-1/2	(419.0)
2-1/2[b]	(63.5)	18-1/2	(470.0)
2-3/4[b]	(69.9)	20-1/2	(521.0)
3[b]	(76.2)	22-1/2	(572.0)
Over 2	(Over 50.8)	30	(762.0)

[a] Openings less than 1/4 inch (6.4 mm) are not to be considered.

[b] These values apply only to openings at the base of the product where the upper edge of the opening is less than 8 inches (203 mm) above the floor. The product is to be in its intended operating position.

[c] Also applies to hot parts.

6.2.5 A moving part is not to be considered when judging compliance with 6.2.2 if:

a) The part is unlikely to be contacted through the opening because of the location of fixed components, including baffles;

b) The part is made inoperative, when exposed, through the use of interlocking devices, or

c) The chassis of the product is of a slide-out type construction that must be withdrawn from its enclosure to expose the moving part that may cause injury to persons.

6.2.6 If an opening consists of a round hole or slot having a major straight line dimension of less than 2 inches (50.8 mm), the distance to a moving part that may cause injury to persons shall be in accordance with Table 6.2. If an opening consists of a round hole or slot having a major straight line dimension more than 2 inches (50.8 mm), the distance to a moving part that may cause injury to persons shall be in accordance with Table 6.1. For an opening having a minor dimension intermediate between two of the values included in the table, the distance from the opening to the moving part shall be not less than that found by interpolation between the corresponding values shown in the appropriate column.

6.3 Electrical protection

6.3.1 Louvers and other openings in the enclosure shall be constructed and located to reduce the risk of unintentional contact with uninsulated live parts. In determining compliance with this requirement, parts such as covers, panels, and grills used as part of the enclosure are to be removed unless tools are required for their removal or an interlock is provided.

6.3.2 Uninsulated high-voltage live parts shall be located, guarded, or enclosed as indicated in 6.3.3 – 6.3.8.

6.3.3 If an opening in the enclosure will not permit the entrance of a 3/4 inch (19.1 mm) diameter rod, the probe illustrated in Figure 6.1 shall not touch any uninsulated live parts and the probe illustrated in Figure 6.2 shall not touch any film-coated wire when inserted through the opening. The probe shall not pass through grilles, screens, louvers, or the like when a force of 5 pounds (22.3 N) is applied.

Table 6.2
Dimension of openings for round holes or slots having a major dimension less than 2 inches (50.8 mm)[a]

Minor dimension of opening		Minimum distance from opening to moving part[b]			
		Round holes		Slots	
inches	(mm)	inches	(mm)	inches	(mm)
1/4	(6.4)	1/8	(3.2)	1/2	(12.7)
3/8	(9.5)	1	(25.4)	1-1/2	(38.1)
1/2	(12.7)	2	(50.8)	2-1/2	(63.5)
3/4	(19.1)	3-1/4	(82.6)	3-1/4	(82.6)
1	(25.1)	4	(102.0)	4	(102.0)

[a] Table 6.1 applies if major dimension of slot is 2 inches (50.8 mm) or greater.

[b] Also applies to hot parts.

Figure 6.1

Probe

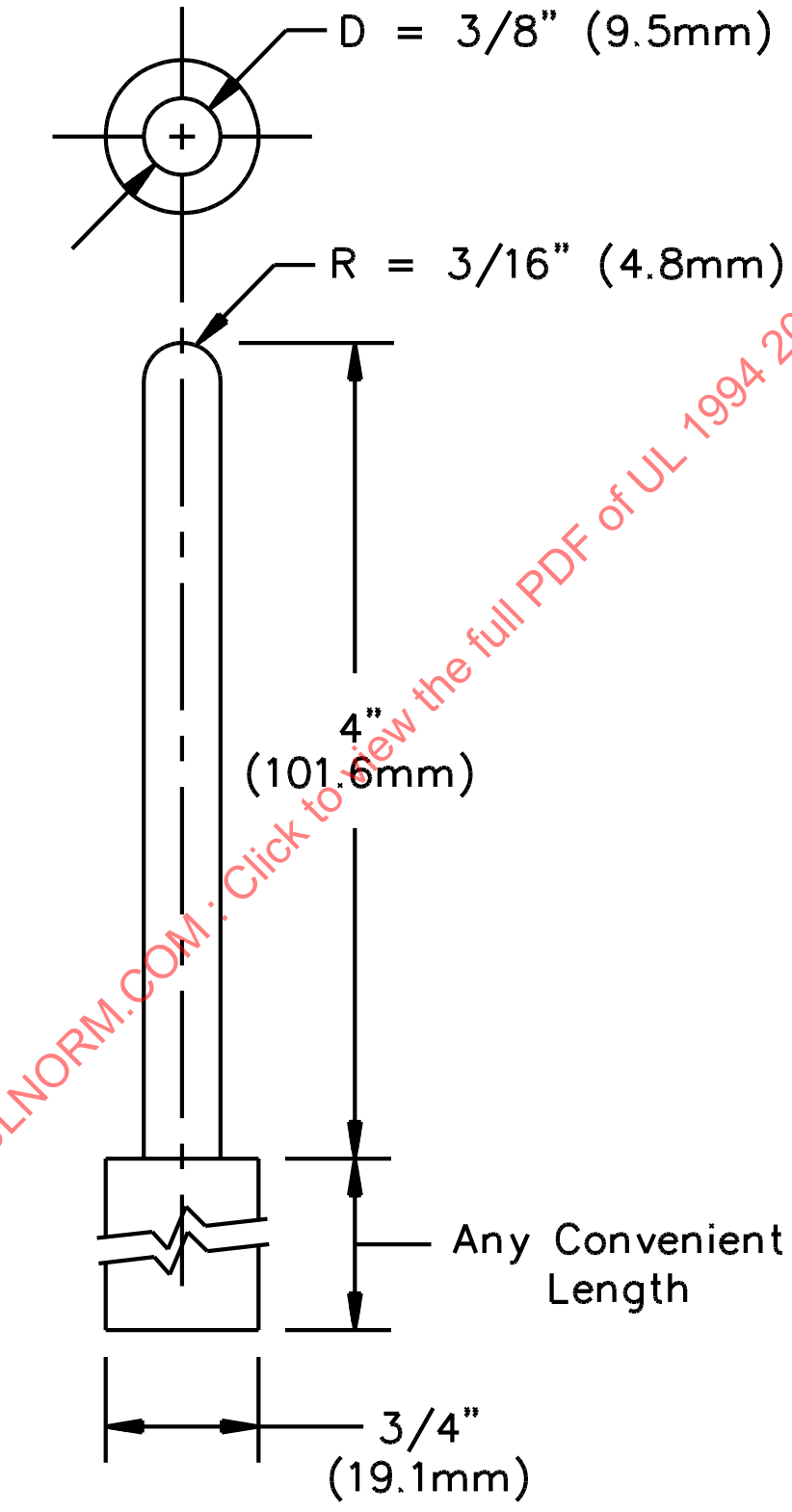
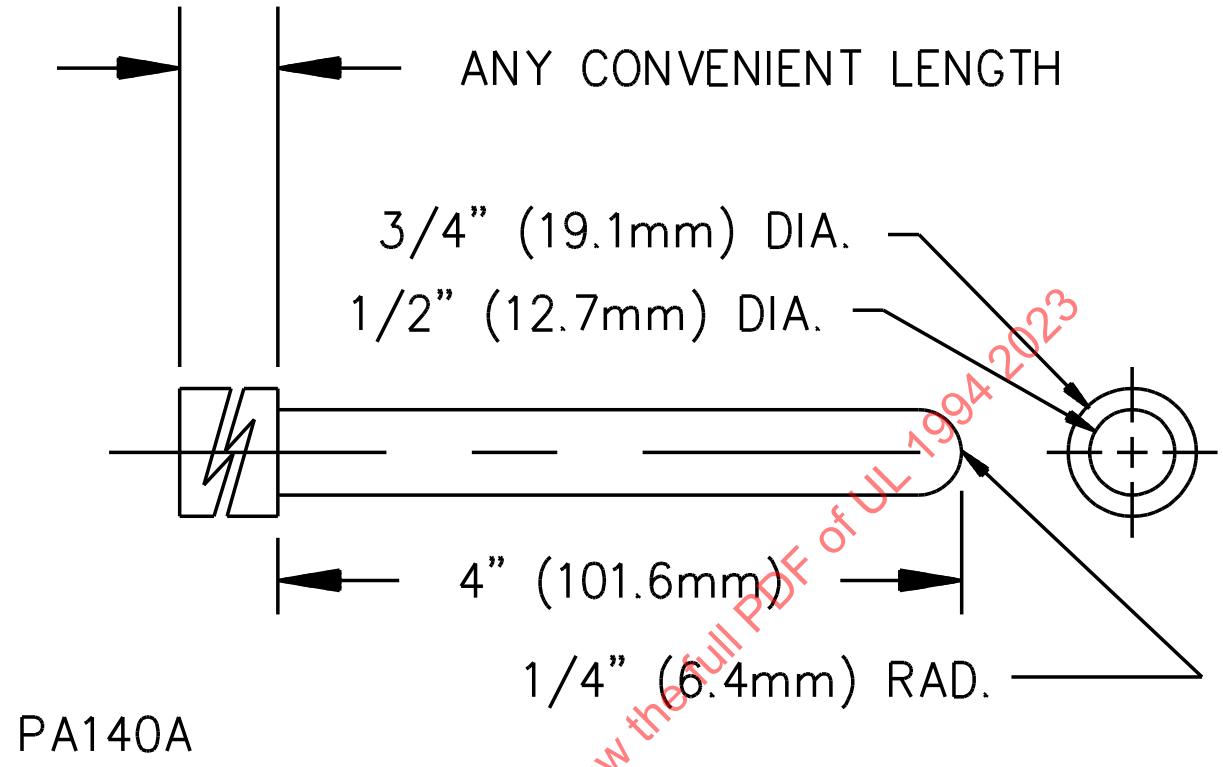


Figure 6.2

Probe



6.3.4 An opening in an electrical enclosure shall not permit entrance of a 1 inch (25.4 mm) diameter rod and shall be sized and so arranged that the probe shown in Figure 6.3 cannot be made to contact any uninsulated live electrical part (other than low-voltage) when inserted through the opening in a straight or articulated position.

6.3.5 An opening that permits entrance of a 1 inch (25.4 mm) diameter rod is acceptable under the conditions described in Figure 6.4.

6.3.6 With respect to 6.3.4, the probe may be articulated into any configuration and may be rotated or angled to any position before, during, or after insertion into the opening, and the penetration may be to any depth allowed by the opening size, including minimal depth combined with maximal articulation.

6.3.7 If any part of the enclosure must be opened or removed for user servicing with or without the use of tools, or can be opened or removed without the use of tools, the probe is to be applied without the part in place.

6.3.8 In addition to the requirements in 6.3.2 – 6.3.5, uninsulated live parts inside the enclosure that are likely to be contacted by persons performing operations such as replacing fuses, resetting manual-reset devices, replacing air filters, oiling motors, or other such intended normal service operations, shall be located, guarded, or enclosed to prevent unintentional contact.

Exception: Uninsulated live parts need not comply with this requirement if tools are required to expose the uninsulated live part or a keyed lock is used to prevent access to the live parts.

Figure 6.3

Probe

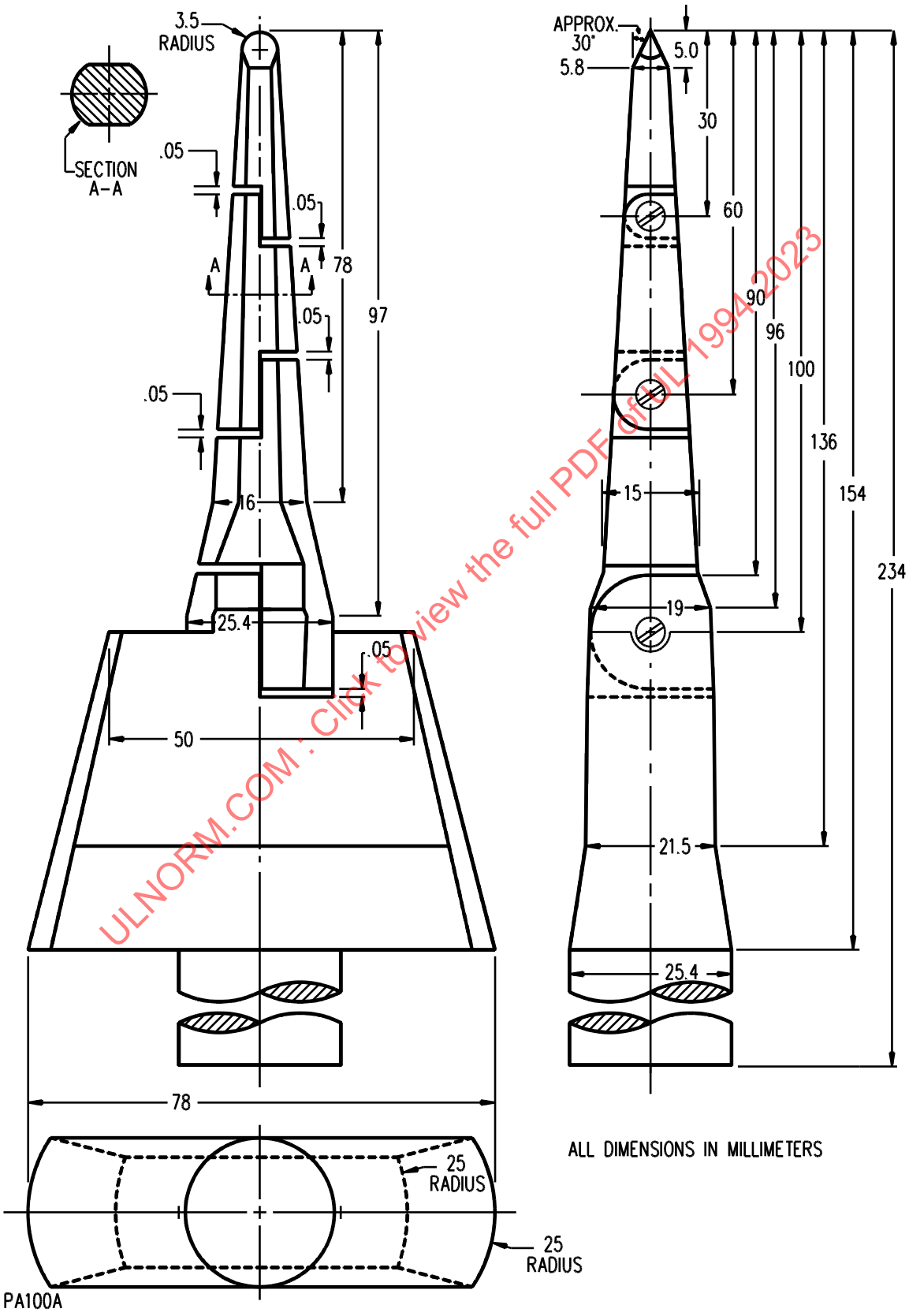
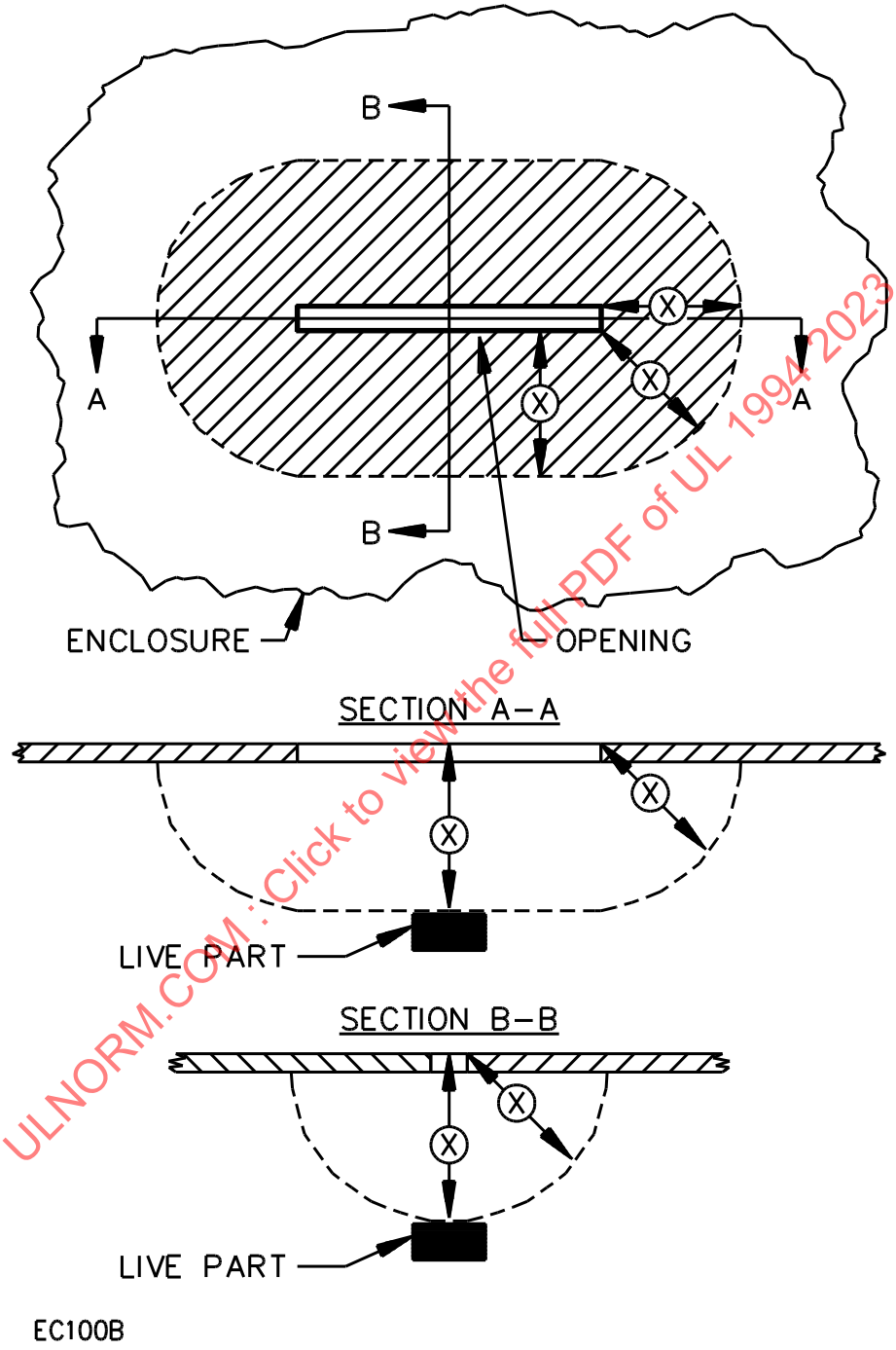


Figure 6.4

Opening in enclosure



The opening is acceptable if, within the enclosure, there is no uninsulated live part or film-coated wire:

1) less than X inches from the perimeter of the opening, as well as

2) within the volume generated by projecting the perimeter X inches normal to its plane.

X equals five time the diameter of the largest diameter rod that can be inserted through the opening, but not less that 4 inches (101.6 mm).

7 Accessories

7.1 A product having provisions for the use of accessories to be attached in the field shall be constructed so that the use of these accessories will not introduce a risk of fire, electric shock, or unintentional contact with moving parts that may cause injury to persons.

7.2 The product shall comply with the requirements of this Standard with or without the accessory installed.

7.3 Electrical installation of accessories by the user shall be restricted to an arrangement that can be accomplished by means of receptacles and plug-in connectors.

7.4 With reference to 7.3, low-voltage accessories may be connected by other means provided the installation does not require rearrangement of components or wiring, cutting or splicing of existing wiring, or soldered connections.

7.5 The installation of accessories by service personnel shall be by means of receptacles, plug-in connectors, insulated wire connectors, or by connection to existing wiring terminals.

7.6 With reference to 7.5, any installation that requires the cutting of wiring or the soldering of connections by the installer is not acceptable. Installations that require cutting, drilling, or welding are not acceptable in electrical enclosures and in other areas where such operations may damage electrical components and wiring within the enclosure.

7.7 A strain relief means shall be provided for the wiring in the accessory if there is a possibility of transmitting strain to the terminal connections during installation. See 35.1 for test of strain relief means.

7.8 All terminals and wiring intended to be field connected shall be identified:

a) On the accessory;

b) On the product if connections are made between the accessory and the product; or

c) On the wiring diagram or diagrams provided with the product.

7.9 Except where it is obvious, the mounting location of the accessory shall be indicated on the product. If the mounting location is obvious due to the function of the accessory and arrangement of the product, and instructions are provided covering the installation and location for the accessory, the mounting location of the accessory need not be indicated on the product.

7.10 As part of the investigation, accessories are to be trial-installed to determine that:

a) Their installation is feasible;

b) The instructions (see Installation and Operating Instructions, Section 44) are detailed and correct; and

c) The use of the accessories does not introduce a risk of fire, electric shock, or unintentional contact with moving parts that may cause injury to persons.

8 Enclosures

8.1 General

8.1.1 Enclosures shall be formed and assembled so that they will have the strength and rigidity necessary to resist the abuses to which they may be subjected without total or partial collapse and resulting reduction of spacings, loosening or displacement of parts, or other serious defects. Enclosures for individual electrical components, outer enclosures, and the combinations of the two are to be considered in determining compliance with this requirement.

8.1.2 Among the factors that are taken into consideration when evaluating an enclosure are:

a) Mechanical strength;

b) Resistance to impact;

c) Moisture-absorptive properties;

d) Flammability;

e) Resistance to distortion at temperatures to which the material may be subjected under conditions of use; and

f) Resistance to corrosion.

For a nonmetallic enclosure or part of an enclosure, all of these factors are considered with respect to aging. See Polymeric Materials, Section 9.

8.1.3 The enclosure or enclosures of the product shall prevent mechanical damage to wiring and electrical components.

8.1.4 The enclosure shall prevent the emission of molten metal, burning insulation, flaming particles, or the like through openings onto flammable material, including surfaces over which the product is mounted.

8.1.5 An outer cabinet or enclosure is not required for a product having all electrical parts, other than motors, individually and completely enclosed; and having all electrical wiring enclosed in metal-clad cable, conduit, or the equivalent.

8.1.6 A piece that is in effect a part of the enclosure, such as a dial or nameplate, shall be of metal or other material as specified for the enclosure.

8.1.7 Where insulating material other than electrical insulation is provided within the enclosure, consideration is to be given to the burning characteristics of the material, and the proximity of an ignition source, in determining compliance with 8.1.4.

8.1.8 All intended mounting positions of the product are to be considered when determining if it complies with 8.1.4.

8.1.9 Unless it can be determined that failure of an electrical component will not result in a risk of fire, components such as controls, solenoids, starting relays, and switches shall be individually enclosed, except at terminals. See 8.3.1 – 8.5.2.

8.1.10 Electrical parts (see 8.1.9) within the outer enclosure need not be individually enclosed if the assembly conforms with the following:

a) Their design and location with respect to openings in the outer enclosure will not result in the emission of flame or molten metal through openings in the enclosure or it can be shown that failure of the component would not result in a risk of fire;

b) There are no openings in the bottom of the compartment in which the part is located that would permit dropping of molten metal, and the like on flammable material; and

c) The part is not in proximity to flammable material other than electrical insulation.

8.1.11 The outer enclosure of a product is to be evaluated with respect to its size, shape, metal thickness, and use. Sheet steel shall have a thickness of not less than 0.026 inch (0.66 mm) if uncoated, not less than 0.029 inch (0.74 mm) if galvanized, or not less than 0.036 inch (0.91 mm) if of nonferrous sheet metal.

8.1.12 Sheet metal to which a wiring system is to be connected in the field shall have a thickness not less than 0.032 inch (0.81 mm) if uncoated steel, not less than 0.034 inch (0.86 mm) if galvanized steel, and not less than 0.045 inch (1.14 mm) if nonferrous.

8.1.13 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 employed, there shall be not less than three nor more than five threads in the metal, and the construction of the product shall be such that a conduit bushing can be properly attached. If threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or the like, there shall be not less than 3-1/2 threads in the metal, and there shall be a smooth rounded inlet hole for the conductors that shall afford protection to the conductor equivalent to that provided by a standard conduit bushing. The inlet hole shall have an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

8.1.14 A knockout in a sheet metal enclosure shall be secured in place, but it shall be removable without deformation of the enclosure that would result in damage to electrical components or reduction in electrical spacings. See 8.1.16.

8.1.15 A knockout shall remain in place when a force of 10 pounds (44.5 N) is applied at right angles to the knockout by a 1/4 inch (6.4 mm) diameter mandrel with a flat end. The mandrel shall be applied at the point most likely to cause movement of the knockout.

8.1.16 A knockout shall be provided with a flat surrounding surface for seating of a conduit bushing and be so located that installation of a bushing at any knockout likely to be used during installation will not result in spacings between uninsulated live parts and the bushing of less than those required by this Standard.

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

Table 8.1
Knockout or hole sizes and dimensions of bushings

Trade size of conduit		Knockout or hole diameter		Bushing dimensions			
				Overall diameter		Height	
inches	(mm) OD	inches	(mm)	inches	(mm)	inches	(mm)
1/2	(21.3)	7/8	(22.2)	1	(25.4)	3/8	(9.5)
3/4	(26.7)	1-3/32	(27.8)	1-15/64	(31.4)	27/64	(10.7)
1	(33.4)	1-23/64	(34.5)	1-19/32	(40.5)	33/64	(13.1)
1-1/4	(42.3)	1-23/32	(43.7)	1-15/16	(49.2)	9/16	(14.3)
1-1/2	(48.3)	1-31/32	(50.0)	2-13/64	(56.0)	19/32	(15.1)
2	(60.3)	2-15/32	(62.7)	2-45/64	(68.7)	5/8	(15.9)
2-1/2	(73.0)	3	(76.2)	3-7/32	(81.8)	3/4	(19.1)
3	(88.9)	3-5/8	(92.1)	3-7/8	(98.4)	13/16	(20.6)
3-1/2	(101.6)	4-1/8	(104.8)	4-7/16	(112.7)	15/16	(23.8)
4	(114.0)	4-5/8	(117.5)	4-31/32	(126.2)	1	(25.4)
4-1/2	(127.0)	5-1/8	(130.2)	5-35/64	(140.9)	1-1/16	(27.0)
5	(141.3)	5-5/8	(142.9)	6-7/32	(158.0)	1-3/16	(30.2)
6	(168.3)	6-3/4	(171.5)	7-7/32	(183.4)	1-1/4	(31.8)

8.1.18 Steel enclosures shall be protected against corrosion by metallic or nonmetallic coatings such as plating or painting.

8.2 Doors and covers

8.2.1 Service covers or panels in the outer enclosure shall require the use of tools for removal or shall be provided with an interlocking mechanism if they give access to unenclosed uninsulated high-voltage live parts or moving parts that may cause injury to persons.

8.2.2 An interlocking mechanism that:

a) Must be engaged in the closed position of the cover before parts are energized; and

b) Will secure the cover in the closed position when engaged is considered to comply with 8.2.1.

8.2.3 A hinged panel or cover shall be so positioned or arranged that when it is in an open position it will not fall or swing due to gravity or vibration so as to cause injury to persons from the panel or cover, from moving parts that may cause injury to persons, or from uninsulated live parts.

8.2.4 The assembly shall be arranged so that an overcurrent protective device, such as a fuse, the intended protective function of which requires renewal, can be replaced and manual-reset devices can be reset without removing parts other than a service cover or panel, and the cover or door enclosing the device.

8.2.5 A required protective device shall be wholly inaccessible from outside the product enclosure without opening a door or cover.

8.2.6 The operating handle of a circuit breaker may project outside the enclosure.

8.2.7 A cover for an enclosure of fuses in high-voltage circuits shall be hinged. See 8.2.8. A cover for a manual-reset overload protective device enclosure shall be hinged if it is necessary to open the cover to reset the device.

8.2.8 A hinged cover is not required where the only fuses enclosed are:

a) Supplementary type control circuit fuses, if the fuses and control circuit loads, other than a fixed control circuit load such as a pilot lamp, are within the same enclosure; or

b) An extractor-type fuse with its own enclosure; or

c) Fuses in low-voltage circuits.

8.2.9 A hinged cover, where required, shall not depend solely upon screws or other similar means to hold them closed. See 8.2.10.

8.2.10 A spring latch, a magnetic latch, a dimple, or any other mechanical arrangement that will hold the door in place and will require some effort of the part of the user to open it is considered to comply with the requirements in 8.2.9. When provided as the sole means for securing the cover or panel, a cover interlocking mechanism as described in 8.2.2 is considered to comply with 8.2.9.

8.2.11 A door or cover giving direct access to fuses in other than low-voltage circuits shall shut closely against a 1/4 inch (6.4 mm) rabbet or shall have either turned flanges for the full length of four edges or angle strips fastened to it. Flanges or angle strips shall fit closely with the outside of the wall of the box proper and shall overlap the edges of the box not less than 1/2 inch (12.7 mm). A special construction such as a fuse enclosure located within an outer enclosure or a flange and rabbet combination that affords the equivalent protection is acceptable.

8.2.12 Strips used to provide rabbets, or angle strips 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 not more than 6 inches (152 mm) apart between these end fastenings.

8.2.13 Except as indicated in 8.2.8, the door or cover of an enclosure shall be hinged:

a) If it gives access to any fuse, circuit breaker, or manually resettable temperature control in other than a low-voltage circuit; and

b) If uninsulated live parts are exposed during the replacement of the fuse or resetting of the manually resettable device.

Such a door or cover shall also be provided with an automatic latch, or the equivalent and, if uninsulated live parts other than the screw shell of a plug fuseholder are exposed inside the enclosure, a captive screw or equivalent means, requiring the use of a tool to open, shall secure the door or cover in place. See 8.2.14.

8.2.14 The captive screw may be omitted from the door or cover of the compartment that houses the uninsulated live parts if it is provided in the cover that must be opened to gain access to the door or cover of the compartment. Arrangements employing two mating hinged doors are acceptable where the automatic latch and captive screw are provided only on one door:

a) If the doors are constructed so that the one provided with the latch must be opened first and closed last; and

b) If the latch and screw will hold the other door closed.

8.2.15 A cover interlocking mechanism that:

a) Must be engaged in the closed position of the cover before electrical parts are energized; and

b) Will secure the cover in the closed position, when provided as the sold means for securing the door or cover closed, is considered to comply with 8.2.13.

8.2.16 If the removal of a door, a panel, or a shield will expose moving parts that may cause injury to persons:

a) The opening or removal of the door, panel, or shield shall require the use of tools;

b) An interlocking device shall shut off the mechanism; or

c) The following or equivalent warning marking shall be displayed in letters not less than 1/8 inch (3.2 mm) high: "CAUTION – To Avoid Injury from Moving Parts, Shut Off the Equipment Before Removing This Cover".

8.2.17 A hinged cover is not required if it is not necessary to open the cover in connection with intended operation of the product, and the only fuse or fuses enclosed is for protection of portions of internal circuits against damage resulting from a fault. The following or equivalent permanent marking in letters not less than 1/8 inch (3.2 mm) in height shall be provided on the outer surface of the cover: "CAUTION – Circuit Fuse or Fuses Inside – Disconnect Power-Supply Prior to Servicing".

8.2.18 Cabinet locks shall be used for all enclosures if access is not required for intended operation of the product.

8.2.19 If access into an enclosure is not required for intended operation, it shall be secured by means of a device requiring the use of a key or tool.

8.2.20 A sheet metal screw threading directly into a metal bracket or enclosure wall shall not be used for attachment of a cover or door that has to be removed for installation or operation of the equipment. They may thread into spring steel nuts permanently held in place and protected against corrosion. Machine screws and self-tapping machine screws may thread directly into sheet metal walls.

8.2.21 A snap-on cover that gives access to uninsulated bare live parts and that does not require a tool for removal shall withstand the Snap-On Cover Test, Section 36.

8.2.22 All nonmetallic covers that give access to uninsulated live parts shall comply with the requirements in 8.1.4, both with the cover screws tightened and with the cover screws loosened one full turn.

8.2.23 An edge of an enclosure opening, frame, guard, knob, handle, or the like of a product shall be smooth and rounded and not sufficiently sharp to cause a cut-type injury when contacted during normal use or user maintenance.

8.3 Electrical component enclosures

8.3.1 Sheet metal complying with Table 8.2 or Table 8.3, is acceptable for the individual enclosure of electrical components.

Table 8.2
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 in inches (mm)			
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,					
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	Uncoated (MSG)		Metal coated (GSG)	
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020	(0.51)	0.023	(0.58)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)	(24)		(24)	
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited		0.026	(0.66)	0.029	(0.74)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)	(22)		(22)	
8.0	(20.3)	Not limited		12.0	(30.5)	Not limited		0.032	(0.81)	0.034	(0.86)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)	(20)		(20)	
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited		0.042	(1.07)	0.045	(1.14)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)	(18)		(18)	
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited		0.053	(1.35)	0.056	(1.42)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)	(16)		(16)	
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited		0.060	(1.52)	0.063	(1.60)
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)	43.0	(109.2)	(15)		(15)	
25.0	(63.5)	Not limited		39.0	(99.1)	Not limited		0.067	(1.70)	0.070	(1.78)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)	(14)		(14)	
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited		0.080	(2.03)	0.084	(2.13)
35.0	(89.0)	47.0	(119.4)	54.0	(137.1)	66.0	(167.6)	(13)		(13)	
42.0	(106.7)	Not limited		64.0	(162.6)	Not limited		0.093	(2.36)	0.097	(2.46)
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)	84.0	(213.4)	(12)		(12)	
52.0	(132.1)	Not limited		80.0	(203.2)	Not limited		0.108	(2.74)	0.111	(2.82)
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)	(11)		(11)	
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123	(3.12)	0.126	(3.20)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)	(10)		(10)	

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments which may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure which is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

1) Single sheet with single formed flanges (formed edges),

2) A single sheet which is corrugated or ribbed, and

3) An enclosure surface loosely attached to a frame, for example, with spring clips.

[b] The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[c] For panels which are not supported along one side for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

Table 8.3
Minimum thickness of sheet metal for electrical 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)	inches	(mm)
3.0	(7.6)	Not limited		7.0	(17.8)	Not limited		0.023	(0.58)
3.5	(8.9)	4.0	(10.2)	8.5	(21.6)	9.5	(24.1)	0.023	(0.58)
4.0	(10.2)	Not limited		10.0	(25.4)	Not limited		0.029	(0.74)
5.0	(12.7)	6.0	(15.2)	10.5	(26.7)	13.5	(34.3)	0.029	(0.74)
6.0	(15.2)	Not limited		14.0	(35.6)	Not limited		0.036	(0.91)
6.5	(16.5)	8.0	(20.3)	15.0	(38.1)	18.0	(45.7)	0.036	(0.91)
8.0	(20.3)	Not limited		19.0	(48.3)	Not limited		0.045	(1.14)
9.5	(24.1)	11.5	(29.2)	21.0	(53.3)	25.0	(63.5)	0.045	(1.14)
12.0	(30.5)	Not limited		28.0	(71.1)	Not limited		0.058	(1.47)
14.0	(35.6)	16.0	(40.6)	30.0	(76.2)	37.0	(94.0)	0.058	(1.47)
18.0	(45.7)	Not limited		42.0	(106.7)	Not limited		0.075	(1.91)
20.0	(50.8)	25.0	(63.5)	45.0	(114.3)	55.0	(139.7)	0.075	(1.91)
25.0	(63.5)	Not limited		60.0	(152.4)	Not limited		0.095	(2.41)
29.0	(73.7)	36.0	(91.4)	64.0	(162.6)	78.0	(198.1)	0.095	(2.41)
37.0	(94.0)	Not limited		87.0	(221.0)	Not limited		0.122	(3.10)
42.0	(106.7)	53.0	(134.6)	93.0	(236.2)	114.0	(289.6)	0.122	(3.10)
52.0	(132.1)	Not limited		123.0	(312.4)	Not limited		0.153	(3.89)
60.0	(152.4)	74.0	(188.0)	130.0	(330.2)	160.0	(406.4)	0.153	(3.89)

[a] See note a to Table 8.2.

[b] See note b to Table 8.2.

[c] See note c to Table 8.2.

8.3.2 Where the assembly and location of the component and the strength and rigidity of the outer enclosure warrant, an individual enclosure of metal thinner than specified in Table 8.2 or Table 8.3, may be employed.

8.3.3 The terminals of an electrical part need not be enclosed if there are no openings in the top surface of the outer enclosure that would permit objects to fall on or near uninsulated live parts and the terminals are not subject to unintentional contact by persons.

8.4 Ventilating openings

8.4.1 For ventilating openings, the following requirements apply:

a) The compartment or that part of an enclosure that contains field wiring splices in the high-voltage circuit shall not be provided with ventilating openings.

b) The ventilating opening shall be necessary to prevent the attainment of excessive or undesirable temperatures on components of the device, as determined by a temperature test with the opening blocked.

c) The nearest portion of a ventilating opening shall be above the bottom of the enclosure by a distance equal to one-quarter of the enclosure height and depth, respectively, or 1 inch (25.4 mm), whichever is smaller

d) There shall be no emission of flame or molten material, or other manifestation of a risk of fire, during any system performance test. See 33.1.11 and 33.1.12. Also see 20.3.1 – 20.3.4..

8.5 Other enclosure openings

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

8.5.2 An opening in an outer enclosure, around a handle, reset button, or other control member is acceptable if the clearance between the control member and the edge of the opening does not exceed 1/8 inch (3.2 mm) for any setting of the control member in any position of the control member within the opening.

8.5.3 Except as permitted for ventilating openings or in 8.5.1 or 8.5.2, the enclosure shall have no open holes other than:

a) No more than four unused holes that may be provided in an enclosure that is intended for mounting various components inside the enclosure. The largest dimension of each such opening shall not be fore than 3/16 inch (4.8 mm).

b) No more than four holes 1/8 inch (3.2 mm) or less in diameter that may be provided for the escape of air or drainage of paint during the painting process if they are located as close to the corners of the enclosure as possible, preferably at the rear of the enclosure.

8.5.4 Except as indicated in 8.5.5, openings provided in the enclosure of a component intended for permanent connection to the power supply shall be so located that they will not vent into concealed spaces of a building structure such as into hollow spaces in the wall, and the like when the equipment is installed as intended.

8.5.5 The requirement in 8.5.6 does not apply to an opening for a mounting screw or nail or for a manufacturing operation (such as paint drainage) if no such opening has a dimension more than 17/64 inches (6.7 mm) or an area more than 0.055 square inch (35.5 mm^2).

8.5.6 An opening for ventilation in the enclosure, other than in the bottom of a product and an opening associated with the dissipation of heated air shall be provided with one or more baffles that will prevent the emission of flame, molten metal, burning insulation, or the like from the product.

Exception: In a compartment other than one that houses an overload or overcurrent protective device, the baffles may be omitted if no ventilating opening in a vertical wall, other than one associated with the dissipation of heated components during the intended operation of the product, is more than 3/8 inch (9.5 mm) wide.

8.5.7 An enclosure, intended for recessed mounting and whose front panel is to be flush with the surface of the wall, shall have no nonfunctional openings.

8.5.8 The thickness of perforated sheet steel and sheet steel used for expanded-metal mesh shall be in accordance with the values in Table 8.4.

Exception: The thickness of expanded steel mesh may be less than specified in Table 8.4, but not less than specified in Table 8.5, if:

a) The indentation of a guard or enclosure will not:

1) Alter the clearance between uninsulated movable live parts and grounded metal, such that performance would be adversely affected; or

2) Reduce spacings below the minimum values given in Sections 29 – 31; and

b) Either:

1) Exposed mesh or any one side or surface of the protected device has an area of not more than 72 square inches (465 cm^2) and has no dimensions greater than 12 inches (305 mm), or

2) The width of a protected opening is not greater than 3-1/2 inches (89 mm).

Table 8.4
Minimum thickness of expanded metal mesh[a]

Openings	Uncoated		Zinc coated	
	inch	(mm)	inch	(mm)
Maximum 1/2 square inch (3.23 cm$^{2)}$	0.042	(1.07)	0.045	(1.14)
More than 1/2 square inch	0.080	(2.03)	0.0084	(2.13)
[a] In accordance with 8.5.9.				

Table 8.5
Minimum thickness of expanded metal mesh[a]

Uncoated		Zinc coated	
inch	(mm)	inch	(mm)
0.020	(0.51)	0.024	(0.62)
[a] In accordance with conditions given in the Exception to 8.5.8			

8.5.9 The wires of screen shall not be smaller than 16 AWG (1.3 mm^2) if the screen openings are 1/2 square inch (3.23 cm^2) or less in area, and shall not be smaller than 12 AWG (3.3 mm^2) for larger screen openings.

8.6 Glass panels

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

8.6.2 Glass for an opening not more than 4 inches (101.6 mm) in any dimension shall not be less than 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 not be less than 1/8 inch (3.2 mm) thick. Glass that covers a larger area shall not be less than 1/8 inch thick and shall conform to one of the Glass Breakage Tests, Section 37.

8.6.3 A transparent material other than glass employed as a covering over an opening in an enclosure shall be investigated to determine if it has adequate mechanical strength and is otherwise acceptable for the purpose.

8.7 Cast metal enclosures

8.7.1 The thickness of cast metal used for an enclosure shall be as indicated in Table 8.6. Cast metal having a thickness 1/32 inch (0.8 mm) less than that indicated in the table may be employed if the surface under consideration is curved, ribbed, or otherwise reinforced, or if the shape or size of the surface is such that equivalent mechanical strength is provided.

8.7.2 Die-cast metal for other than flush boxes is acceptable if it complies with one of the alloy specifications given in the Standard Specification for Zinc and Zinc-Aluminum (ZA) Alloy Foundry and Die Castings, ASTM B86-98.

Table 8.6
Cast-metal electrical enclosures

Use or dimensions of area involved[a]	Minimum thickness			
	Die-cast metal		Cast metal of other than the die-cast type	
	inch	(mm)	inch	(mm)
Area of 24 square inches (155 cm^2) or less having no dimension greater than 6 inches (152 mm)	1/16	(1.6)	1/8	(3.2)
Area greater than 24 square inches (155 cm^2) or having any dimension greater than 6 inches (152 mm)	3/32	(2.4)	1/8	(3.2)
At a threaded conduit hole	1/4	(6.4)	1/4	(6.4)
At an unthreaded conduit hole	1/8	(3.2)	1/8	(3.2)

[a] The area limitations for metal 1/16 inch (1.6 mm) thick may be obtained by the provision of reinforcing ribs subdividing a larger area.

8.8 Product enclosure mounting

8.8.1 The product enclosure shall be provided with means for mounting in the intended manner. All necessary fittings, such as brackets, hangers, or the like shall be furnished with the product.

8.8.2 The mounting means shall be accessible without the disassembly of any operating part of the product. The removal of a completely assembled panel, cover, or equivalent is not considered to be disassembly of an operating part.

8.8.3 Bolts, screws, or other parts used for mounting the product shall be independent of those used for securing component parts of the assembly.

8.8.4 A product need not be furnished with an outlet box:

a) If means for attachment to a standard outlet box are provided; and

b) The product is mounted in such a box and the required electrical spacings are provided and maintained.

9 Polymeric Materials

9.1 General

9.1.1 These requirements apply to polymeric materials used to form the outer enclosures of NEC Class 1 and Class 3 circuits, structural or functional parts, thermal and acoustical insulation, and miscellaneous

parts of the product. They do not apply to NEC Class 2 circuits or materials used as electrical insulation nor to small parts such as control knobs, buttons, insulating bushings, resilient mounts, clamps, and wiring straps.

9.1.2 The acceptability of polymeric material shall be determined for each application.

9.1.3 Among the factors that are taken into consideration when judging the acceptability of a polymeric material are:

a) Flame resistance;

b) Mechanical strength;

c) Resistance to impact;

d) Moisture absorptive properties;

e) Resistance to distortion at temperature to which the materials may be subjected under conditions of normal or abnormal usage; and

f) The effect of exposure to weathering (outdoor sections only).

All of these factors are considered with respect to aging. See the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

9.1.4 Polymeric materials that are used to form part of the outer enclosure of NEC Class 1 or Class 3 circuits shall comply with the requirements for stationary equipment in accordance with the Standard for Polymeric Materials– Use in Electrical Equipment Evaluations, UL 746C.

9.1.5 For the purpose of evaluating electrical spacings between uninsulated live parts and a polymeric material, the material shall be treated as a dead metal part unless it complies with the performance requirements of the Volume Resistivity Test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

9.1.6 Special consideration shall be given to the possibility of external ignition of a nonmetallic outer enclosure.

9.2 Material classification

9.2.1 Materials are designated with respect to flammability characteristics and are identified as 5VA, 5VB, V-0, V-1, or V-2; HF-1 or HF-2; HB, and HBF materials. See the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

9.3 Ignition sources

9.3.1 As used in 9.4.1 – 9.4.5, possible ignition sources within the product are considered to be wiring and any electrical component such as a switch, relay, transformer, motor winding, and the like, not enclosed in metal or 5VA or 5VB material.

9.4 Material application

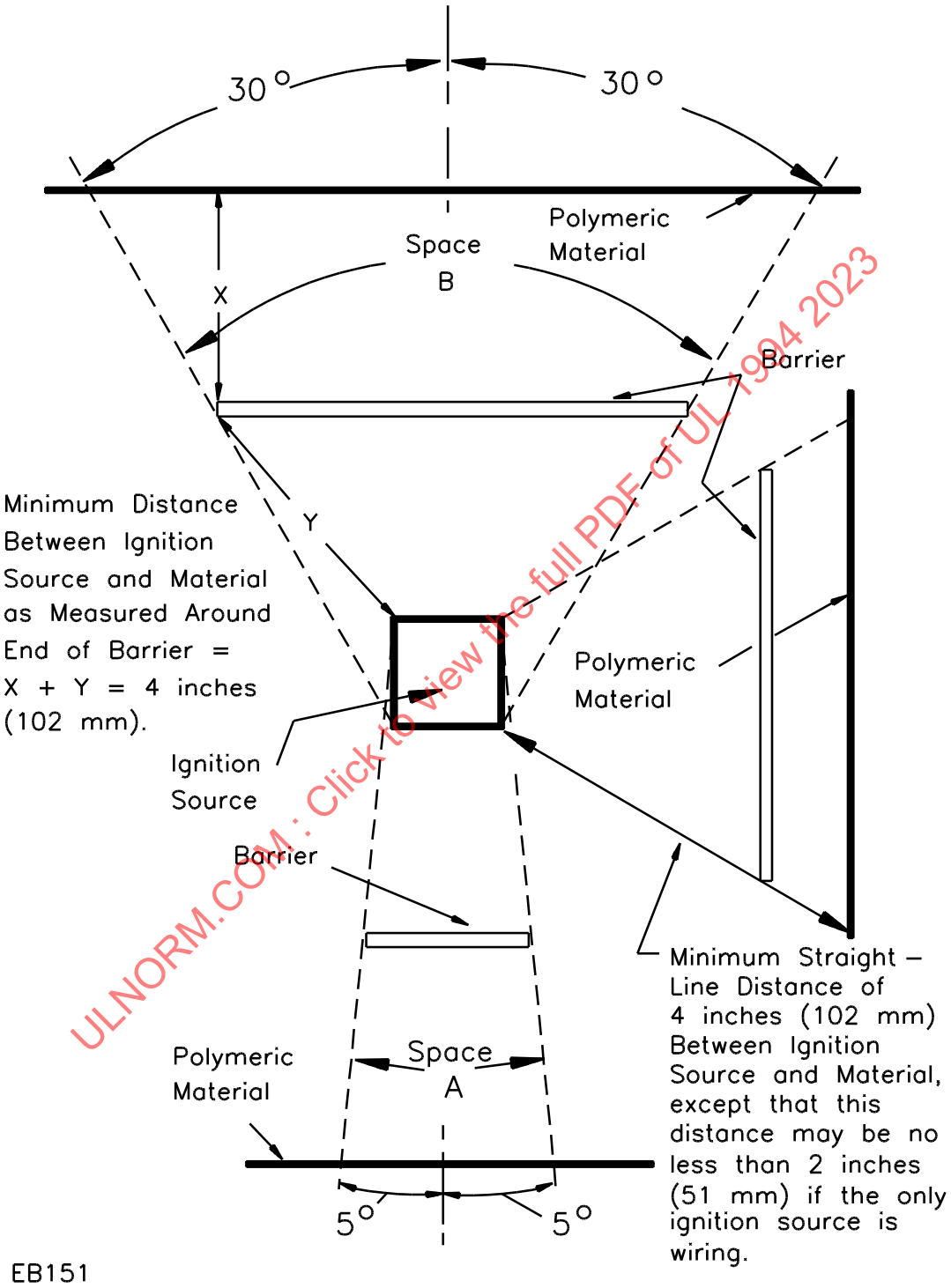
9.4.1 Parts formed of polymeric material that support or isolate electrical components, or that are exposed to ignition sources within the product, shall be of 5VA or 5VB material.

9.4.2 A polymeric material that does not conform with the flammability requirements for 5VA or 5VB materials shall be V-0, V-1 or V-2. See 9.4.6 and 9.4.7. Such materials shall not be used for the support or isolation of wiring or electrical components.

9.4.3 A V-0 or V-1 material may be used if it is not exposed to ignition sources. See 9.4.4 and 9.4.5. A V-2 material may be used if, in addition to being isolated from ignition sources in the same manner as V-0 or V-1 materials, there are no flammable materials or openings in the enclosure below the V-2 material within a volume defined by Space A of Figure 9.1.

Figure 9.1

Exposure to ignition source



Space A – Represents the volume below the ignition source determined by a straight line that moves about the ignition source while remaining at an angle of 5 degrees from the vertical and is always so oriented that the volume is maximum.

Space B – Represents the volume above the ignition source determined in the same manner as Space A, except that the angle is 30 degrees from the vertical.

9.4.4 A material located below the ignition source and within Space A of Figure 9.1 may be isolated by means of a horizontal barrier extending at least to the boundary surface of the space. A material located above the ignition source and within Space B of Figure 9.1 may be isolated by means of a barrier, extending at least to the boundary surface of the space, and so located that the minimum distance between the material and ignition source is 2 inches (50.8 mm) for wiring and 4 inches (102 mm) for electrical components.

9.4.5 A material located essentially in the vertical plane and adjacent to an ignition source is considered isolated from the ignition source if it is separated from wiring by a distance of 2 inches (50.8 mm) and from electrical components by a distance of 4 inches (102 mm). A barrier may be used for isolation provided the size of the barrier is such that the minimum straight-line distance between the material and ignition source is 2 inches for wiring and 4 inches for electrical components. See Figure 9.1.

9.4.6 If required by 9.4.4 or 9.4.5, a barrier shall be formed of metal or of a 5VA or 5VB material and shall be mechanically secured in place.

9.4.7 The requirements in 9.4.2 – 9.4.5 do not apply to polymeric materials completely enclosed in metal that is at least 0.010 inch (0.254 mm) thick nor to materials classified as HB, V-0, V-1, V-2, HF-1, HF-2, or HBF that are laminated between two metal surfaces if:

a) The thickness of the metal of each surface is 0.010 inch (0.254 mm) or more.

b) The exposed vertical surface of the material has a width of not more than 3/8 inch (9.5 mm).

10 Protection Against Corrosion

10.1 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, Sherardizing, plating, or other equivalent means.

Exception No. 1: This requirement does not apply to parts such as washers, screws, bolts, and the like, if corrosion of such unprotected parts would not be likely to result in a risk of fire or electric shock.

Exception No. 2: Parts made of stainless steel do not require additional protection against corrosion.

10.2 Metals shall be used in combinations that are galvanically compatible.

FIELD WIRING CONNECTIONS

11 General

11.1 General

11.1.1 There shall be sufficient space within the enclosure for the installation of those wires and cables likely to be used in connecting the normal and emergency circuits to the equipment.

11.1.2 In the investigation of wiring spaces, it is assumed that the size, type, and conductor material of a wire to be used for installation of wiring connections will be in accordance with the National Electrical Code, ANSI/NFPA 70.

11.2 Wire-bending space

11.2.1 Wire-bending space when the conductor does not enter or leave the enclosure through the wall opposite its terminal shall be as specified in Table 11.1.

Table 11.1
Minimum wire-bending space in inches[a,b,c]

Wire size AWG or MCM	Wire per terminal (pole)	
	1	2
14 – 10	Not specified	Not specified
8 – 6	1-1/2	–
4 – 3	2	–
2	2-1/2	–
1	3	–
0 – 2/0	3-1/2	5
3/0 – 4/0	4	6
250	4-1/2	6

[a] For SI units: one inch = 25.4 millimeters.

[b] Wire-bending space at terminals is to be measured in a straight line from the center of the wire opening, in the direction the wire leaves the terminal, to the wall, barrier, or obstruction. See 11.2.5.

[c] The minimum wire-bending space required for wire sizes or combinations of wires not covered will be determined by investigation.

11.2.2 Wire-bending space when the conductor enters or leaves the enclosure through the wall opposite its terminal shall be as specified in Table 11.2.

Table 11.2
Minimum wire-bending space in inches[a,b,c]

Wire size AWG or MCM	Wires per terminal (pole)	
	1	2
14 – 10	Not specified	Not specified
8	1-1/2	–
6	2	–
4	3	–
3	3	–
2	3-1/2	–
1	4-1/2	–
0	5-1/2	5-1/2
2/0	6	6
3/0	6-1/2 (1/2)[d]	6-1/2 (1/2)[d]
4/0	7 (1)[d]	7-1/2 (1-1/2)[d]
250	8-1/2 (2)[d]	8-1/2 (2)[d]

[a] For SI units: one inch = 25.4 millimeters.

[b] Wire-bending space at terminals is to be measured in a straight line from the edge of the terminal closest to the wall, in a direction perpendicular to the enclosure wall. See 11.2.5.

[c] The minimum wire-bending space required for wire sizes or combinations of wires not covered will be determined by investigation.

[d] For removable wire terminals (as defined in 11.2.3) and lay-in wire terminals intended for only one wire, bending space may be reduced by the number of inches shown in parentheses.

11.2.3 For the purpose of wire-bending space requirements, a removable wire connector is one that can be removed from its intended location without disturbing structural or electrical parts, other than a cover, and that can be reinstalled with the conductor in place.

11.2.4 If a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance is to be measured from the end of the barrier.

11.2.5 For wire-bending space measurement, the lug or connector is to be at the smallest angle it can assume to the perpendicular of the wall the box is mounted to without defeating any means provided to prevent its turning (such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, and the like). However, it is assumed that the connector is not so oriented that the wire will be directed into a corner of the box to such an extent that the wall situated across from the box wall would necessitate additional bending of the wire. If a terminal is provided with one or more lugs or connectors for the connection of conductors in multiple, the distance is to be measured from the wire opening closest to the wall of the enclosure. If the connectors for a circuit are fixed in position (for example, by the walls of a recess) so that they are turned toward each other, the distance is to be measured at the wire opening nearest to the wall in a direction perpendicular to the wall. A barrier, shoulder, or the like is to be disregarded when the measurement is being made if it does not reduce the radius to which the wire must be bent otherwise.

11.2.6 A wiring space in which knockouts are provided shall be of such a width to accommodate (with respect to bending) conductors of the maximum size likely to be used at that knockout.

Exception: The wiring space may be of lesser width if:

a) Knockouts of required size are provided elsewhere in the equipment,

b) The wiring space at such other point or points is sufficiently wide to accommodate the conductors in question, and

c) The knockout or knockouts at such other points can be conveniently used in the intended wiring of the device. The values of the minimum acceptable width of a wiring space, with respect to conductors entering the knockout, are the same as the values of minimum bending space given in Table 11.1.

12 Cord-Connected Products

12.1 A product intended for cord connection to the power supply shall be provided with a flexible cord and attachment plug of the type, voltage rating, and ampacity consistent with the rating and intended application of the product.

12.2 The marked rating of the attachment plug of a cord-connected product shall not be less than 125 percent of the rating of the product.

12.3 A cord-connected product shall employ grounding-type attachment plugs that conform to the American National Standards designated in the following Table 12.1.

Table 12.1
Attachment plugs

Nameplate rating			Attachment plug	
volts	phase	amperes[a]	rating	ANSI designation[b]
110 – 120	1	12.0	15 amperes, 125 volts	5 – 15P
110 – 120	1	16.0	20 amperes, 125 volts	5 – 20P
200 – 240	1	12.0	15 amperes, 250 volts	6 – 15P
200 – 240	1	16.0	20 amperes, 250 volts	6 – 20P
110 – 120/200 – 240	1	12.0	15 amperes, 125/250 volts	14 – 15P
110 – 120/200 – 240	1	16.0	20 amperes, 125/250 volts	14 – 20P

[a] Ampere rating is maximum permitted to be marked on the product nameplate for attachment plug indicated.

[b] Standard for Wiring Devices – Dimensional Requirements, ANSI/NEMA WD6-1988.

12.4 A cord-connected product may employ Type S, SJ, SJO, SJTO, SO, SP-3, SPT-3, ST, or STO power-supply cord rated for use at a voltage not less than the rated voltage of the product. The ampacity of the cord as given in the National Electrical Code, ANSI/NFPA 70, shall be not less than that required by the product.

12.5 The length of a power-supply cord shall not be longer than 36 inches (914 mm). The length is to be measured between the point at which the cord exits the product and the attachment plug.

12.6 The power-supply cord shall be provided with a strain relief means so that a stress on the cord will not be transmitted to terminals, splices, or internal wiring. If a metallic cord grip is provided, it shall not contact uninsulated live parts or reduce spacings within the enclosure if the cord is moved inward. The cord shall not be subject to damage by moving parts if it can be moved inward.

12.7 The edges of the entry hole for the power-supply cord, including the cord entry hole in a bushing, shall be smooth and rounded, and without burrs, fins, or sharp edges that may damage the cord insulation. The power-supply cord shall be routed to prevent damage to the cord insulation.

13 Permanently-Connected Products

13.1 General

13.1.1 Products of the following types shall have provision for permanent connection to the power supply:

a) Products that have a total marked rating exceeding 20 amperes full load current.

b) Polyphase units.

c) Products rated in excess of 250 volts.

d) Products requiring field wired control.

e) Products requiring 120/208 or 120/240 volts, three-wire supply circuits.

13.1.2 With reference to 13.1.1(a), the largest sum of concurrent loads shown on the nameplate shall be used to determine the total marked rating.

13.1.3 The product shall have provision for connection of one of the wiring systems, in accordance with the National Electrical Code, ANSI/NFPA 70.

13.1.4 The knockout provided for connection of a field-wiring system to a field-wiring compartment shall accommodate conduit of the trade size determined by applying Table 13.1.

Table 13.1
Trade size of conduit in inches[a,b]

Wire size		Number of wires				
AWG	(mm^2)	2	3	4	5	6
14	(2.1)	1/2	1/2	1/2	1/2	1/2
12	(3.3)	1/2	1/2	1/2	3/4	3/4
10	(5.3)	1/2	1/2	1/2	3/4	3/4
8	(8.4)	3/4	3/4	1	1	1-1/4
6	(13.3)	3/4	1	1	1-1/4	1-1/4
4	(21.2)	1	1	1-1/4	1-1/4	1-1/2
3	(26.7)	1	1-1/4	1-1/4	1-1/2	1-1/2
2	(33.6)	1	1-1/4	1-1/4	1-1/2	2
1	(42.4)	1-1/4	1-1/4	1-1/2	2	2
0	(53.5)	1-1/4	1-1/2	2	2	2-1/2
2/0	(67.4)	1-1/2	1-1/2	2	2	2-1/2
3/0	(85.0)	1-1/2	2	2	2-1/2	2-1/2
4/0	(107.2)	2	2	2-1/2	2-1/2	3

[a] This table is based on the assumption that all conductors will be of the same size and there will be no more than six conductors in the conduit. If more than six conductors will be involved or if all of them are not of the same size, the internal cross-sectional area of the smallest conduit that may be used is determined by multiplying by 2.5 the total cross-sectional area of the wires, based on the cross-sectional area of Type THW wire.

[b] 1 inch = 25.4 mm.

13.1.5 The location of a terminal box or compartment in which power supply connections are to be made shall be such that the connections can be inspected after the unit is installed. The connections are to be accessible without removing parts other than a service cover or panel and the cover of the outlet box or compartment in which the connections are made.

13.1.6 A terminal compartment intended for the connection of a supply raceway shall be secured in position and shall be prevented from turning.

13.1.7 The product shall be provided with field-wiring terminals or leads for the connection of conductors having an ampacity of not less than that required by the product. It is assumed that branch-circuit conductors rated 60°C (140°F) will be used.

13.2 Field-wiring terminals

13.2.1 As used in 13.2.2 – 13.2.8, field-wiring terminals are those terminals to which power supply, control, or equipment grounding connections will be made in the field when the product is installed.

13.2.2 A field-wiring terminal shall be prevented from turning or shifting in position. This may be accomplished by means such as two screws or rivets; by square shoulders or mortices; by a dowel pin,

lug, or offset; or by a connecting strap or clip fitted into an adjacent part. Friction between surfaces is not acceptable for preventing movement of the terminals.

13.2.3 For 8 AWG (8.4 mm^2) and larger conductors, pressure wire connectors shall be used. For 10 AWG (5.3 mm^2) and smaller conductors, the parts to which wiring connections are made may consist of clamps or wire binding screws with cupped washers, terminal plates, or the equivalent to hold the wire in position.

13.2.4 A wire binding screw at a field-wiring terminal shall be not smaller than No. 10 (4.8 mm diameter).

Exception: A No. 8 (4.2 mm diameter) screw may be used for the connection of one 14 AWG (2.1 mm^2) and a No. 6 (3.5 mm diameter) screw may be used for the connection of a 16 AWG (1.3 mm^2) or 18 AWG (0.82 mm^2) control circuit conductor.

13.2.5 According to the National Electrical Code, ANSI/NFPA 70, 14 AWG (2.1 mm^2) is the smallest conductor that may be used for branch-circuit wiring and thus is the smallest conductor that may be anticipated at a terminal for the connection of a power-supply wire.

13.2.6 A terminal plate 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. In either case, the wire binding screw shall have two full threads in the metal unless a lesser number of threads results in a connection in which the threads will not strip with normal tightening torque in accordance with the values indicated in the Standard for Wire Connectors, UL 486A-486B. See 13.2.7.

13.2.7 A terminal plate formed from stock having the minimum required thickness may have the metal extruded at the tapped hole for the binding screw.

13.2.8 Upturned lugs or a cupped washer shall be capable of retaining a conductor of the size mentioned in 13.2.5 but no smaller than 14 AWG (2.1 mm^2), under the head of the screw or washer.

13.2.9 A wire binding screw shall thread into metal.

13.2.10 A field-wiring terminal intended for the connection of a grounded conductor shall be of a metal or plated with a metal substantially white in color and shall be readily distinguishable from the other terminals, or identification of that terminal shall be shown in some other manner, such as on an attached wiring diagram.

13.3 Field-wiring leads

13.3.1 The length of a lead inside an outlet box or wiring compartment shall be 6 inches (152 mm) or more if the lead is intended for field connection to an external circuit.

Exception: The lead may be less than 6 inches long if it is evident that the use of a longer lead may result in damage to the lead insulation.

13.3.2 Leads intended for connection to an external circuit shall be provided with a strain relief means if stress on the lead may be transmitted to terminals, splices, or internal wiring.

13.3.3 Leads provided for spliced connections to an external high-voltage circuit shall not be connected to wire binding screws or pressure wire connectors located in the same compartment as the splice, unless the screws or connectors are rendered unusable for field-wiring connections or the leads are insulated at the unconnected ends.

13.3.4 A lead intended for the connection of a grounded conductor shall be finished to show a white or gray color, shall be readily distinguishable from other leads, and no other lead shall be so identified.

14 Grounding

14.1 The following are considered to constitute means for grounding:

a) In a product intended to be permanently connected by a metal enclosed wiring system; a knockout or equivalent opening in the metal enclosure of the product.

b) In a product intended to be permanently connected by a nonmetal enclosed wiring system such as nonmetallic-sheathed cable; an equipment grounding terminal or lead.

c) In a cord-connected product; an equipment grounding conductor in the cord.

14.2 On a permanently-connected product, a terminal intended solely for the connection of an equipment grounding conductor shall be capable of securing a conductor of the size suitable for the particular application in accordance with the National Electrical Code, ANSI/NFPA 70.

14.3 A soldering lug, a push-in, screwless connector, or quick-connect or similar friction-fit connector shall not be used for the grounding terminal intended for the connection of field supply connections or for the grounding wire in a supply cord.

14.4 On a permanently-connected product, a wire binding screw intended for the connection of an equipment grounding conductor shall have a green colored head that is hexagonal, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be plainly identified such as by being marked ⏚, "G ", " GR ", "GND ", or the like, or by a marking on a wiring diagram provided on the product. See also 14.5. The wire binding screw or pressure wire connector shall be secured to the frame or enclosure of the product and shall be located so that it is unlikely to be removed during service operations such as replacing fuses, resetting manual-reset devices, or oiling motors.

14.5 A pressure wire connector intended for grounding that is located where it may be mistaken for a neutral conductor of a grounded supply, shall be identified by a marking "EQUIPMENT GROUND" or with a green color identification.

14.6 On a permanently-connected product, the surface of an insulated lead intended solely for the connection of an equipment grounding conductor shall be finished in a continuous green color or a continuous green color with one or more yellow stripes, and no other lead shall be so identified.

14.7 On a cord-connected product, the grounding conductor of the flexible cord shall be finished with a continuous green color or with a continuous green color with one or more yellow stripes, and no other conductor shall be so identified. The grounding conductor shall be secured to the frame or enclosure of the product by a positive means, (see Bonding for Grounding, Section 19), that is not likely to be removed during any servicing operation not involving the power-supply cord. The grounding conductor shall be connected to the grounding blade of the attachment plug.

14.8 The continuity of the grounding system of the product shall not rely on the dimensional integrity of nonmetallic material.

INTERNAL WIRING

15 Cord-Connected Products

15.1 The internal wiring shall be Type S, SJ, SJO, SJT, SO, SP-3, SPT-3, or ST flexible cord, appliance wiring material, or equivalent wiring material.

15.2 Except as indicated in 15.4 and 15.5:

a) If 16 or 18 AWG (1.3 or 0.8 mm^2) conductors are used, the wiring shall be Type S, SJ, SJO, SJT, SJTO, SO, SP-3, SPT-3, ST, or STO cord, or appliance wiring material having insulation at least 4/64 inch (1.6 mm) thick.

b) If 14 or 12 AWG (3.3 or 2.1 mm^2) conductors are used, the wiring is to be Type S, SO, ST, SP-3, or SPT-3 cord, or appliance wiring material having insulation at least 5/64 inch (2.0 mm) thick.

15.3 Parallel-conductor appliance wiring material of the integral type shall not be ripped more than 3 inches (76 mm) unless the thickness of the conductor insulation after ripping is at least 0.058 inch (1.47 mm) for 16 AWG or smaller conductors and at least 0.070 inch (1.78 mm) for 14 AWG conductors. The length of a rip is not limited if the material is within a separate metal enclosure and the conductor insulation after ripping is at least 0.028 inch (0.71 mm) thick.

15.4 Rubber, neoprene, or thermoplastic insulated fixture wire and thermoplastic insulated appliance wiring material having an insulation thickness not less than 0.028 inch (0.71 mm), or rubber-insulated appliance wiring material having an insulation thickness not less than 0.043 inch (1.09 mm) may be used if contained in separate metal enclosures, conduit, electrical metallic tubing, metal raceways, or the equivalent, or contained in suitable insulating tubing having a wall thickness not less than 0.028 inch for 16 AWG (1.3 mm^2) or smaller conductors and 0.043 inch for 14 AWG (2.1 mm^2) conductors. Wires not longer than 3 inches (76 mm) may extend outside of such protective enclosures to facilitate connection to electrical components.

15.5 Neoprene or thermoplastic insulated appliance wiring material having 2/64 inch (0.8 mm) conductor insulation need not be provided with protective enclosures or additional insulation as indicated in 15.4 if all of the following conditions are met:

a) Wiring is not subject to movement by air or vibration.

b) Where practicable, individual leads are bunched together to form a cable.

c) Wiring is secured to fixed panels or similar surfaces at frequent intervals to assure proper routing and to prevent the likelihood of hooking of slack during routine servicing operations.

d) Wiring is located in a compartment that is provided with a complete base pan or similar bottom closure.

e) Wiring cannot be contacted through openings in the outer enclosure or cabinet when judged in accordance with 6.3.3 or 6.3.5 and Figure 6.1. In judging compliance with this condition, a grille, cover, panel, and the like that may be removed without the use of tools are to be removed.

15.6 Wire insulation shall be of material rated for the potential involved and for the temperature to which it may be subjected in actual use.

15.7 The required temperature rating for wiring is based on the temperatures measured in the temperature tests. See 33.1.11 and 33.1.12. A 60°C wire or cord is considered acceptable if the temperature rise measured in the test does not exceed 35°C above the test ambient. A 75°C wire or cord is considered acceptable if the measured temperature rise does not exceed 50°C above the test ambient.

15.8 The insulation of wires or cords connected to fan motors shall be of an oil-resistant type, such as Type SJO, SJT, or SPT-3 cord or appliance wiring materials having oil-resistant insulation.

15.9 Crossover leads between the cabinet and a door shall be constructed and installed so as to reduce the possibility of damage to insulation and conductors due to opening and closing the door. The insulation provided on crossover leads shall be equivalent to that indicated in 15.1.

15.10 Wiring that is color coded green or green with one or more yellow stripes shall be used only for grounding conductors. Wiring used for other purposes shall not be identified with these codes.

16 Permanently-Connected Products

16.1 General

16.1.1 Wiring shall have insulation rated for the potential involved and the temperatures to which it may be subjected.

16.1.2 Wiring is to be judged on the basis of the temperatures measured during the temperature tests. See 33.1.11 and 33.1.12.

16.2 High-voltage circuits

16.2.1 The internal wiring of a product shall be completed to the means provided for field wiring connection.

16.2.2 Control equipment, including an auxiliary device, that is not part of the product but that is supplied with the product for field installation shall have provision for field wiring connections except that special connectors may be used if both mating parts are provided and factory attached to the product or the auxiliary device.

16.2.3 Conductors shall be a minimum of 18 AWG (0.8 mm^2) except for short integral leads of small electrical components such as relay coils and clock motors.

16.2.4 Except as indicated in 16.2.6 and 16.2.7, wiring shall be enclosed in metal-clad cable, conduit, electric metallic tubing, metal raceways, control boxes, or the equivalent. Appropriate fittings shall be used.

16.2.5 Refer to Group A in Table 16.1 for some wiring materials acceptable when enclosed as indicated in 16.2.4.

16.2.6 Cords or appliance wiring material as referenced in Group B of Table 16.1 may be employed in lieu of the enclosed wiring specified in 16.2.4 provided the wiring is enclosed by the product enclosure or enclosures. Thermoplastic wiring materials, as referenced in Group A of Table 16.1, with insulation thickness of 2/64 inch (0.8 mm) for 16 AWG (1.3 mm^2) or 18 AWG (0.8 mm^2), and 3/64 inch (1.2 mm) for 14 AWG (2.1 mm^2), 12 AWG (3.3 mm^2), 10 AWG (5.3 mm^2), or 8 AWG (8.3 mm^2), are considered equivalent to the wiring material referenced in Group B when the conductors are covered with 2/64 inch wall thickness thermoplastic insulating tubing of a type suitable for the purpose from the standpoint of electrical, mechanical, and flammability properties. For 6 AWG (13.3 mm^2), 4 AWG (21.2 mm^2), and 2 AWG (33.6 mm^2) thermoplastic wiring materials, as referenced in Group A of Table 16.1, enclosed in thermoplastic tubing as described above, are considered equivalent to the wiring materials specified in Group B when the total wall thickness (conductor and tubing) is not less than shown for Group B.

Table 16.1
Typical wiring materials WR

Group	Type of wire, cord, or cable	Wire size		Insulation thickness	
		AWG	$(mm)^2$	inch	(mm)
A	FFH-2, TF, TFF, TFN, TFFN,SF-2, SFF, RH, RHH, RHW, THW, XHHW, MTW, THW-MTW, THWN, PF, PGF, PFF, PGFF, TW, or thermoplastic appliance wiring material, with insulation thicknesses shown at the right corresponding to wire sizes indicated	10 and smaller	(5.3)	2/64	(0.8)
		8	(8.4)	3/64	(1.2)
		6	(13.3)	4/64	(1.6)
		4	(21.2)	4/64	(1.6)
		3	(26.7)	4/64	(1.6)
		2	(33.6)	4/64	(1.6)
		1	(42.4)	5/64	(2.0)
		1/0	(53.5)	5/64	(2.0)
		2/0	(67.4)	5/64	(2.0)
		3/0	(85.0)	5/64	(2.0)
		4/0	(107.2)	5/64	(2.0)
B	SO, ST, SPT-3E, SJO, SJT, or appliance wiring material having thermoplastic or neoprene insulation, with insulation thicknesses shown at right corresponding to the wire sizes indicated	18	(0.82)	4/64	(1.6)
		16	(1.3)	4/64	(1.6)
		14	(2.1)	5/64	(2.0)
		12	(3.3)	5/64	(2.0)
		10	(5.3)	5/64	(2.0)
		8	(8.4)	6/64	(2.4)
		6	(13.3)	8/64	(3.2)
C	S, SJ, SP-3, or Appliance wiring material with rubber insulation	Same as Group B			

16.2.7 With reference to 16.2.6, if the compartment enclosing the wiring has no openings other than for conduit or piping and contains no combustible material other than electrical insulation, the cord or appliance material referenced in Group C of Table 16.1 may be employed. Jumper leads not longer than 3 inches (76.2 mm) of any of the wiring materials indicated in Table 16.1 may be used between the terminals on a control panel in such a compartment.

16.3 Low-voltage circuits

16.3.1 If any failure of low-voltage wiring may cause malfunctioning of a protective device that may result in a risk of fire or electric shock, such wiring shall be enclosed as indicated in 16.2.4 and 16.2.6 or shall be Type SPT-2 or SP-2 cord or one of the types indicated in Group B or C of Table 16.1. Wires of types indicated in Group A of Table 16.1 or low energy safety control wire may be used if such wiring is located in a cavity or compartment of the product and is adequately protected against mechanical damage.

17 Wiring Methods

17.1 General

17.1.1 All wires and cords shall be routed and supported to prevent damage due to sharp edges, surfaces and parts that operate at a temperature in excess of that for which the wire insulation is rated, and moving parts. Clamping means shall have smooth, rounded surfaces.

17.1.2 Holes in walls, panels, or barriers through which insulated wires or cords pass and on which they may bear shall be provided with smoothly rounded bushings or the surfaces upon which the wires or cords may bear shall be smooth and rounded to prevent abrasion of the insulation. Bushings shall be fabricated from materials such as ceramic, phenolic, cold-molded composition, or fiber. Thermoplastic tape wrapped over a sharp edge is not acceptable.

17.2 Splices

17.2.1 All splices and connections shall be mechanically secured and electrically bonded. A soldered connection shall be made mechanically secure before being soldered if breaking or loosening of the connection may result in a risk of fire or electric shock.

17.2.2 Splices shall be located within the product enclosure. They shall be secured in position or located in a separate enclosure so that they are not subject to flexing, motion, or vibration due to air movement, or the like. A strain relief means shall be provided on the conductors if the wiring is likely to be moved during normal service operations, such as replacing fuses or resetting manual-reset devices.

17.2.3 A splice shall be provided with insulation equivalent to that of the wires involved if permanence of spacing between the splice and other metal parts is not maintained.

17.2.4 Splicing devices, such as fixture-type splicing connectors and pressure wire connectors, may be employed if they provide mechanical security and employ insulation rated for the voltage to which they are subjected. In determining if splice insulation consisting of coated fabric, thermoplastic, or other type of tubing is acceptable, consideration is to be given to such factors as its electrical, mechanical, and flammability properties.

17.3 Terminations

17.3.1 Quick-connecting assemblies shall form a secure electrical connection, such as by detents in the mating parts, and are to be capable of carrying the current involved.

17.3.2 Wire binding screws shall thread into metal.

17.3.3 At terminals, stranded conductors shall be secured by soldered or pressure-type terminal connectors, or the conductors shall be soldered or otherwise assembled to prevent loose strands after assembly. Soldered connections shall be made mechanically secure before being soldered.

17.3.4 Open-slot-type connectors shall not be used unless they are constructed to prevent disconnection resulting from loosening of the clamping means.

17.3.5 The shanks of terminal connectors shall be protected by electrical insulation not less than 0.028 inch (0.71 mm) thick if the spacings may be reduced below the minimum acceptable values by slight loosening of the clamping means. The insulating material shall be secured in position.

18 Separation of Circuits

18.1 Unless provided with insulation rated for the highest voltage involved, insulated conductors of different circuits, that is, internal wiring including wires in a wiring compartment, shall be separated by barriers or shall be segregated, and shall, in any case, be so separated or segregated from uninsulated live parts connected to different circuits.

18.2 Segregation of insulated conductors may be accomplished by clamping, routing, or other means that provides permanent separation from insulated or uninsulated live parts of a different circuit.

18.3 Field-installed conductors of any circuit shall be segregated or separated by barriers from field-installed and factory-installed conductors connected to any other circuit unless conductors of both circuits are insulated for the maximum voltage of either circuit.

18.4 Field-installed conductors of a high-voltage circuit or a low-voltage circuit with Class 1 National Electrical Code wiring shall be segregated or separated by barriers as follows:

a) From uninsulated live parts connected to a different circuit, other than wiring terminals; and

b) From any uninsulated live parts of electrical components, such as a pressure-limiting device, motor overload protective device, or other protective device, if short-circuiting or grounding may result in a risk of fire or electric shock, except at wiring terminals.

18.5 Field-installed conductors of a low-voltage circuit with Class 2 National Electrical Code wiring shall be segregated or separated by barriers as follows:

a) From uninsulated live parts connected to a high-voltage circuit; and

b) From wiring terminals and any other uninsulated live parts of low-voltage electrical components (such as a pressure-limiting device, motor overload protective device, or other protective device), if short-circuiting or grounding may result in a risk of fire or electric shock.

18.6 A barrier used to provide separation between the wiring of different circuits shall be of metal or of a rigid insulating material secured in place.

19 Bonding for Grounding

19.1 Provision shall be made for the grounding of all exposed or accessible noncurrent-carrying metal parts that are likely to become energized and that may be contacted by a user or by service personnel during service operations likely to be performed when the product is energized.

19.2 Uninsulated metal parts, such as cabinets, electrical enclosures, motor frames and mounting brackets, controller mounting brackets, capacitors, and other electrical components shall be bonded for grounding if they may be contacted by the user or serviceman.

Exception: Metal parts described as follows need not be grounded:

a) Adhesive-attached metal-foil markings, screws, handles, and the like that are located on the outside of enclosures or cabinets and isolated from electrical components or wiring by grounded metal parts so that they are not likely to become energized.

b) Isolated metal parts, such as motor controller magnet frames and armatures or small assembly screws, that are positively separated from wiring and uninsulated live parts.

c) Cabinets, panels, and covers that do not enclose uninsulated live parts if wiring is positively separated from the cabinet, panel, or cover so that it is not likely to become energized.

d) Panels and covers that are insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar materials not less than 0.028 inch (0.71 mm) thick, and secured in place. If material having a lesser thickness is used, consideration is to be given to such factors as its electrical, mechanical, and flammability properties when compared with materials in thicknesses specified above.

19.3 The metal enclosure of a product having a slide-out chassis is considered to be grounded if the resistance between the point of connection of the equipment grounding means and enclosure does not exceed 0.1 ohm. Unless a separate grounding conductor is used, this will require that all nonconductive

coatings between the enclosure and equipment grounding means be penetrated when the chassis is inserted in the enclosure. In such cases, metal-to-metal contact shall be maintained at any point of insertion or withdrawal of the chassis.

19.4 Metal-to-metal hinge bearing members for a door or cover are considered to be a means for bonding a door or cover for grounding if a multiple-bearing pin-type hinge or hinges are used.

19.5 A separate component bonding conductor shall be of copper, a copper alloy, or other material acceptable for use as an electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by metallic or nonmetallic coatings, such as enameling, galvanizing, or plating. A separate bonding conductor or strap shall:

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

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

19.6 The bonding shall be by a positive means such as clamped, riveted, bolted, or screwed connection; welding, soldering, and brazing materials having a softening or melting point greater than 445°C (833°F). The bonding connection shall penetrate nonconductive coatings such as paint or vitreous enamel. Bonding around a resilient mount shall not depend on the clamping action of rubber or other nonmetallic material.

Exception: A connection that depends on the clamping action exerted by rubber or other nonmetallic material may be used if it complies with the requirements in 19.9.

19.7 With reference to 19.6, a bolted or screwed connection that incorporates a star washer under the screwhead or a serrated screwhead is acceptable for penetrating nonconductive coatings. If the bonding means depends upon screw threads, two or more screws or two full threads of a single screw shall engage the metal.

19.8 An internal connection for bonding internal parts to the 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 of the specified dimensions if the connector is not likely to be displaced and the component is limited to use on a circuit having a branch-circuit protective device, rated as specified in Table 19.1.

Table 19.1
Minimum internal terminal connections for bonding

Terminal dimensions, inch (mm)	Rating of protective device, amperes
0.20 by 0.187 by 0.250 (0.51 by 4.75 by 6.35)	20 or less
0.032 by 0.187 by 0.250 (0.81 by 4.75 by 6.35)	20 or less
0.032 by 0.205 by 0.250 (0.81 by 5.2 by 6.35)	20 or less
0.032 by 0.250 by 0.312 (0.81 by 6.35 by 7.92)	60 or less

19.9 A connection that depends upon the clamping action exerted by rubber or other nonmetallic material may be acceptable if it complies with the requirements specified in 19.13 under any normal degree of compression permitted by a variable clamping device and if the results are still acceptable after exposure to the effects of oil, grease, moisture, and thermal degradation that may occur in service. Also, the effect of assembling and disassembling for maintenance purposes, such a clamping device is to be

considered, with particular emphasis on the likelihood of the clamping device being reassembled in its intended fashion.

19.10 Except as mentioned in 19.13 and 19.14, on a cord-connected product, a bonding conductor or strap shall have a cross-sectional area not less than that of the grounding conductor of the supply cord.

19.11 On a permanently-connected product, the size of a conductor used to bond an electrical enclosure shall be based on the rating of the branch-circuit overcurrent device to which the equipment will be connected. The size of the conductor or strap shall not be less than as specified in Table 19.2.

Exception: A smaller conductor may be used if it complies with the requirements in 19.13.

Table 19.2
Minimum bonding wire conductor size

Rating of overcurrent device	Size of bonding conductor[a]			
	Copper wire		Aluminum wire	
amperes	AWG	(mm^2)	AWG	(mm^2)
15	14	(2.1)	12	(3.3)
20	12	(3.3)	10	(5.3)
30	10	(5.3)	8	(8.4)
40	10	(5.3)	8	(8.4)
60	10	(5.3)	8	(8.4)
100	8	(8.4)	6	(13.3)
200	6	(13.3)	4	(21.2)

[a] Or equivalent cross-sectional area.

19.12 A conductor, such as a clamp or strap, used in place of a separate wire conductor as specified in 19.11, is considered acceptable if the minimum cross-sectional conducting area is equivalent to the wire sizes specified in Table 19.2.

19.13 A smaller conductor may be used if the bonding conductor and connection comply with the bonding conductor test described in the Standard for Emergency Lighting and Power Equipment, UL 924, or the requirements for power units other than Class 2, UL 1012. See 33.1.11 and 33.1.12.

19.14 A bonding conductor to a motor or other electrical component need not be larger than the size of the motor-circuit conductors supplying the component. See 19.7.

19.15 Splices shall not be used in wire conductors used to bond electrical enclosures or other electrical components.

19.16 If more than one size branch-circuit overcurrent protection 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.

COMPONENTS, ELECTRICAL

20 General

20.1 Mounting of components

20.1.1 A switch, lampholder, attachment-plug, connector base, or similar electrical component shall be secured in position, and, except as specified in 20.1.2 – 20.2.1, shall be prevented from turning.

20.1.2 In the mounting or supporting of small, fragile, insulating parts, screws or other fastenings shall not be tight enough to cause cracking or breaking of these parts with expansion and contraction. Generally, such parts should be slightly loose.

20.1.3 The requirement that a switch be prevented from turning may be waived if all four of the following conditions are met:

a) The switch is a plunger or other type that does not tend to rotate when operated. A toggle switch is considered to be subject to forces that tend to rotate the switch during intended operation of the switch.

b) The means for mounting the switch makes it unlikely that the operation of the switch will loosen it.

c) Spacings are not reduced below the minimum required values if the switch rotates.

d) The operation of the switch is by mechanical linkage rather than by direct contact by persons.

20.1.4 A lampholder of the type in which the lamp cannot be replaced, such as a neon pilot or indicator light in which the lamp is sealed in a nonremovable jewel, need not be prevented from turning if rotation will not reduce spacings below the minimum required values.

20.1.5 Uninsulated live parts shall be so secured to the base or mounting surface that they will be prevented from turning or shifting in position, if such motion may result in a reduction of spacings below the acceptable values. (The securing of contact assemblies shall provide for the continued alignment of contacts.)

20.1.6 The means for preventing turning shall consist of more than friction between surfaces.

20.1.7 A toothed lock washer that provides both spring take-up and an interference lock is acceptable as the means for preventing a small stem-mounted switch or other device having a single-hole mounting means from turning.

20.1.8 A flush plate for outlet-box mounting shall be of 0.030 inch (0.76 mm) or thicker ferrous metal, of 0.040 inch (1.02 mm) or thicker nonferrous metal, or of 0.100 inch (2.54 mm) or thicker nonconductive material.

20.1.9 A yoke or strap or the mounting ears of a part intended to be mounted on a standard outlet box shall be of 0.040 inch (1.02 mm) or thicker steel. If a nonferrous metal is used, it shall be of thickness sufficient to provide mechanical strength and rigidity not less than that of 0.040 inch thick steel.

20.2 Insulating materials

20.2.1 Material for the mounting of current-carrying parts shall be porcelain, phenolic or cold-molded composition, or the equivalent.

20.2.2 Vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not for the sole support for uninsulated current-carrying parts of other than low-voltage circuits. A barrier of vulcanized fiber or similar material employed as a guard for uninsulated high-voltage live parts shall be not less than 1/32 inch (0.8 mm) thick.

20.2.3 Polymeric materials may be used for the sole support of uninsulated live parts if the material is found to have the mechanical strength and rigidity, dielectric voltage withstand, resistance to heat, flame propagation, arcing, creep, moisture, and other properties beyond the minimum acceptable level as a result of aging as required by the applicable performance requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

20.2.4 The thickness of a flat sheet of insulating material, such as phenolic composition or the equivalent, used for panel-mounting of parts shall be not less than that specified in Table 20.1.

Table 20.1
Thicknesses of flat sheets of insulating material

Maximum dimensions				Minimum thickness[a,b]	
Length or width		Area			
inch	(cm)	inch^2	(cm^2)	inch	(mm)
24	(60.9)	360	(2322)	3/8	(9.5)
48	(122.0)	1152	(7432)	1/2	(12.7)
48	(122.0)	1728	(11,148)	5/8	(15.9)
Over 48	(Over 122.0)	1728	(11,148)	3/4	(19.1)

[a] Material not less than 1/8 inch (3.2 mm) in thickness may be employed for a panel that is adequately supported or reinforced to provide rigidity not less than that of a 3/8 inch sheet.

[b] Material less than 1/8 inch thick may be employed for subassemblies, such as supports for terminals for internal wiring, resistors, and other components.

20.2.5 The thickness of a flat sheet of insulating material, such as phenolic composition or the equivalent, employed for panel mounting of parts, shall be not less than 3/8 inch (9.5 mm) thick, except that material less than 3/8 inch but not less than 1/8 inch (3.2 mm) thick, may be employed for a panel if the panel is supported or reinforced to provide rigidity not less than that of a 3/8 inch sheet. Material less than 1/8 inch may be employed for subassemblies, such as supports for terminals for internal wiring, resistors, and other components.

20.2.6 A terminal block mounted on a metal surface that may be grounded shall be provided with an insulating barrier between the mounting surface and all live parts exposed on the underside of the block unless the parts are staked, upset, sealed, or equivalently prevented from loosening so as to prevent the parts and the ends of replaceable terminal screws from reducing spacings below the minimum required values.

20.3 Uninsulated live parts

20.3.1 Uninsulated live parts of a high-voltage circuit shall be located, guarded, or enclosed so as to prevent unintentional contact through openings in the enclosure, or while performing service (maintenance) operations such as oiling motors or adjusting controls.

20.3.2 In the examination of a product in connection with the requirements in 20.3.1, part of the outer enclosure is to be disregarded if it:

a) May be removed without the use of tools; or

b) May be removed by the user to allow access for making normal operating adjustments; that is, it will not be assumed that the part in question provides protection against a risk of electric shock.

20.3.3 Uninsulated live parts in compartments that are normally opened for refilling, coil collecting, relamping, lubricating, control adjusting, control resetting, or other such required service (maintenance) operations shall be so enclosed, located, or guarded as to prevent unintentional contact while performing such operations.

20.3.4 The requirement in 20.3.3 will necessitate the use of enclosures, covers, or barriers over uninsulated live parts. A cover or barrier that must be removed in performing these functions is not considered as providing the protection required.

20.4 Current-carrying parts

20.4.1 All current-carrying parts shall be of silver, copper, a copper alloy, or other material acceptable for use as an electrical conductor.

20.4.2 Aluminum may be used as a current-carrying part if treated to resist oxidation and corrosion.

20.4.3 Bearings, hinges, and the like are not acceptable for use as current-carrying parts.

21 Capacitors

21.1 A capacitor shall employ such materials and shall be so constructed that it will not constitute a risk of fire. Its operation shall not be impaired by the temperatures to which it is subjected under the most severe conditions of its intended use. A paper capacitor shall be impregnated or otherwise treated or enclosed to exclude moisture.

21.2 A motor starting or running capacitor (or a capacitor connected across the line, that is, a capacitor for radio-interference elimination) shall be housed within an enclosure or container that will protect the plates against mechanical damage and will prevent the emission of flame or molten material resulting from failure of the capacitor. Except as noted in 21.3 and 21.7, the container shall be of metal providing strength and protection not less than that of uncoated steel having a thickness of 0.020 inch (0.51 mm).

21.3 The container of a capacitor may be of sheet steel of thickness less than that mentioned in 21.2 or may be of material other than metal if the capacitor is mounted in an enclosure that houses other components and if the enclosure is acceptable for the enclosure of live parts.

21.4 If the container of an electrolytic capacitor is constructed of metal, it shall be considered as a live part and shall be either permanently insulated from dead metal parts by moisture-resistant insulation not less than 1/32 inch (0.8 mm) thick, or be separated from dead metal parts as indicated under Spacings.

21.5 A capacitor employing a dielectric medium more combustible than askarel shall be protected against expulsion of the dielectric medium when tested in accordance with the performance requirements specified in 33.1.11 and 33.1.12, including faulted overcurrent conditions based on the circuit in which it is used.

21.6 If the capacitor is protected against damage by the outer enclosure of the product, a separate enclosure for the container is not required. If the metal shell of a capacitor complies with the Table of Thickness of Sheet Metal, see Table 8.2, an additional enclosure is not required, provided the terminals are enclosed.

21.7 The individual enclosure of an electrolytic capacitor with means for venting shall provide protection against mechanical damage. The requirement for minimum enclosure thickness does not apply. The individual enclosure of an electrolytic capacitor not provided with means for venting and with an opening more than 1/16 inch (1.59 mm) wide between the capacitor enclosure and the motor need not comply with the requirement for enclosure thickness given in 21.2 if it complies with the following: several samples of the capacitor and its enclosures, with cotton placed around openings in the enclosure, are to be subjected to such overvoltage as to cause failure. If the cotton ignites on failure of the capacitor, the results are not acceptable.

22 Coil Windings

22.1 The insulation of coil windings of relays, transformers, and the like shall resist the absorption of moisture.

22.2 Film-coated wire is not required to be given additional treatment to prevent moisture absorption.

22.3 Coil windings shall comply with the applicable requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and either the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2, or the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

23 Electric-Discharge Lighting Systems

23.1 Electric-discharge lighting systems shall be constructed for an open circuit potential of 1000 volts or less.

23.2 All components, such as ballasts, starters, capacitors, and lampholders of an electric-discharge lighting system shall be located within the product enclosure.

23.3 An electric-discharge lampholder shall have a voltage rating not less than the output voltage rating marked on the ballast used, except that if the ballast is also marked with a lesser secondary voltage to ground, the rating of the lampholder may be less than the output voltage marked on the ballast, but not less than the marked secondary voltage to ground.

23.4 The voltage rating of the secondary-circuit wiring of an electric-discharge lamp shall be not less than the output voltage rating marked on the ballast or ballasts to which it is connected, but not less than 300 volts in any case.

23.5 Integral leads provided as part of a lampholder shall have voltage ratings not exceeding the voltage rating of the lampholder unless a higher voltage rating is printed on the surface of the leads.

23.6 A product employing electric-discharge lamps shall be provided with a ballast designed for the operation of lamps of the size for which the product is designed and shall be wired in accordance with the diagram or instructions on the ballast.

23.7 A product provided with an instant-start ballast that involves a potential of more than 300 volts, but not more than 600 volts, shall be provided with lampholders of the circuit interrupting type at the low-voltage end of the lamps, except that nonshort-circuiting type lampholders may be used if the product is marked [visible during relamping in letters at least 1/8 inch (3.2 mm) high] to indicate that it is for use with instant-start lamps.

23.8 An electric-discharge lighting system shall have no exposed live parts that may be contacted by persons.

23.9 An electric-discharge lighting system that involves a potential of more than 300 volts shall be constructed so that no uninsulated live parts will be accessible when the lamps are in place or removed, or while they are being inserted or removed.

23.10 The terminals of a lamp are considered to be live parts when any terminal of that lamp is in contact with an uninsulated live part involving a potential of more than 300 volts.

23.11 Except where electric lampholders having recessed inaccessible contacts are used, compliance with 23.9 will require:

a) The use of lampholders constructed and wired so that when a lamp is removed, the potential in that lamp circuit is less than 300 volts; or

b) That the primary circuit is open during the relamping operation and all live parts are inaccessible when the lamps are removed and the primary circuit is reestablished.

23.12 Lampholders and ballasts installed in moist areas shall be constructed of moisture-resistant materials or treated to resist the absorption of moisture.

23.13 Ballasts shall be provided with a housing of nonflammable, moisture-resistant material, except that a reactor-type ballast of the open-core-and-coil type without a housing may be used within the enclosure of the product. An enclosed type ballast having an all-metal housing need not be additionally enclosed provided:

a) The housing has the strength and rigidity equivalent to 0.026 inch (0.66 mm) sheet steel; and

b) It is installed in a location where it will not be subject to mechanical damage.

23.14 If ballasts are installed so that thermal insulation may cause overheating, subject to external heat, or mounted at more than one level within a common compartment, they shall be tested during the temperature tests. See 33.1.11 and 33.1.12.

24 Fuseholders

24.1 A fuseholder shall be of either the cartridge-enclosed or plug-fuse type. Plug fuses shall not be used with equipment rated more than 125 or 125/250 volts.

24.2 A fuseholder or circuit breaker shall not be accessible from outside the enclosure of the product without opening a door or cover, except that the operating handle of a circuit breaker may project outside the enclosure. A plug fuseholder shall be so installed that uninsulated live parts other than the screw shell will not be exposed to contact by persons removing or replacing fuses.

24.3 A plug fuseholder intended to be connected to a 120 or a 120/240 volt, three-wire circuit shall be wired in the unidentified (ungrounded) conductor with the screw shell connected towards the load.

24.4 A fuseholder shall be so constructed, installed, or protected that adjacent uninsulated high-voltage live parts, other than the screw shell of a plug fuseholder, cartridge fuse clips, or wiring terminals to the fuseholder, will not be exposed to contact by persons removing or replacing fuses. A separation of less than 4 inches (102 mm) is considered to be adjacent.

Exception: This requirement does not apply to fuseholders installed in compartments with restricted access, such as the use of a key lock, intended for the replacement of fuses only by qualified service personnel. See 43.5.

25 Lampholders and Lamps

25.1 Lampholders and lamps shall be rated for the circuit in which they are employed.

25.2 A lampholder employing a metal shell, such as a screw shell, used in a high-voltage circuit shall be so wired that the metal shell will be connected to an identified (grounded circuit) conductor. If more than one lampholder of this type is provided, the metal shells of all such lampholders shall be connected to the same conductor.

25.3 Except as noted in 25.4, a lampholder shall be so installed that uninsulated live parts, other than the screw shell and center contact, will not be exposed to contact by persons removing or replacing lamps.

25.4 The requirement in 25.3 may be waived if it is necessary to dismantle the product by means of tools in order to remove or replace a lamp.

26 Overcurrent Protection

26.1 Unless intended to be connected to a power supply separate from that supplying other loads, overcurrent protection shall be provided by a circuit breaker(s) or fuse(s) that is intended for branch circuit use, as a part of the product, for each receptacle or lighting circuit included in the product. Such overcurrent protection may be omitted if, in accordance with the National Electrical Code, ANSI/NFPA 70, the product can be connected to a branch circuit rated at not more than 20 amperes.

26.2 Unless exempted by 26.1, a 15 ampere protective device shall be provided if a single 15 ampere receptacle outlet is furnished. Two or more 15 ampere receptacles (two separate receptacles or a duplex receptacle) shall be protected by either a 15 or 20 ampere protective device. A 20 ampere receptacle or a combination 15 and 20 ampere receptacle shall be protected by a 20 ampere protective device.

27 Switches and Controllers

27.1 A manually operable switch having a marked off position shall be installed on a cord-connected product for shutting off the assembly.

27.2 A switch or other control device shall be rated for the load that it controls.

27.3 A switch provided for the control of an inductive load, such as a transformer, shall have a current rating of not less than twice the total marked current ratings of the transformer or other equipment that it controls.

27.4 A single-pole switching device shall not be connected to the identified (grounded) conductor.

27.5 An automatic control that does not have a marked off position is not required to comply with 27.4.

28 Transformers

28.1 Except as noted in 28.2, a transformer shall be of the two-coil or insulated type.

28.2 An autotransformer may be employed if the terminal or lead common to both input and output circuits is identified and the output circuits are located only within the enclosure containing the autotransformer.

28.3 Coils shall be treated with an insulating varnish and baked or otherwise impregnated to exclude moisture. See 22.1.