

UL 1778

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Uninterruptible Power Supply Equipment

Underwriters Laboratories Inc. (UL)
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UL Standard for Safety for UL Standard for Safety for Uninterruptible Power Supply Equipment, UL 1778

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Revisions: This Standard contains revisions through and including January 5, 2000.

A change is indicated by a note following the affected item. The note is preceded and followed by an asterisk.

The new and revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated August 19, 1999 . The bulletin(s) is now obsolete and may be discarded.

The revisions dated January 5, 2000 include a reprinted title page (page1) for this Standard.

The revisions dated November 17, 1997 include changing references to UL 519, Standard for Impedance-Protected Motors, and UL 547, Standard for Thermal Protectors for Motors, to UL 2111, Standard for Overheating Protection for Motors. UL 519 and UL 547 have been withdrawn and replaced by UL 2111.

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An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

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Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction which conflict with specific requirements of the Standard cannot be judged to comply with the Standard. A product employing materials or having forms of construction not addressed by this Standard may be examined and tested according to the intent of the requirements and, if found to meet the intent of this Standard, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

PART 1 – ALL UPS EQUIPMENT

INTRODUCTION

1 Scope

1.1 These requirements cover uninterruptible power supplies (UPS) rated 600 volts or less ac or dc that are intended for installation in accordance with the National Electrical Code, NFPA 70. During normal operation, the UPS allows the primary or normal power source to deliver ac power to the protected load through either the power conversion portion of the UPS or a bypass source. The power conversion portion of the UPS consists of a rectifier, an inverter, or both. During periods of power fluctuations, or power outages, or both, the connected load receives ac power from the battery supply and power conversion portion of the UPS.

1.2 Products that are used with UPS and that are covered by this standard include:

- a) Remote battery supply cabinets with or without batteries;
- b) Remote status panels;
- c) Bypass switches;
- d) Maintenance bypass switches;
- e) Rectifier, power conversion units, or both; and
- f) Power distribution panels.

1.3 A battery supply (see 2.4) used with a UPS covered by this standard may consist of any of the following described in (a) – (c):

- a) A battery supply that is integral with the UPS. The batteries may or may not be furnished with the UPS.
- b) A battery supply that is contained in a remote cabinet. For a cord-and-plug-connected UPS having an ac input rating of 20 amperes or less and 125 volts ac maximum, the battery supply is furnished with the UPS. For all other UPS intended for use with a remote battery and cabinet assembly, the battery supply may or may not be furnished with the UPS.
- c) A battery supply that is contained in a separate battery room. This type of battery supply may or may not be furnished with the UPS.

1.4 These requirements cover static type UPS – not rotary type UPS.

1.5 Uninterruptible power supplies for use in health care facilities are covered by these requirements in addition to the applicable requirements in the Standard for Electric Medical and Dental Equipment, UL 544.

1.6 These requirements cover UPS equipment that may be installed in accordance with the Standard for Protection of Electronic Computer/Data-Processing Equipment, ANSI/NFPA 75. This equipment is marked indicating that it is suitable for such use. See 72.1.27.

1.7 Engine-driven, dc power generators intended to provide backup power for the battery supply circuit of UPS units are investigated for compliance with the requirements in the Standard for Engine-Generator Assemblies for Use in Recreational Vehicles, UL 1248.

1.8 These requirements do not cover UPS units for use as emergency systems nor legally required standby systems described in Articles 700 and 701 respectively of the National Electrical Code, ANSI/NFPA 70.

1.9 A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this Standard, and that involves a risk of fire, electric shock, or injury to persons shall be evaluated using the appropriate additional component and end-product requirements to determine that the level of safety as originally anticipated by the intent of this Standard is maintained. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this Standard shall not be judged to comply with this Standard. Where appropriate, revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this Standard.

1.9 revised January 5, 2000

2 Glossary

2.1 In the text of this standard, the term "unit" refers to any product covered by this standard. The letters "UPS" refers to an uninterruptible power supply. For the purpose of this standard, the definitions in 2.2 – 2.41 apply.

2.2 BARRIER – A part inside an enclosure that reduces the risk of access to a part that involves a risk of fire, electric shock, injury to persons, or electrical energy – high current levels. See 2.31 – 2.33.

2.3 BATTERY CASE/COVER – The container that directly encloses and confines the electrolyte of a battery or cell.

2.4 BATTERY SUPPLY – One or more single-cell or multi-cell batteries that together supply power for the unit. A battery supply may consist of a collection of individual and separately replaceable single-cell or multicell batteries in a series or parallel array, or both, or consist of a series or parallel array, or both, of permanently interconnected and not separately replaceable single-cell or multicell batteries – for example, a battery pack.

2.5 BATTERY, VALVE-REGULATED – A battery in which the venting of the products of electrolysis is controlled by a reclosing pressure-sensitive valve. These batteries have commonly been referred to as "maintenance-free, starved electrolyte."

2.6 BATTERY, VENTED – A battery in which the products of electrolysis and evaporation are allowed to escape freely to the atmosphere. These batteries have commonly been referred to as "flooded" or "wet."

2.7 BRANCH CIRCUIT – The portion of the building wiring system beyond the final overcurrent protective device on the power-distribution panel that protects the circuit to the field-wiring terminals in a permanently connected unit or to the receptacle outlet for a cord-connected unit.

2.8 BYPASS SOURCE – A branch circuit, generator, or other UPS module to which the protected load is connected when the power conversion portion of the UPS is not supplying power to the protected load.

2.9 CELL – The main components are two electrodes of dissimilar material separated from one another by a common ionically conductive electrolyte, that are intended to convert chemical energy directly into electrical energy.

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2.10 CLASS 2 TRANSFORMER – A step-down transformer complying with the applicable requirements in the Standard for Class 2 and Class 3 Transformers, UL 1585.

2.11 CONTROL CIRCUIT – A circuit that carries electric signals but not main power current.

2.12 CONTROLLED ENVIRONMENT – An environment that is a heated, indoor location such as a computer room, office, or a factory floor that is relatively free of conductive contaminants such as carbon dust and the like.

2.13 ELECTROLYTE – A semisolid, liquid, or aqueous salt solution that permits ionic conduction between positive and negative electrodes of a cell.

2.14 ENCLOSURE – That portion of a unit that:

- a) Reduces the accessibility of a part that may involve a risk of fire, electric shock or injury to persons; or
- b) Reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

2.15 FIELD-WIRING LEAD – Any lead to which a supply, load, or other wire is intended to be connected by an installer.

2.16 FIELD-WIRING TERMINAL – A terminal to which a supply, load, or other wire is intended to be connected by an installer.

2.17 FIXED UNIT – A unit that is intended to be permanently connected electrically.

2.18 GUARD – A part outside of the enclosure that reduces the risk of access to a component that may result in a risk of injury to persons.

2.19 LIMITED-ENERGY CIRCUIT – An ac or dc circuit having a voltage not exceeding 1000 volts and the energy limited to 100 volt-amperes by any of the following:

- a) Secondary winding of a transformer;
- b) One or more resistors complying with 24.10; or
- c) A regulating network complying with 24.11.

2.20 LINEAR LOAD – A load that does not rectify the current or otherwise alter the current wave shape, resulting in a load current that is proportional to the instantaneous voltage.

2.21 LIVE PART – Denotes metal or a conductive part within the unit that during intended use has a potential difference with respect to earth ground.

2.22 LOW-VOLTAGE, LIMITED-ENERGY (LVLE) CIRCUIT – A circuit involving an alternating current voltage of not more than 30 volts rms (42.4 volts peak) or a direct current voltage of not more than 60 volts and supplied by:

a) An inherently limited Class 2 transformer or a not inherently limited Class 2 transformer, and an overcurrent protective device that is:

- 1) Not of the automatic reclosing type;
- 2) Trip-free from the reclosing mechanism; and
- 3) Either not readily interchangeable with a device of a different rating, or provided with a marking in accordance with 72.2.12;

b) A combination of an isolated transformer secondary winding and one or more resistors, or a regulating network complying with 24.11 that complies with all the performance requirements for an inherently limited Class 2 transformer or power source; or

c) A battery that is isolated from the primary circuit or a combination of a battery, including the battery charging circuit of a unit that is isolated from the primary circuit, and one or more resistors or a regulating network complying with 24.11.

2.23 MULTI-CELL BATTERY – A battery consisting, internally, of a series or parallel array of two or more cells.

2.24 NORMAL MODE – Condition of operation in which the battery is fully charged and the UPS is receiving power from the primary or normal power source and delivering maximum rated power.

2.25 PRESSURE TERMINAL CONNECTOR – A field wiring terminal that accomplishes the connection of one or more conductors by means of pressure without the use of solder. A pressure terminal connector may be the barrel and setscrew type, crimp-type barrel, or clamping plate and screw type.

2.26 PRIMARY CIRCUIT – Wiring and components that are conductively connected to a branch circuit.

2.27 PRIMARY SOURCE – The branch circuit to which the power conversion portion of the UPS is connected.

2.28 PROTECTED LOAD – Appliances and equipment connected to the alternating current output circuit of a UPS.

2.29 RECHARGING MODE – As defined in 44.1(a).

2.30 RESERVE MODE – As defined in 44.1(b).

2.31 RISK OF ELECTRICAL ENERGY – HIGH CURRENT LEVELS – The capability for damage to property or injury to persons, other than by electric shock, from available electrical energy is considered to exist, if between a live part and an adjacent dead metal part or between live parts of different polarity, there exists a potential of 2 volts or more and either:

- a) An available continuous power level of 240 volt-amperes or more; or
- b) A reactive energy level of 20 joules or more.

For example, a tool, or other metal short-circuiting a component may cause a burn or a fire if enough energy is available at the component to vaporize, melt, or more than warm the metal.

2.32 RISK OF ELECTRIC SHOCK – As defined in Section 8, Electric Shock.

2.33 RISK OF FIRE – A risk of fire is considered to exist at any component unless an investigation of the supply delivering power to that component complies with the criteria in 24.4 – 24.12.

2.34 SAFETY CIRCUIT – Any primary or secondary circuit that is relied upon to reduce the risk of fire, electric shock, injury to persons, or electrical energy – high current levels. For example, in some applications, an interlock circuit is considered to be a safety circuit.

2.35 SAFETY INTERLOCK – A means relied upon to reduce the accessibility to an area that may result in a risk of electric shock, electrical energy – high current levels, or injury to persons until the risk has been removed, or to automatically remove the risk when access is gained.

2.36 SECONDARY CIRCUIT – A circuit supplied from a secondary winding of an isolating transformer. See 22.3.

2.37 SERVICE PERSONNEL – Trained persons having familiarity with the construction and operation of the equipment and the risks involved.

2.38 STATIONARY UNIT – A cord and plug connected unit that is intended to be fastened in place or located in a dedicated place.

2.39 SWITCH, BYPASS – A switch providing a means to connect the protected load directly to the bypass source without going through the power conversion portion of the UPS.

2.40 SWITCH, MAINTENANCE BYPASS – An arrangement of a switch or switches, or other means to supply power to the protected load without going through either the internal bypass switch mechanism or the power conversion portion of the UPS.

2.41 TOOL – A screwdriver, coin, key, or any other object that may be used to operate a screw, latch, or similar fastening means.

3 General

3.1 Components

3.1.1 Except as indicated in 3.1.2, a component used as a part of a unit covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the units covered by this standard.

3.1.2 A component need not comply with a specific requirement that:

- a) Involves a feature or characteristic not needed in the application of the component in the product covered by this standard, or
- b) Is superseded by a requirement in this standard.

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

3.1.4 Specific components are recognized as being 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 for which they have been recognized.

3.1.5 Circuits intended to be connected to the telecommunication network shall comply with the applicable requirements in UL 1459, the Standard for Telephone Equipment, or the Third Edition of UL 1950, the Standard for Information Technology Equipment. Telecommunication type connectors or terminals that are not intended for connection to the telecommunication network shall be marked in accordance with 72.1.34. (Examples of telecommunication type connectors and terminals include but are not limited to RJ and CA series modular jacks, 50-pin ribbon connectors, and insulation piercing terminals.)

Added 3.1.5 effective January 11, 2001

3.1.6 The evaluation of telecommunication circuits shall include components, circuit spacings and separation, accessibility, earthing, leakage current due to an external source of analog ringing voltage (120 V rms), protection from overheating from available power on telecommunication wiring (1.3A), and protection from overvoltage due to power line crosses and lightning on exposed telecommunication wiring.

Added 3.1.6 effective January 11, 2001

3.1.7 Connectors and associated accessories intended to be connected to the telecommunication network shall comply with the applicable requirements in UL 1863, the Standard for Communication Circuit Accessories.

Added 3.1.7 effective January 11, 2001

3.1.8 Devices and associated circuits that provide overvoltage and/or overcurrent protection for external feed-through connections, intended to interconnect other equipment or circuits to the telecommunication network, shall comply with the requirements in UL 497A, the Standard for Secondary Protectors for Communications Circuits.

Exception: This requirement does not apply when both of following situations are met:

- a) Protection is provided only for telecommunication circuits that terminate in the UPS and is not intended for any external feed-through connection; and*
- b) Protection for any external feed-through connection is not referenced or implied to the user in any way, such as through markings, instructions, product literature, or similar written or visual media.*

Added 3.1.8 effective January 11, 2001

3.1.9 With reference to 3.1.8, when any protection is referenced or implied to the user in any way, such as through markings, instructions, product literature, or similar written or visual media, the protection shall comply with UL 497A, the Standard for Secondary Protectors for Communication Circuits.

Added 3.1.9 effective January 11, 2001

3.2 Units of measurement

3.2.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

CONSTRUCTION

4 Materials

4.1 The material of a part, such as an enclosure, a frame, a guard, or the like, the breakage of which may result in a risk of injury to persons, shall have such properties as to meet the demand of expected use conditions.

4.2 The requirement in 5.1.1 applies to those portions of a part adjacent to moving parts considered to involve a risk of injury to persons.

4.3 A part as mentioned in 5.1.1 shall withstand the impact test described in Section 65, Impact Test – Guards Over Moving Parts, without being affected to the extent that:

- a) The performance of the UPS is adversely affected so as to result in a risk of injury; or
- b) Parts capable of causing injury to persons are exposed to unintentional contact.

Exception: A component such as a pilot lamp, lens, or control knob need not be subjected to the impact test.

5 Frame and Enclosure

5.1 General

5.1.1 A unit shall be provided with one or more enclosures that house all live parts. The enclosure shall protect the various parts of the unit against mechanical damage from forces external to the unit. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, injury to persons, and electrical energy – high current levels shall comply with the applicable enclosure requirements specified in this standard.

Exception: Live parts, including terminals, which do not present a risk of electric shock or a risk of electrical energy – high current levels, need not be enclosed.

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5.1.2 The rotor of a motor, a pulley, a fan blade, a belt, a gear, or other moving part that is capable of causing injury to persons shall be enclosed or provided with other means to reduce the likelihood of unintentional contact.

Exception: A part or portion of a part that is necessarily exposed to perform the working function is not required to be enclosed but, when necessary, guarding shall be provided.

5.1.2 revised January 11, 1999

5.1.3 The degree of protection required by 5.1.2 depends upon the general construction and intended use of a unit.

5.1.4 The frame or chassis of a unit shall not be used to carry current during intended operation (see 18.12).

5.1.5 A part, such as a dial, display face, or nameplate, that serves as a functional part of the enclosure shall comply with the enclosure requirements.

5.1.6 If an electrical instrument, such as a meter, forms part of the enclosure, the face or the back of the instrument housing, or both together, shall comply with the requirements for an enclosure.

Exception: A meter complying with the requirements in the Standard for Electrical Analog Instruments – Panelboard Types, UL 1437 need not comply.

5.2 Modular units

5.2.1 Individual modules of a modular unit may be of the open construction – either no enclosure or a partial enclosure is supplied – provided that when the modules are assembled together in the field as intended, the unit enclosure complies with the requirement in 5.1.1. Identification of the modules and instructions for assembling shall be provided in accordance with 72.1.24 and 74.1(q). The provisions for electrical connection between modules shall comply with 15.7.8 and 85.1 – 85.5.

5.3 Access covers

5.3.1 An access cover shall be hinged if it gives access to a fuse or other overload-protective device, the functioning of which requires renewal or resetting, or if it is necessary to open the cover in connection with intended operation of the unit. A means shall be provided to hold the cover closed.

Exception No. 1: A hinged cover is not required if the only overload-protective device enclosed is:

- a) Connected in a control circuit, provided the protective device and the circuit loads are within the same enclosure;*
- b) Rated 2 amperes or less for loads not exceeding 100 volt-amperes;*
- c) An extractor fuse having an integral enclosure; or*
- d) Connected in a low-voltage, limited-energy circuit.*

Exception No. 2: A hinged cover is not required for an enclosure that:

- a) Contains no user-serviceable or -operable parts; and*
- b) Is marked in accordance with 72.2.11.*

5.3.2 A door or cover giving access to a fuse shall be tight-fitting.

5.4 Cast metal enclosures

5.4.1 The thickness of cast metal for an enclosure shall be as specified in Table 5.1. Die-cast metal may be employed only if, upon investigation, it is found to have adequate mechanical strength and to be otherwise acceptable for the particular application.

Exception: Cast metal of a lesser thickness may be employed if upon investigation (consideration being given to the shape, size, and function of the enclosure) it is found to have acceptable mechanical strength for the intended use.

Table 5.1
Thickness of cast-metal enclosures

Use, or dimension of area involved	Minimum thickness, inch (mm)	
	Die-cast metal	Cast metal of other than the die-cast type
Area of 24 square inches (154.8 cm ²) or less and having no dimension greater than 6 inches (152 mm)	1/16 ^a (1.6)	1/8 (3.2)
Area greater than 24 square inches (154.8 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 limitation for metal 1/16 inch (1.6 mm) thick may be obtained by the provision of reinforcing ribs subdividing a larger area.		

5.5 Sheet metal enclosures

5.5.1 Sheet metal enclosures shall comply with 5.5.2 or the requirements in the Standard for Enclosures for Electrical Equipment, UL 50:

5.5.2 With reference to 5.5.1, the thickness of a sheet-metal enclosure shall not be less than that specified in Tables 5.2 and 5.3. Uncoated steel shall not be less than 0.032 inch (0.81 mm) thick, zinc-coated steel shall not be less than 0.034 inch (0.86 mm) thick, and nonferrous metal shall not be less than 0.045 inch (1.14 mm) thick for surfaces of an enclosure at which a wiring system is to be connected.

Exception: The thickness of a sheet metal enclosure may be less than specified in Tables 5.2 and 5.3 if investigated and found acceptable for the application.

5.5.3 Tables 5.2 and 5.3 are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

5.5.4 With reference to Tables 5.2 and 5.3, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and that has the torsional rigidity to resist the bending moments that may be applied via the enclosure surface. A construction that is considered to have equivalent reinforcement may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels.

5.5.5 With reference to 5.5.4 and Tables 5.2 and 5.3, a construction is not considered to have a supporting frame if it is:

- a) A single sheet with single formed flanges – formed edges;
- b) A single sheet that is corrugated or ribbed;
- c) An enclosure formed or fabricated from sheet metal; or
- d) An enclosure surface loosely attached to a frame – for example, by spring clips.

Table 5.2
Thickness of carbon steel or stainless steel enclosures

Without supporting frame ^a		With supporting frame or equivalent reinforcing ^a		Minimum thickness inch (mm)	
Maximum width, ^b		Maximum length, ^c			
Inches	(cm)	Inches	(cm)	Inches	(cm)
4.0	(10.2)	Not limited		6.25	(15.9)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)
6.0	(15.2)	Not limited		9.5	(24.1)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)
8.0	(20.3)	Not limited		12.0	(30.5)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)
12.5	(31.8)	Not limited		19.5	(49.5)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)
18.0	(45.7)	Not limited		27.0	(68.6)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)
22.0	(55.9)	Not limited		33.0	(83.8)
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)
25.0	(63.5)	Not limited		39.0	(99.1)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)
33.0	(83.8)	Not limited		51.0	(129.5)
38.0	(103.4)	47.0	(119.4)	54.0	(137.2)
42.0	(106.7)	Not limited		64.0	(162.6)
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)
52.0	(132.1)	Not limited		80.0	(203.2)
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)
63.0	(160.0)	Not limited		97.0	(246.4)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)
				127.0	(322.6)

^a See 5.5.4 and 5.5.5.

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

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

^d Sheet steel for an enclosure intended for outdoor use shall not be less than 0.034 inch (0.86 mm) thick if metal coated and not less than 0.032 inch (0.81 mm) thick if uncoated.

Table 5.3
Thickness of aluminum, copper, or brass enclosures

Without supporting frame ^a		With supporting frame or equivalent reinforcing ^a		Minimum thickness inches (mm)
Maximum width ^b inches (cm)	Maximum length ^c inches (cm)	Maximum width ^b inches (cm)	Maximum length inches (cm)	
3.0 (7.6)	Not limited	7.0 (17.8)	Not limited	0.023 ^d
3.5 (8.9)	4.0 (10.2)	8.5 (21.6)	9.5 (24.1)	(0.58)
4.0 (10.2)	Not limited	10.0 (25.4)	Not limited	0.029
5.0 (12.7)	6.0 (15.2)	10.5 (26.7)	13.5 (34.3)	(0.74)
6.0 (15.2)	Not limited	14.0 (35.6)	Not limited	0.036
6.5 (16.5)	8.0 (20.3)	15.0 (38.1)	18.0 (45.7)	(0.91)
8.0 (20.3)	Not limited	19.0 (48.3)	Not limited	0.045
9.5 (24.1)	11.5 (29.2)	21.0 (53.3)	25.0 (63.5)	(1.14)
12.0 (30.5)	Not limited	28.0 (71.1)	Not limited	0.058
14.0 (35.6)	16.0 (40.6)	30.0 (76.2)	37.0 (94.0)	(1.47)
18.0 (45.7)	Not limited	42.0 (106.7)	Not limited	0.075
20.0 (50.8)	25.0 (63.4)	45.0 (114.3)	55.0 (139.7)	(1.91)
25.0 (63.4)	Not limited	60.0 (152.4)	Not limited	0.095
29.0 (73.7)	36.0 (91.4)	64.0 (162.6)	78.0 (198.1)	(2.41)
37.0 (94.0)	Not limited	87.0 (221.0)	Not limited	0.122
42.0 (106.7)	53.0 (134.6)	93.0 (236.2)	114.0 (289.6)	(3.10)
52.0 (132.1)	Not limited	123.0 (312.4)	Not limited	0.153
60.0 (152.4)	74.0 (188.0)	130.0 (330.2)	160.0 (406.4)	(3.89)

^a See 5.5.4 and 5.5.5.

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

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

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

5.6 Nonmetallic enclosures

5.6.1 A polymeric enclosure or polymeric part of an enclosure shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. See 5.6.2 and 5.6.3.

5.6.2 With reference to 5.6.1, for a cord-connected unit that is intended to be supported on a bench, desk, table, or the like, the flammability requirements for portable equipment specified in UL 746C, Polymeric Materials – Use in Electrical Equipment Evaluations, are to be applied.

5.6.3 A nonmetallic part that forms part of the enclosure need not comply with the requirement in 5.6.1 under any one of the following conditions:

- a) The part covers an opening that has no dimension greater than 1 inch (25.4 mm) and the component is made of a material classed as V-0, V-1, V-2, or HB;
- b) The part is made of a material classed V-0, V-1, V-2, or HB and covers an opening which does not allow access to live parts involving a risk of fire, electric shock, or electric energy – high current levels – or moving parts to the user when the part is removed;
- c) The part covers an opening that has no dimension greater than 4 inches (101.6 mm) and the part is made of a material classed as V-0, V-1, V-2, or HB, and there is no source of a risk of fire (see 2.31 and 2.32) closer than 4 inches from the surface of the enclosure; or
- d) The part is made of a material classed V-0, V-1, V-2, or HB and there is a barrier or a device that forms a barrier made of a material classed V-0 between the part and a source of a risk of fire.

The flammability classifications shall be in accordance with UL 94, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.

Exception: A part of a component need not be classed V-0, V-1, V-2, or HB if it complies with the flammability class applicable to the component.

5.6.3 revised January 11, 1999

5.6.4 A polymeric material enclosure having in any single unbroken section, a projected surface area greater than 10 square feet (0.93 m²), or a single linear dimension greater than 6 feet (1.83 m) shall have a flame-spread rating of 200 or less (see 5.6.5) when tested in accordance with the:

- a) Standard for Test for Surface Burning Characteristics of Building Materials, UL 723; or
- b) Radiant-panel furnace method in the Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source, ASTM E162-1990.

5.6.5 A unit marked indicating that it is suitable for computer room applications (see 72.1.27) shall have a flame-spread rating of 50 or less when tested as indicated in 5.6.4.

5.6.6 A material with a flame-spread rating higher than specified in 5.6.4 can be used as the exterior finish or covering on any portion of the enclosure if the flame-spread rating of the combination of the base material and finish or covering complies with 5.6.4.

5.6.7 A conductive coating applied to a nonmetallic surface (such as the inside surface of a cover or an enclosure) shall comply with the appropriate requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: If flaking or peeling of the coating will not result in a risk of fire or electric shock as a result of a reduction of spacings or the bridging of live parts, then the coating need not comply with UL 746C.

5.7 Glass covered openings

5.7.1 Glass covering an opening shall be secured in place so that it cannot be readily displaced in service, and shall provide mechanical protection for the enclosed parts. Glass for an opening shall comply with the following dimensions:

- a) Glass for an opening not more than 4 inches (102 mm) in any dimension shall not be less than 1/16 inch (1.6 mm) thick;
- b) Glass for an opening not more than 144 square inches (929 cm²) in area and having no dimension greater than 12 inches (305 mm) shall not be less than 1/8 inch (3.2 mm) thick; and
- c) Glass used to cover an area larger than noted in (b) shall not be less than 1/8 inch thick and shall:
 - 1) Be of a nonshattering or tempered type that, when broken, complies with the Safety Performance Specifications and Methods of Test for Glazing Materials Used in Buildings, ANSI Z97.1-1984; or
 - 2) Be subjected to the test described in Section 64, Impact on Glass Covered Openings.

5.8 Openings for wiring

5.8.1 The requirements described in 5.8.2 – 5.8.9 apply to fixed units.

5.8.2 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 not be less than three nor more than five threads in the metal, and the construction of the enclosure 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 not be less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors equivalent to that provided by a standard conduit bushing with an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

5.8.3 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, and the like that are supplied as a part of an enclosure shall comply with the Standard for Metallic Outlet Boxes, UL 514A, and the Standard for Fittings for Conduit and Outlet Boxes, UL 514B.

5.8.4 A knockout in a sheet-metal enclosure shall be secured but shall be removable without undue deformation of the enclosure.

5.8.5 A knockout shall be provided with a flat surrounding surface adequate for proper seating of a conduit bushing, and shall be located so that installation of a bushing at any knockout likely to be used during installation will not result in spacing between an uninsulated live part and the bushing to be less than that specified in Spacings, Section 23.

5.8.6 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as mentioned in 5.8.5, it is to be assumed that a bushing having the dimensions specified in Table 5.4 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

5.8.7 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum specified in Spacings, Section 23 shall be provided between uninsulated live parts and a conduit bushing installed at any location likely to be used during installation. Permanent marking on the enclosure, a template, or a drawing furnished with the unit may be used to specify such a location. The specified location of the openings shall be such that damage to internal parts shall not result when openings are made.

5.8.8 With respect to the requirement in 5.8.7, means shall be provided so that an opening for conduit can be made without subjecting internal parts to contamination resulting from the presence of metallic particles. Compliance with this requirement may be accomplished by the use of a removable, bolted plate.

5.8.9 A polymeric- or metal-closure plug for an unused conduit opening shall comply with the requirements in the Standard for Outlet Boxes, UL 514A.

Table 5.4
Knockout or hole sizes and dimensions of bushings

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

5.9 Openings in an enclosure

5.9.1 The enclosure of a unit shall be designed and constructed to reduce the risk of emission of flame, molten metal, flaming or glowing particles, or flaming drops.

5.10 Enclosure bottom openings

5.10.1 The requirement in 5.9.1 necessitates a complete noncombustible bottom or a construction employing individual noncombustible barriers under components, groups of components, or assemblies, as specified in Figure 5.1.

Exception No. 1: Ventilating openings may be provided in the bottom panel if noncombustible baffle plates are provided to reduce the risk of materials from falling directly from the interior of the unit onto the supporting surface or any other location under the unit. An example of an acceptable baffle is illustrated in Figure 5.2.

Exception No. 2: Ventilation openings may be provided in the bottom of an enclosure if the openings incorporate a perforated metal plate as described in Table 5.5, or a galvanized or stainless steel screen having a 14- by 14-mesh per inch (25.4-mm) constructed of wire with a diameter of 0.018 inch (0.5 mm) minimum.

Exception No. 3: Other constructions complying with the hot, flaming oil test in Section 68, Ignition Test Through Bottom-Panel Openings, need not comply with this requirement.

Exception No. 4: The bottom of the enclosure under areas containing only materials classed V-1 or better in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, may have openings no larger than 1/4 inch (6.4 mm) square. Openings that are not square can be provided if they do not have an area greater than 1/16 square inch (40 mm²).

Exception No. 5: Ventilating openings without limitation on their size and number but complying with 7.10 may be provided in the bottom panel in areas:

- a) That contain only wires, cables, plugs, receptacles, transformers, and impedance protected or thermally protected motors; and*
- b) That contain only capacitors that are described in 31.4.*

5.10.1 revised January 11, 1999

5.11 Enclosure top openings

5.11.1 The minor dimension (see 7.6) of any opening in the top of an enclosure directly over an uninsulated live part involving a risk of electric shock or electrical energy – high current levels – shall not exceed 3/16 inch (4.8 mm) unless the configuration is such that direct vertical entry of a falling object is prevented from reaching such uninsulated live parts by means of a trap or restriction. See Figure 5.3 for examples of top surface openings that prevent direct entry.

Exception: Openings located 6 feet (1.8 meters) or higher from the floor, when the unit is installed in accordance with the manufacturer's instructions, may have a minor dimension greater than 3/16 inch. Such openings shall comply with the accessibility requirements in Section 7.

5.12 Guards

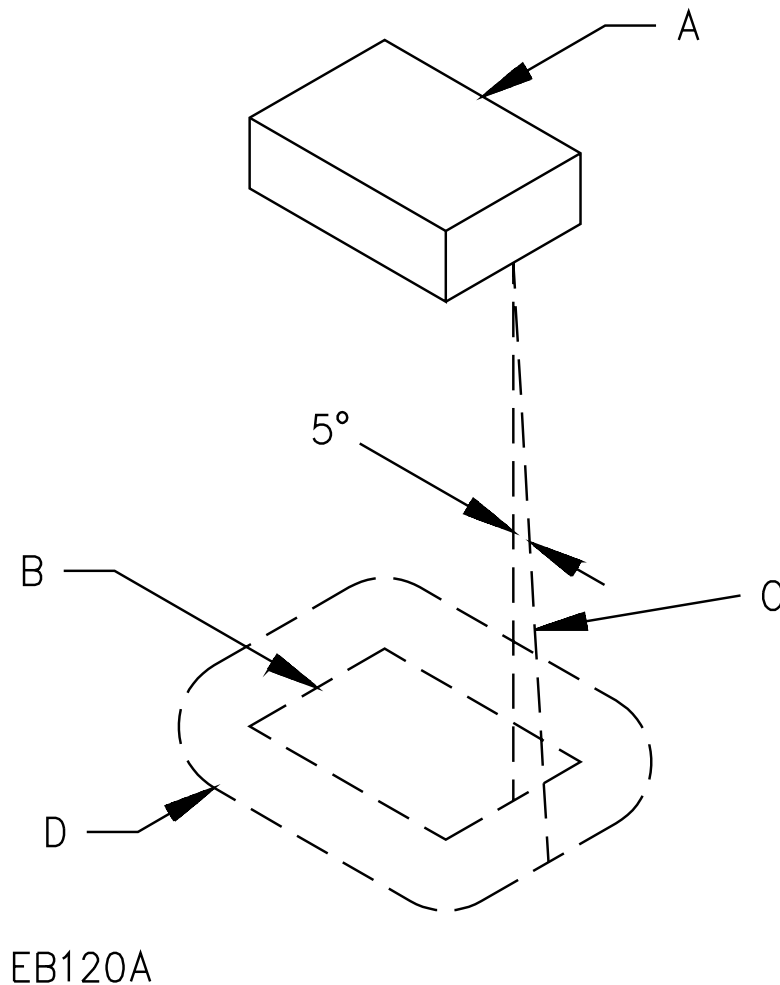
5.12.1 Some guards are required to be self-restoring. Other features of guards that are to be considered include:

- a) Removability without the use of a tool;
- b) Removability for servicing;
- c) Strength and rigidity;
- d) Completeness; and
- e) Creation of a risk of injury to persons, such as a pinch point, and the necessity for additional handling because of the increased need for servicing, such as for cleaning, unjamming, and the like.

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Figure 5.1
Enclosure bottom

Figure 5.1 revised November 17, 1997



A – Region to be shielded by barrier. This will consist of the entire component if it is not otherwise shielded, and will consist of the unshielded portion of a component which is partially shielded by the component enclosure or equivalent.

B – Projection of outline of component on horizontal plane.

C – Inclined line which traces out minimum area of barrier. When moving, the line is always:

- 1) Tangent to the component,
- 2) Five degrees from the vertical, and
- 3) So oriented that the area traced out on a horizontal plane is maximum.

D – Location (horizontal) and minimum area for barrier. The area is that included inside the line of intersection traced out by the inclined line C and the horizontal plane of the barrier.

Figure 5.2
Example of acceptable bottom-enclosure baffle

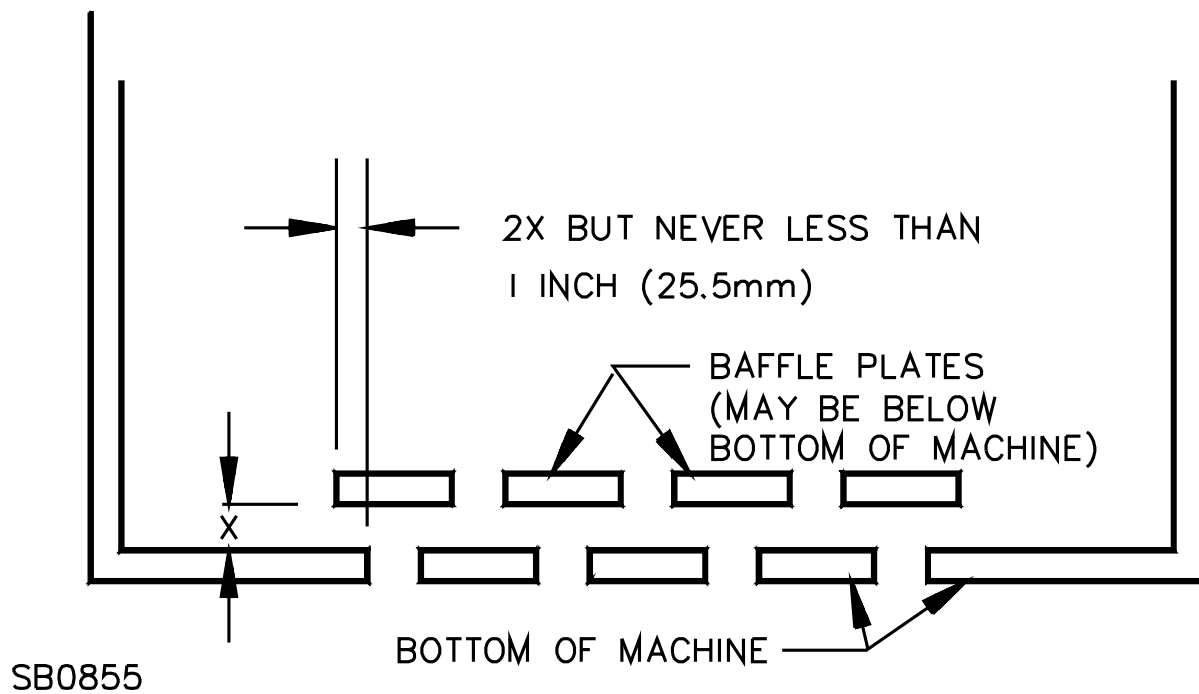
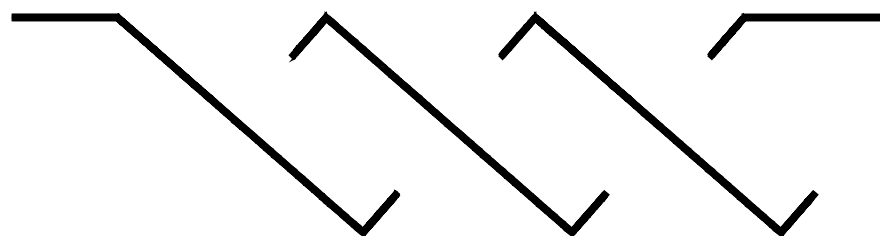
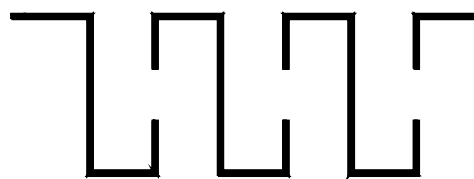


Figure 5.3
Cross sections of top-enclosure designs



SLANTED OPENINGS



EC500

VERTICAL OPENINGS

Table 5.5
Perforated metal plates for enclosure bottom^a

Minimum thickness,		Maximum diameter of holes,		Minimum spacings of holes center to center,	
inch	(mm)	inch	(mm)	inch	(mm)
0.026	(0.66)	0.045	(1.14)	0.067	(1.70)
				233 holes per inch ² (645 mm ²)	
0.026	(0.66)	0.047	(1.19)	0.093	(2.36)
0.030	(0.76)	0.045	(1.14)	0.067	(1.70)
0.030	(0.76)	0.047	(1.19)	0.093	(2.36)
0.032	(0.81)	0.075	(1.91)	0.125	(3.18)
				72 holes per inch ² (645 mm ²)	
0.035	(0.89)	0.075	(1.90)	0.125	(3.18)
0.036	(0.91)	0.063	(1.60)	0.109	(2.77)
0.036	(0.91)	0.078	(1.98)	0.125	(3.18)
0.039	(0.99)	0.063	(1.60)	0.109	(2.77)
0.039	(0.99)	0.079	(2.00)	0.118	(3.00)

^a In accordance with Exception No. 2 to 5.10.1.

6 Sharp Edges

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

Exception: This requirement does not apply to a part or portion of a part that needs to be sharp to perform a working function.

6.2 Whenever referee measurements are necessary to determine that a part as mentioned in 6.1 is not sufficiently sharp to constitute a risk of injury to persons, the method described in the Standard for Tests of Sharpness of Edges on Equipment, UL 1439 is to be employed.

7 Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts – and User Servicing

7.1 The requirements in this section apply to parts that are accessible to the user. For protection of service personnel requirements, refer to Section 39, Protection of Service Personnel.

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

- a) For an opening that has a minor dimension (see 7.6) less than 1 inch (25.4 mm), such a part or wire shall not be contacted by the probe illustrated in Figure 7.1.
- b) For an opening that has a minor dimension of 1 inch or more, such a part or wire shall be spaced from the opening as specified in Table 7.1.

Exception: An opening in an integral enclosure of a motor need not comply with these requirements if it complies with the requirements in 7.3.

7.3 With respect to a part or wire as mentioned in 7.2, in an integral enclosure of a motor as mentioned in the Exception to 7.2:

- a) An opening that has a minor dimension (see 7.6) less than 3/4 inch (19.1 mm) is acceptable if:
 - 1) A moving part cannot be contacted by the probe illustrated in Figure 7.2;
 - 2) Film-coated wire cannot be contacted by the probe illustrated in Figure 7.3;
 - 3) In a directly accessible motor (see 7.8), an uninsulated live part cannot be contacted by the probe illustrated in Figure 7.1; and
 - 4) In an indirectly accessible motor (see 7.7), an uninsulated live part cannot be contacted by the probe illustrated in Figure 7.2.
- b) An opening that has a minor dimension of 3/4 inch or more is acceptable if a part or wire is spaced from the opening as specified in Table 7.1.

7.4 The probes mentioned in 7.2 and 7.3 and illustrated in Figures 7.1 – 7.3 shall be applied to any depth that the opening will permit; and shall be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the enclosure. The probe illustrated in Figure 7.1 shall be applied in any possible configuration; and, if necessary, the configuration shall be changed after insertion through the opening.

7.5 The probes mentioned in 7.4 shall be used as measuring instruments to judge the accessibility provided by an opening, and not as instruments to judge the strength of a material. The probes shall be applied with a maximum force of 1 pound (4.4 N).

7.6 With reference to the requirements in 7.2 and 7.3, the minor dimension of an opening is the diameter of the largest cylindrical probe that can be inserted through the opening.

7.7 With reference to the requirements in 7.3, an indirectly accessible motor is a motor:

- a) That is accessible only by opening or removing a part of the outer enclosure, such as a guard or panel, that can be opened or removed without using a tool (see 2.41);
- b) That is guarded or enclosed so that it is unlikely to be contacted; or
- c) That it is considered unlikely to be contacted (see 7.9) due to its location.

7.8 A directly accessible motor is a motor:

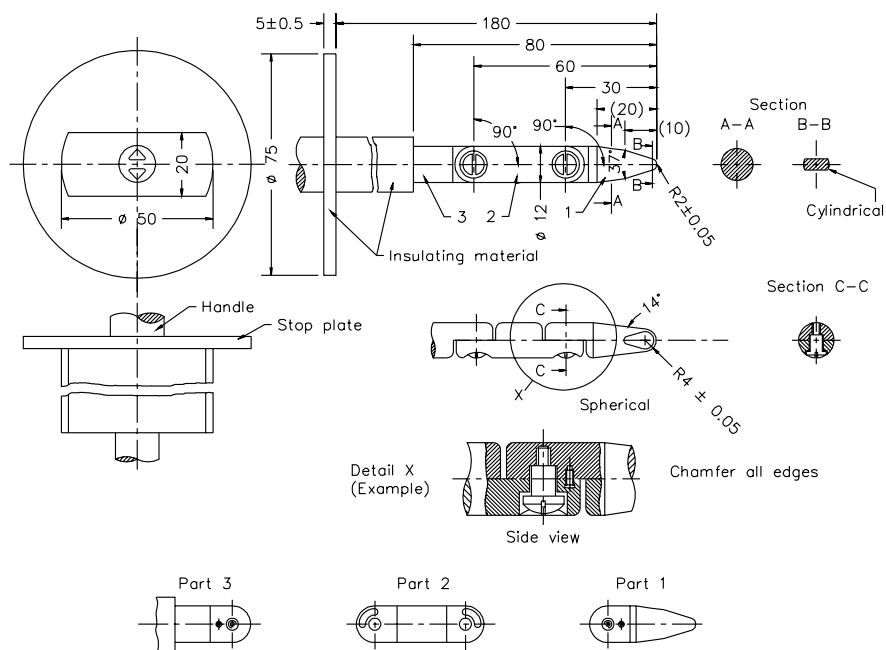
- a) That can be contacted without opening or removing any part; and
- b) That is located so as to be accessible to contact.

7.9 With reference to 7.7(c), a motor is indirectly accessible by location when it is located at either a minimum height of 6 feet (1.8 m) from the floor level or the total distance from the floor level plus the distance along a horizontal surface of the unit is not less than 7-1/2 feet (2.3 m) - see Figure 7.5.

7.9 revised January 11, 1999

7.10 The test pin illustrated in Figure 7.4, when inserted as specified in 7.4 through an opening in an enclosure, shall not touch any uninsulated live part that involves a risk of electric shock.

Figure 7.1
Articulate probe



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Figure 7.2
Probe for moving parts and uninsulated live parts in motors (see 7.3)

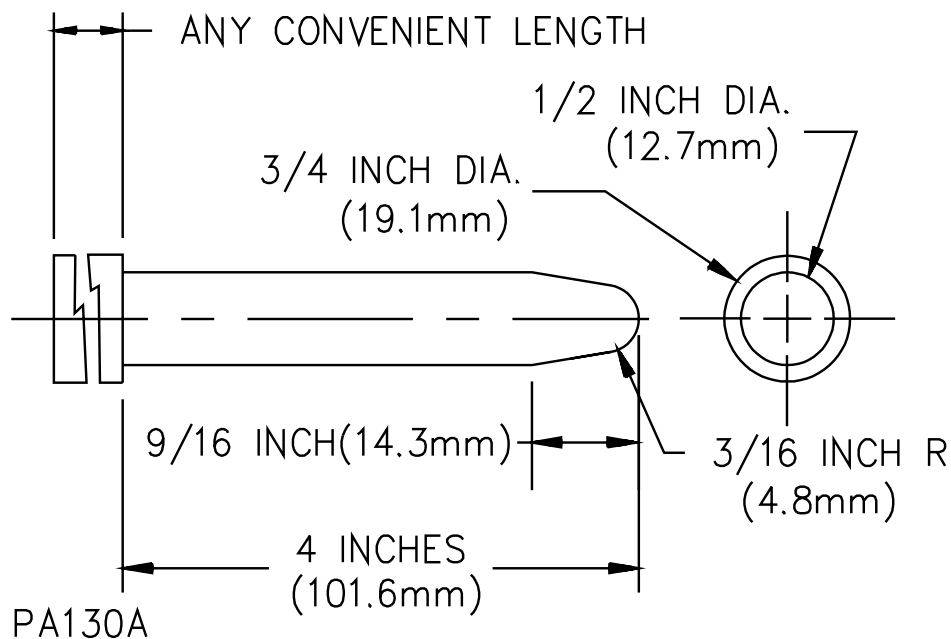


Figure 7.3
Probe for film-coated wire in motors (see 7.3)

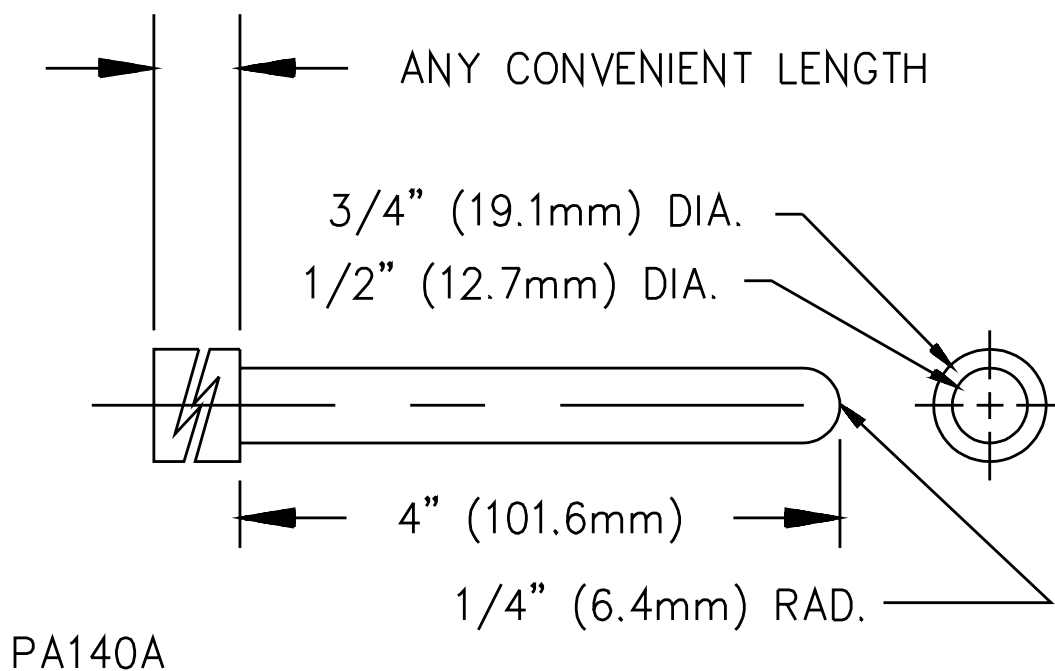


Table 7.1
Minimum acceptable distance from an opening to a part that may involve a risk of electric shock, electrical energy-high current level, or injury to persons

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

^a See 7.6.
^b Between 3/4 (19.1 mm) and 2-1/8 inches (54 mm), interpolation is to be used to determine a value between values specified in the table.
^c Any dimension less than 1 inch (25.4 mm) applies to a motor only.
^d More than 2-1/8 inches (54 mm), but not more than 6 inches (152.0 mm).

7.11 The probe shown in Figure 7.1 and the test pin shown in Figure 7.4 are to be inserted as specified in 7.4 into all openings, including those in the bottom of the unit. The unit is to be moved in whatever way necessary to make the entire bottom accessible for insertion of the probe.

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

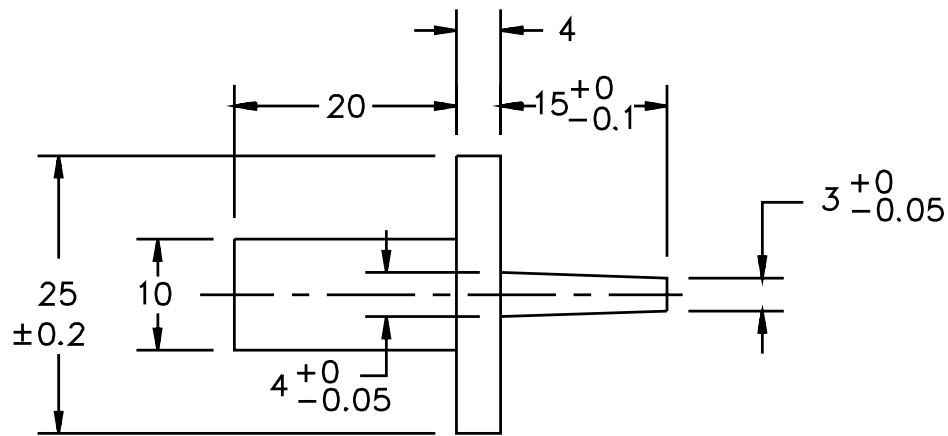
7.12 During the examination of a unit to determine whether it complies with the requirements in 7.2 or 7.3, a part of the enclosure that may be opened or removed by the user without using a tool (to attach an accessory, to make an operating adjustment, to give access to a fuse or other overload protective device as described in 5.3.1, or for other reasons) is to be opened or removed. A fastener, such as a slotted-head thumb screw, that can be turned by hand, is not considered to require the use of a tool.

7.13 With reference to the requirements in 7.2 and 7.3, insulated brush caps are not required to be additionally enclosed.

7.14 The maximum voltage of a battery supply of a unit employing batteries intended for user replacement shall not exceed 60 volts.

Figure 7.4
Test pin

Figure 7.4 revised November 17, 1997



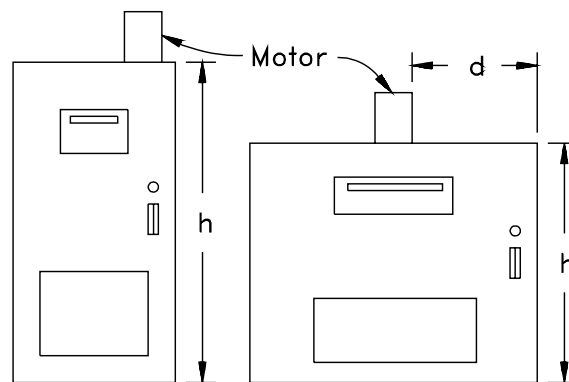
S2962

Dimensions in millimeters

1 mm = 0.039 inch

Figure 7.5
Indirectly accessible motor by location^a

Figure 7.5 revised November 17, 1997



S3522

$h \geq 6$ feet (1.8 m)

$h + d = 7\text{-}1/2$ feet (2.3 m) minimum

^a See 7.9.

7.15 Uninsulated live parts at a potential involving a risk of electric shock that are located in the area containing batteries intended for replacement by the user shall be insulated or enclosed to reduce the likelihood of contact with such parts, regardless of their location.

7.16 The instruction manual for a unit containing batteries intended for user installation or replacement shall include instructions for battery replacement as specified in 74.1.2(y).

8 Electric Shock

8.1 Voltage

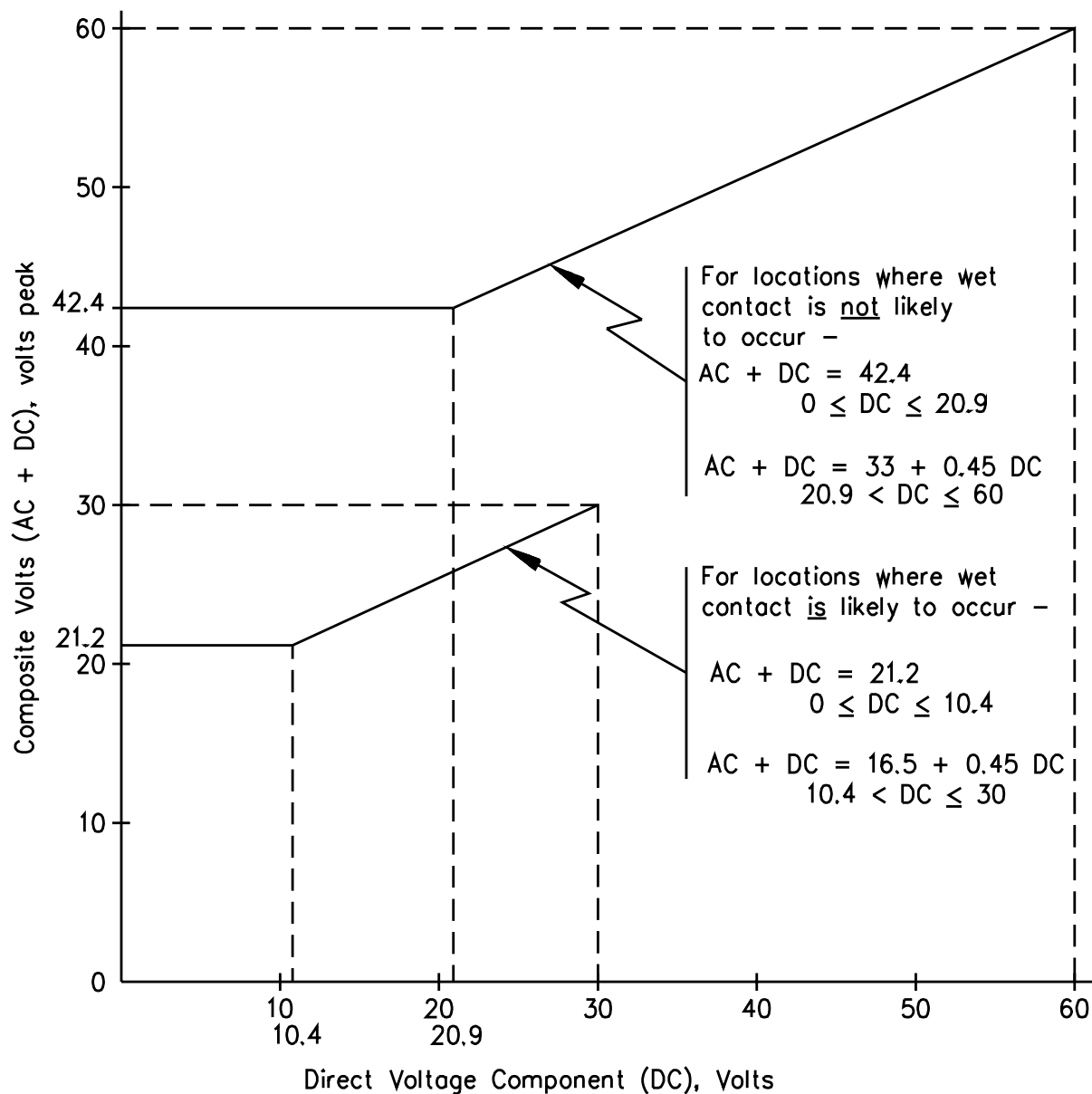
8.1.1 The requirements described in 8.1.2 – 8.2.2 are used to determine if the voltage of an accessible live part is considered to be a risk of electric shock. Determination of whether a live part is accessible to users and service personnel is specified in Section 7, Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts – and User Servicing, and Section 39, Protection of Service Personnel, respectively.

8.1.2 A live part is not considered to be a risk of electric shock if the voltage of the part does not exceed the values specified in Table 8.1.

Table 8.1
Risk of electric shock – maximum acceptable voltage

Voltage type		Indoor-use units (wet contact not likely)	Outdoor-use units (wet contact likely – immersion not included)
1.	Sinusoidal, ac	30 V, rms	15 V, rms
2.	Nonsinusoidal, ac	42.4 V, peak	21.2 V, peak
3.	Pure dc	60 V	30 V
4.	DC interrupted at a rate of 10 to 200 Hertz	24.8 V, peak	12.4 V, peak
5.	Combinations of dc and sinusoidal ac at frequencies not greater than 100 Hertz	See Figure 8.1	See Figure 8.1

Figure 8.1
Maximum acceptable voltage



S3253A

8.2 Stored energy

8.2.1 The allowable capacitance between capacitor terminals that are accessible as determined by the requirements in Section 7, Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts and User Servicing and Section 39, Protection of Service Personnel, shall satisfy the following expressions:

$$V < 40,000 \text{ where } C < 0.00328$$

$$V < 729 C^{-0.7} \text{ where } 0.00328 \leq C < 2.67$$

$$V < 367 \text{ where } 2.67 \leq C < 13.9$$

$$V < 2314 C^{-0.7} \text{ where } 13.9 \leq C < 184.5 \text{ in a DRY environment}$$

$$V < 60 \text{ where } C \geq 184.5 \text{ in a DRY environment}$$

$$V < 2314 C^{-0.7} \text{ where } 13.9 \leq C < 497 \text{ in a WET environment}$$

$$V < 30 \text{ where } C \geq 497 \text{ in a WET environment}$$

in which:

C is the capacitance of the capacitor in microfarads; and

V is the voltage across the capacitor in volts. V is to be measured 5 seconds after the capacitor terminals are accessible by the removal or opening of an interlocked cover, or the like. Typical calculated values appear in Table 8.2, and the equation is shown graphically in Figure 8.2.

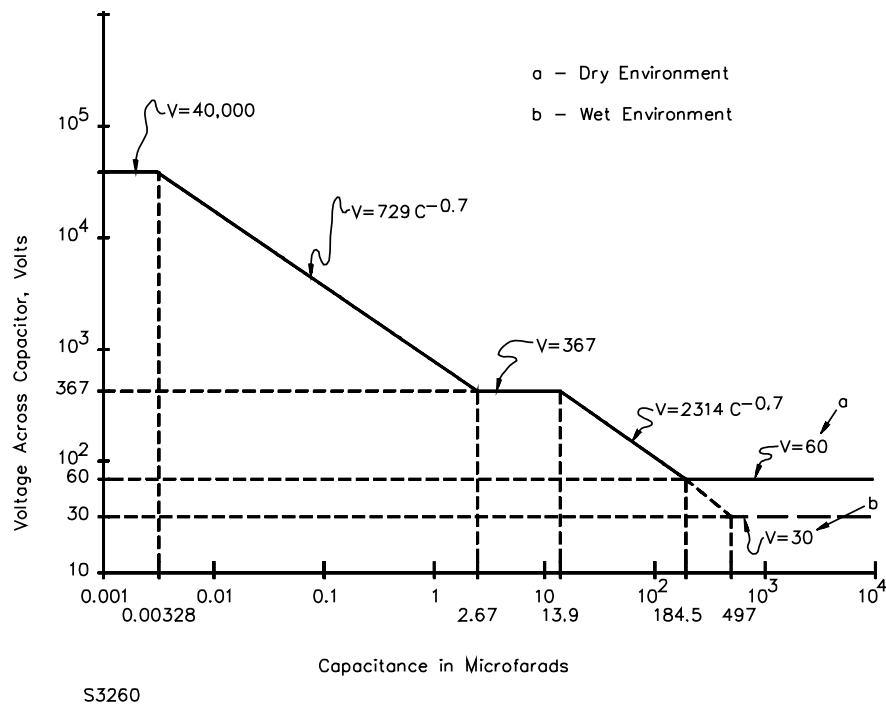
8.2.2 With reference to 8.2.1, a part involving a potential of more than 40 kilovolts peak is to be investigated to determine whether or not it involves a risk of electric shock.

Table 8.2
Risk of electric shock – stored energy current

Environment	Capacitance in microfarads ^a	Maximum allowable voltage across the capacitor, in volts
Wet or Dry	0.00328 or less	40,000
Wet or Dry	0.005	29,749
Wet or Dry	0.01	18,313
Wet or Dry	0.02	11,273
Wet or Dry	0.05	5,936
Wet or Dry	0.1	3,654
Wet or Dry	0.2	2,249
Wet or Dry	0.5	1,184
Wet or Dry	1.0	729
Wet or Dry	2.0	449
Wet or Dry	2.0	449
Wet or Dry	2.67 to 13.9	367
Wet or Dry	20.0	284
Wet or Dry	50.0	150
Wet or Dry	100.0	92.1
Wet or Dry	184.5	60.0
Dry only	184.5 or more	60.0
Wet	200	56.7
Wet	497 or more	30.0

^a See 8.1.2 and Figure 8.2.

Figure 8.2
Limited for voltage across capacitance



9 Mounting

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

9.2 Keyhole slots for mounting screws may be provided if they are arranged to prevent wall-mounting screws from projecting into a compartment containing electrical parts and reducing spacings to less than those specified in Section 23, Spacings.

9.3 For a unit having bottom ventilation openings, if the supporting feet are made of rubber or neoprene material, then the aging and physical properties of the material shall be investigated in accordance with Section 81, Accelerated Aging Test.

Exception: As specified in 45.8 and 52.1.5 for a unit subjected to the temperature and abnormal tests, the supporting means shall be removed prior to the tests.

9.4 A fixed unit shall not be provided with casters.

Exception: A unit may have casters if they are used solely for transporting the unit and provided with leveling feet that are intended to be lowered after the unit is installed.

10 Corrosion Protection

10.1 Iron and steel parts shall be protected against corrosion by painting, galvanizing, sherardizing, plating, or other equivalent means. This requirement applies to all enclosure parts, whether of sheet steel or cast iron, and to all springs and other parts upon which intended mechanical operation may depend. Bearing surfaces shall be of such materials and constructed so that binding due to corrosion is inhibited.

Exception: The parts specified in (a) – (d) need not be protected against corrosion:

- a) Bearings, or the like, where such protection is impracticable;*
- b) A minor part, such as a washer, screw, bolt, and the like, if the failure of such unprotected parts would not be likely to result in a risk of fire, electric shock, electrical energy-high current levels, or injury to persons, or the operation of the unit being affected adversely;*
- c) A decorative grille that is not required to form a part of the enclosure; and*
- d) A part made of stainless steel (properly polished or treated, if necessary).*

11 Mechanical Assembly

11.1 Loosening of parts in a unit as a result of vibration due to handling and operation of the unit shall not result in a risk of fire, electric shock, injury to persons, or electrical energy – high current levels.

11.2 A moving part that may involve a risk of injury to persons shall comply with the requirements specified in Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 7, and shall be considered with respect to:

- a) The degree of exposure necessary to perform its intended function;
- b) The sharpness of the moving part;
- c) The likelihood of unintentional contact with the moving part;
- d) The speed of the moving part; and
- e) The likelihood that a part of the body could be endangered or that clothing could be entangled, resulting in a risk of injury to persons.

These factors are to be considered with respect to both intended operation of the UPS and reasonably foreseeable misuse.

11.3 Screws with properly applied lock washers, screws tightened by means of a power tool, rivets, and staked and upset screws are considered not subject to loosening. See 11.4.

11.4 The construction of staked and upset screws is to consist of an interference fit between the nut and bolt resulting in uneasy turning of the screw. This may be accomplished by the use of a center punch applied to the end of a bolt after assembly, mismatching of the nut and bolt threads, or the equivalent.

11.5 A rotating part that, when loosened, results in a risk of fire, electric shock, electrical energy – high current levels, or injury to persons shall be assembled so that the direction of rotation tends to tighten the means that hold the rotating part in place.

Exception: A keyed part, a press fit, a part locked in place with a pin, or equivalent means can be used to hold a rotating part in place.

11.6 A switch, fuseholder, lampholder, attachment-plug receptacle, motor-attachment plug, or other component that is handled by the operator shall be mounted securely, not turn, and comply with the requirements specified in 11.7.

Exception: The requirement that a switch shall not turn may be waived if all the following conditions are met:

- a) The switch is of a plunger, slide, or other type that does not tend to rotate during intended operation (a toggle switch is considered to be subjected to forces that tend to turn the switch);*
- b) The means of mounting the switch make it unlikely that operation will loosen the switch;*
- c) Spacings are not reduced below the minimum required value if the switch rotates; and*
- d) Intended operation of the switch is by mechanical means rather than by direct contact by persons.*

11.7 The means of securing components mentioned in 11.6 shall include more than friction between surfaces. A lock washer can be used as a means to secure a device having a single-hole mounting means.

11.8 A blower or fan motor including the blower or fan blade itself shall be secured by any of the following or equivalent means in order to reduce the likelihood of the motor, blower, or fan blade from vibrating loose and falling from its mounting support:

- a) Bolts and nuts complying with 11.4;
- b) Bolts and nuts having holes or slots with properly applied cotter pins;
- c) Bolts having a compression type lock nut; or
- d) Rivets.

Exception No. 1: A blower or fan motor, including the blower or fan blade itself, secured by means described in 11.3 and oriented, positioned, or located above a barrier such that either the motor, blower, or fan blade is not likely to contact other components resulting in a risk of fire, electric shock, or electrical energy – high current levels in the event that such parts vibrated loose from their support need not comply with this requirement.

Exception No. 2: Blowers and fans rated 200 cubic feet per minute (340 m³/hour) or less need not comply with this requirement.

12 Switches and Controls

12.1 A switch or other control device shall have current and voltage ratings not less than those of the circuit that it controls when the unit is operated in its intended manner.

12.2 A primary-circuit switch that controls an inductive load having a power factor less than 75 percent, such as a transformer or some ballasts and that does not have an inductive rating, shall be either:

- a) Rated not less than twice the maximum load current under normal operating conditions; or
- b) Investigated for the application.

12.3 A switch used to connect a load to various sources or potentials shall be a type that has been investigated and rated for such use. This would include a switch used for switching a voltmeter, frequency meter, and power factor meter between various phases.

12.4 A switch or other device controlling a relay, solenoid coil, or the like shall have a suitable pilot duty rating.

Exception: A device as described in 12.5 need not comply.

12.5 A device that is rated for across-the-line motor starting of an alternating current motor is acceptable for alternating current pilot duty without further tests provided the power factor for the motor test was 0.5 or less and the overload test current was at least 150 percent of the pilot duty inrush current at the same voltage. Switching devices rated in accordance with Table 12.1 are considered to comply with this requirement.

Table 12.1
Horsepower rating versus pilot duty rating

Horsepower rating 1 phase (120 – 600 volts)	Alternating current pilot duty rating
1/10	125 VA (light duty)
1/2	360 VA (standard duty)
1	720 VA (heavy duty)

12.6 Each pole of a snap switch rated as a 2-circuit, 3-circuit, or multicircuit switch may control a separate load at the full voltage rating of the switch. Each pole of a snap switch rated as a 240-volt, 2-pole switch may control a separate 120-volt load, or both poles may be used to control both legs of a single 240-volt load. Each pole of a snap switch rated as a 240-volt, 3-pole switch may control a separate load not exceeding 139 volts or the three poles may be used to control the three legs of a 3-phase, 240-volt load.

12.7 A 240-volt or 250-volt snap switch used in a circuit involving more than 120 volts to ground shall be rated for such use as indicated by a double underlining under the voltage rating.

12.8 A switch shall not disconnect the grounded conductor of a circuit.

Exception No. 1: The grounded conductor may be disconnected by a switch that simultaneously disconnects all conductors of the circuit.

Exception No. 2: The grounded conductor may be disconnected by a switch that is so arranged that the grounded conductor may not be disconnected until the ungrounded conductors of the circuit have been disconnected.