UL 1778

ISBN 1-55989-674-4

Uninterruptible Power Supply Equipment

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062-2096

UL Standard for Safety for UL Standard for Safety for Uninterruptible Power Supply Equipment, UL 1778

Second Edition, Dated October 25, 1994

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 UL 519 and UL 547 have been withdrawn and replaced by UL 2111.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

The master for this Standard at UL's Northbrook Office is the official document insofar as it relates to a UL service and the compliance of a product with respect to the requirements for that product and service, or if there are questions regarding the accuracy of this Standard.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

This Standard consists of pages dated as shown in the following checklist:

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UL 1778

Standard for Uninterruptible Power Supply Equipment

First Edition – November, 1989

Second Edition

October 25, 1994

Approval as an American National Standard (ANSI) covers the numbered paragraphs on pages dated October 25, 1994 . These pages should not be discarded when revised or additional pages are issued if it is desired to retain the ANSI approved text.

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

Approved as ANSI/UL 1778-1991, August 16, 1991
Approved as ANSI/UL 1778-1996, February 8, 1996

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.

ISBN 1-55989-674-4

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PERFORMANCE

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]		Maximum width,[b]		Maximum length,					
Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)	Uncoated		Metal coated	
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020[d]	(0.51)	0.023[d]	(0.58)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)				
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited		0.026[d]	(0.66)	0.029[d]	(0.74)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)				
8.0	(20.3)	Not limited		12.0	(30.5)	Not limited		0.032	(0.81)	0.034	(0.86)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)				
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited		0.042	(1.07)	0.045	(1.14)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)				
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited		0.053	(1.35)	0.056	(1.42)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)				
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited		0.060	(1.52)	0.063	(1.60)
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)	43.0	(109.2)				
25.0	(63.5)	Not limited		39.0	(99.1)	Not limited		0.067	(1.70)	0.070	(1.78)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)				
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited		0.080	(2.03)	0.084	(2.13)
38.0	(103.4)	47.0	(119.4)	54.0	(137.2)	66.0	(167.6)				
42.0	(106.7)	Not limited		64.0	(162.6)	Not limited		0.093	(2.36)	0.097	(2.46)
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)	84.0	(213.4)				
52.0	(132.1)	Not limited		80.0	(203.2)	Not limited		0.108	(2.74)	0.111	(2.82)
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)				
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123	(3.12)	0.126	(3.20)
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]		Maximum length[c]		Maximum width[b]		Maximum length		
inches	(cm)	inches	(cm)	inches	(cm)	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 m^2), 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 cm^2) 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 mm^2).

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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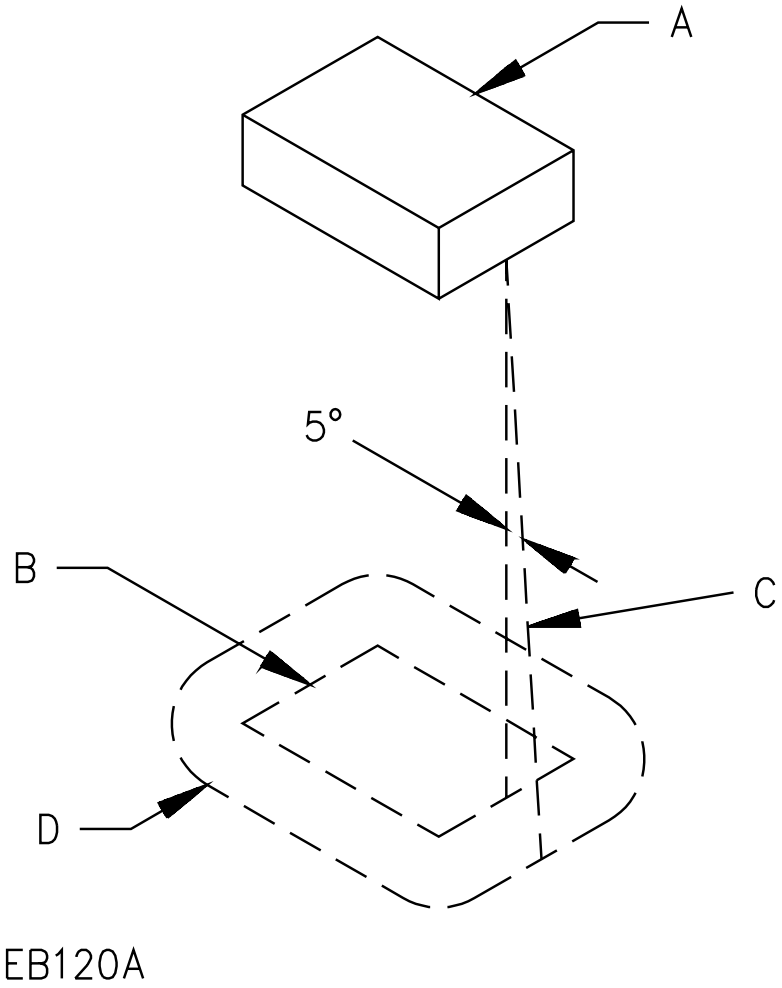
Figure 5.1
Enclosure bottom

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

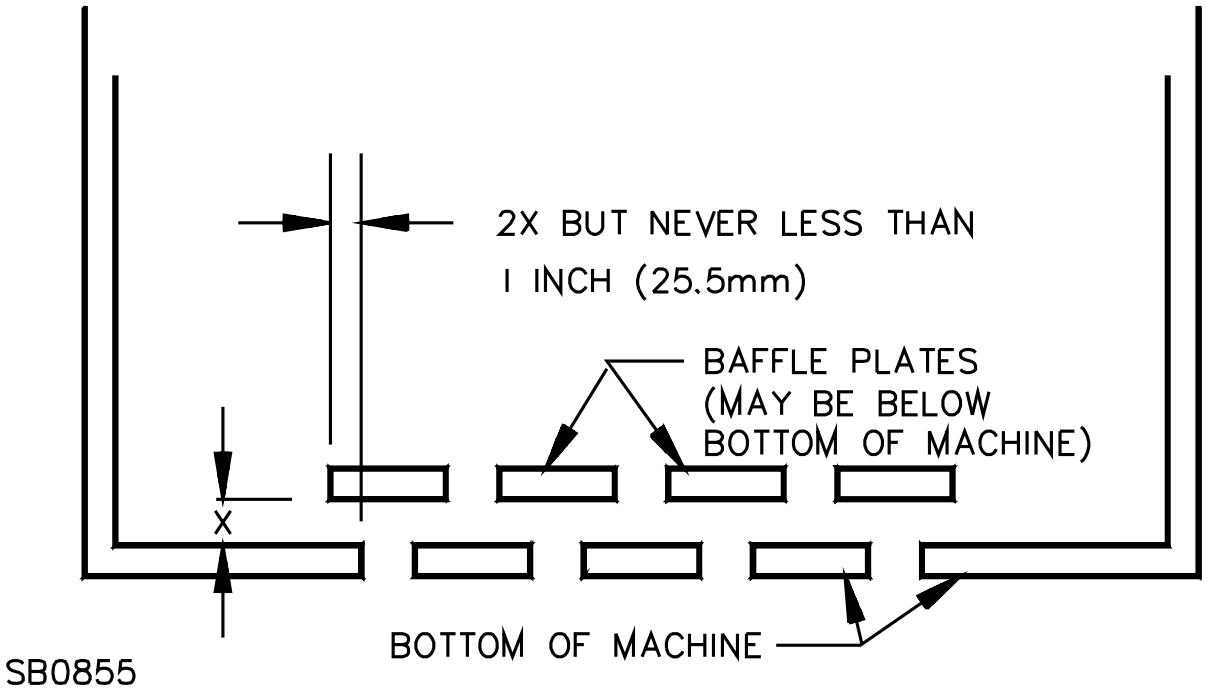
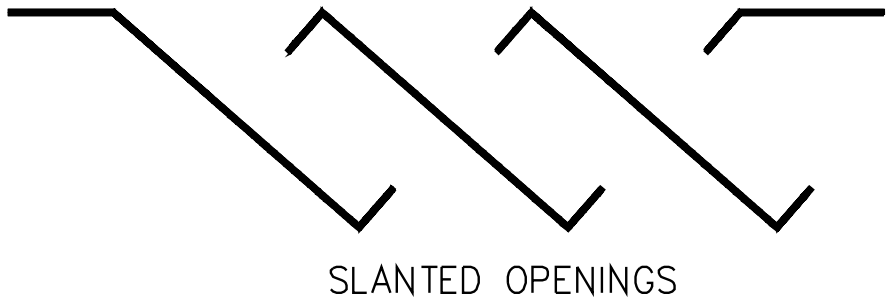
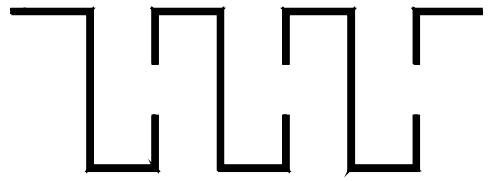


Figure 5.3
Cross sections of top-enclosure designs





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 from any side 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

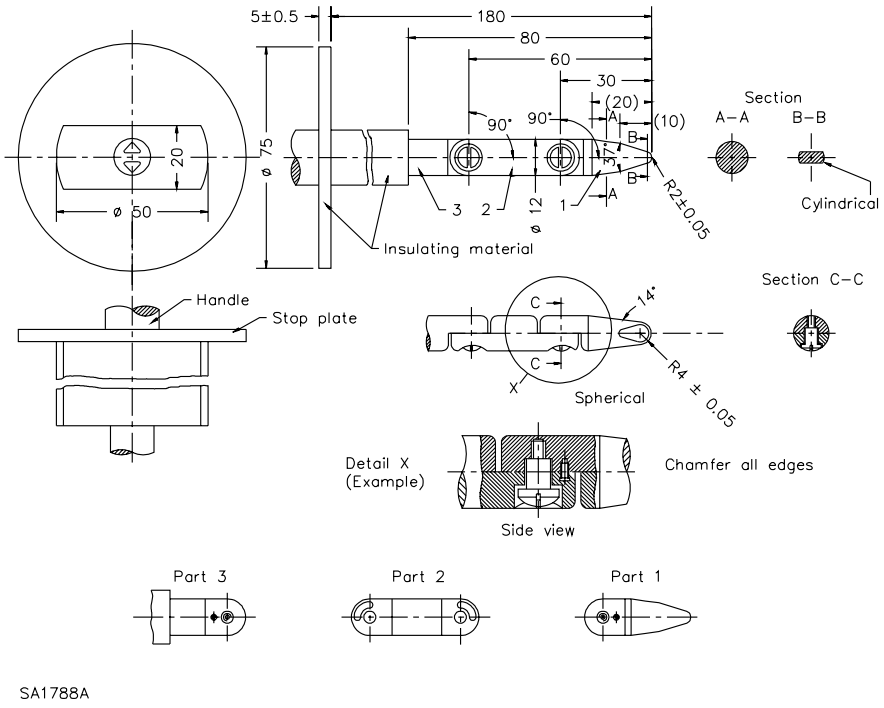


Figure 7.2
Probe for moving parts and uninsulated live parts in motors (see 7.3)

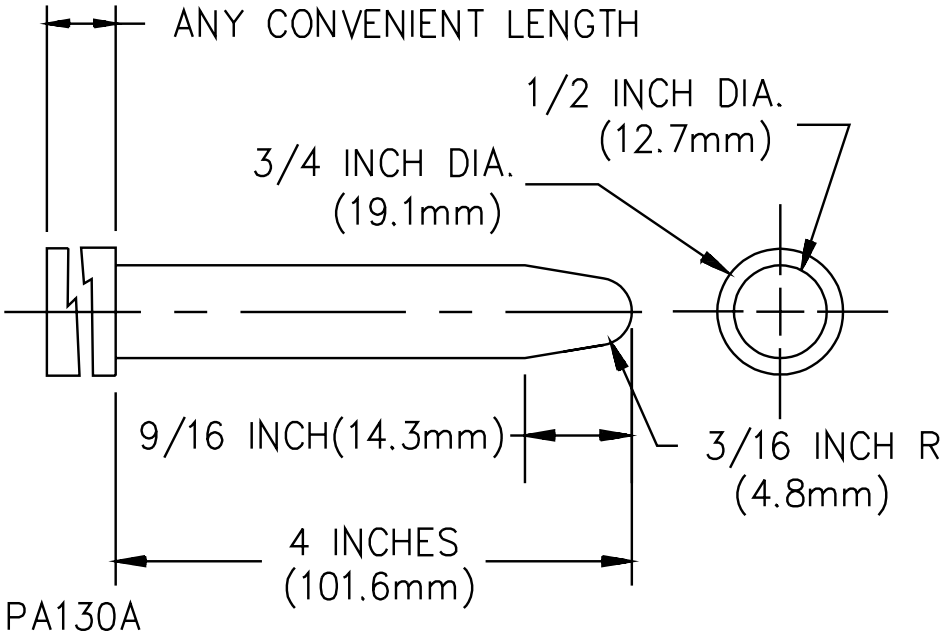


Figure 7.3
Probe for film-coated wire in motors (see 7.3)

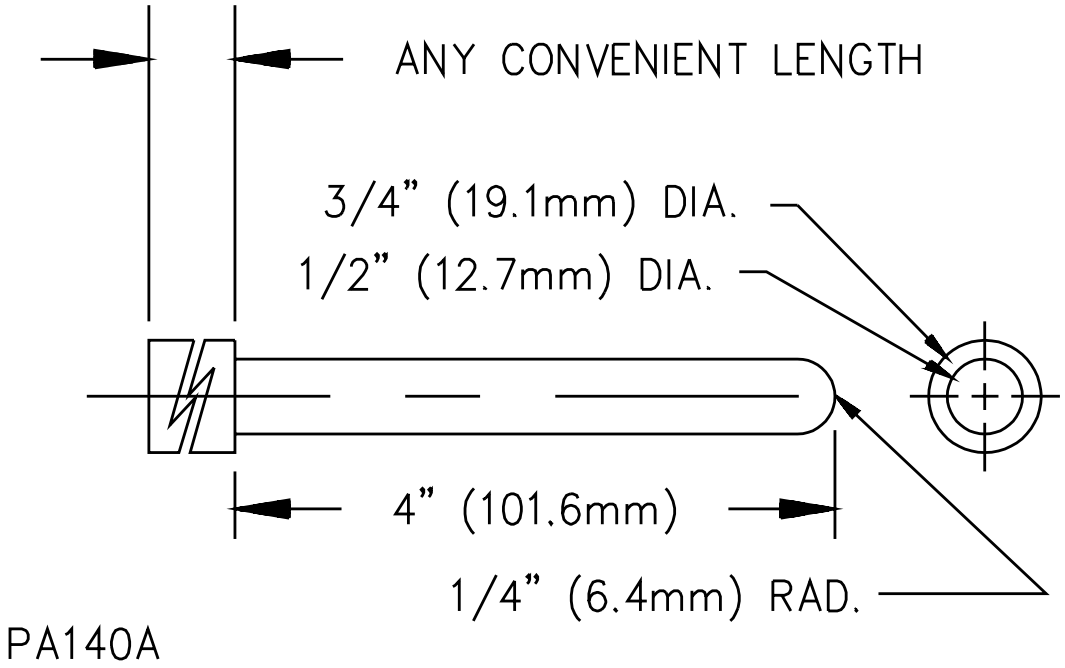


Table 7.1
Minimum acceptable distance from an opening to a part that may involve a risk of electric shock, electrical energy-high current level, or injury to persons

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.

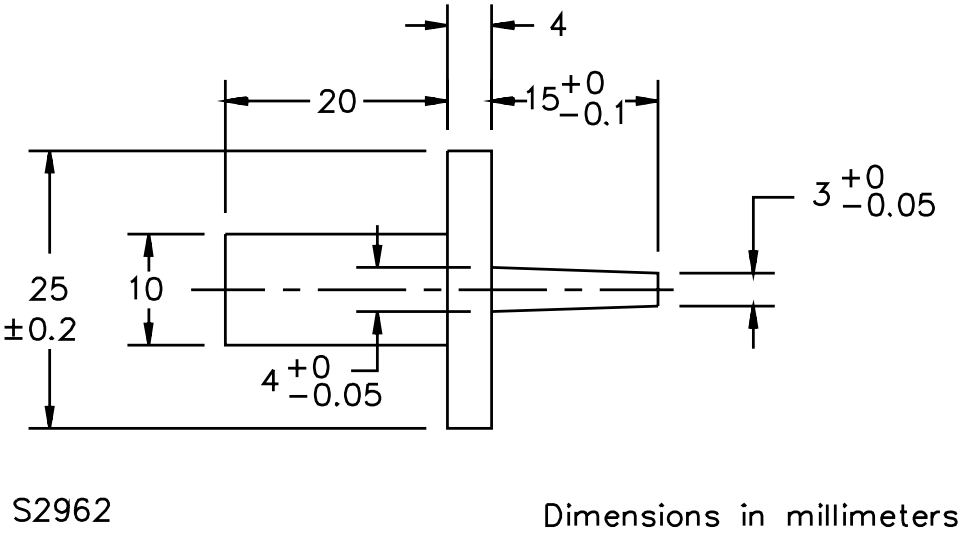
7.12 During the examination of a unit to determine whether it complies with the requirements in 7.2 or 7.3, a part of the enclosure that may be opened or removed by the user without using a tool (to attach an accessory, to make an operating adjustment, to give access to a fuse or other overload protective device as described in 5.3.1, or for other reasons) is to be opened or removed. A fastner, 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

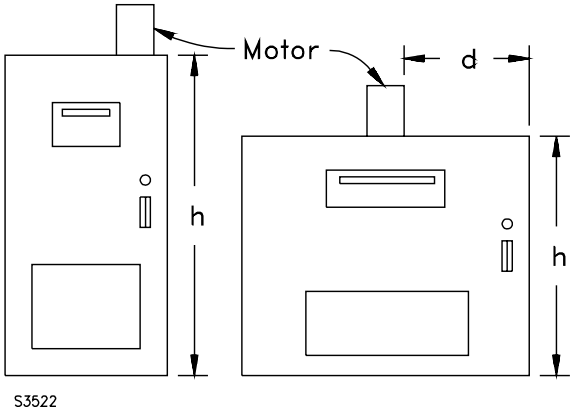
Figure 7.4 revised November 17, 1997



1 mm = 0.039 inch

Figure 7.5
Indirectly accessible motor by location[a]

Figure 7.5 revised November 17, 1997



h ≥ 6 feet (1.8 m)

h + d = 7-1/2 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

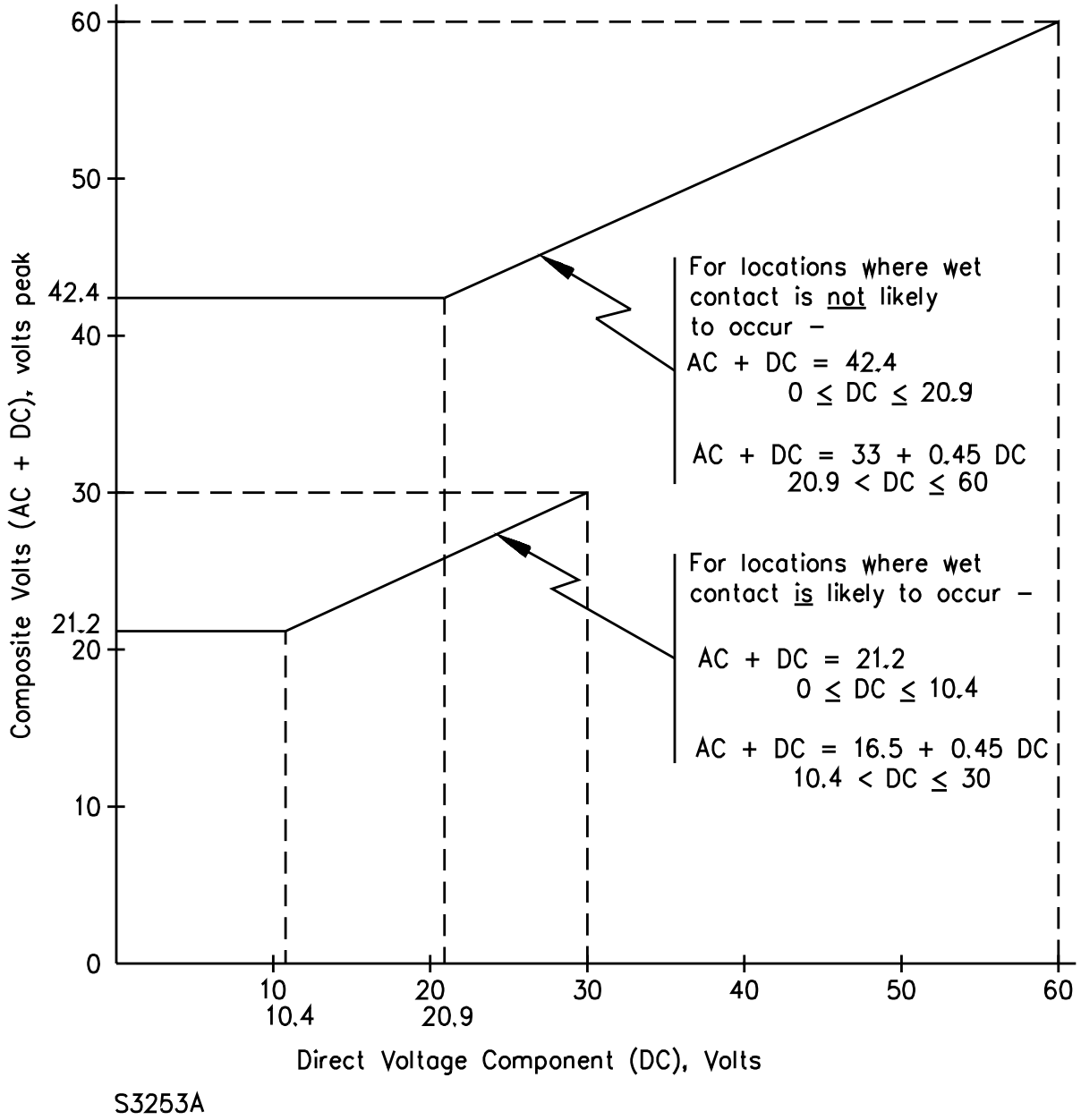
8.1.1 The requirements described in 8.1.2 – 8.2.2 are used to determine if the voltage of an accessible live part is considered to be a risk of electric shock. Determination of whether a live part is accessible to users and service personnel is specified in Section 7, Protection of Users – Accessibility 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



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:

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

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

$V < 367$ where $2.67 \leq C < 13.9$

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

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

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

$V < 30$ where $C \geq 497$ 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.

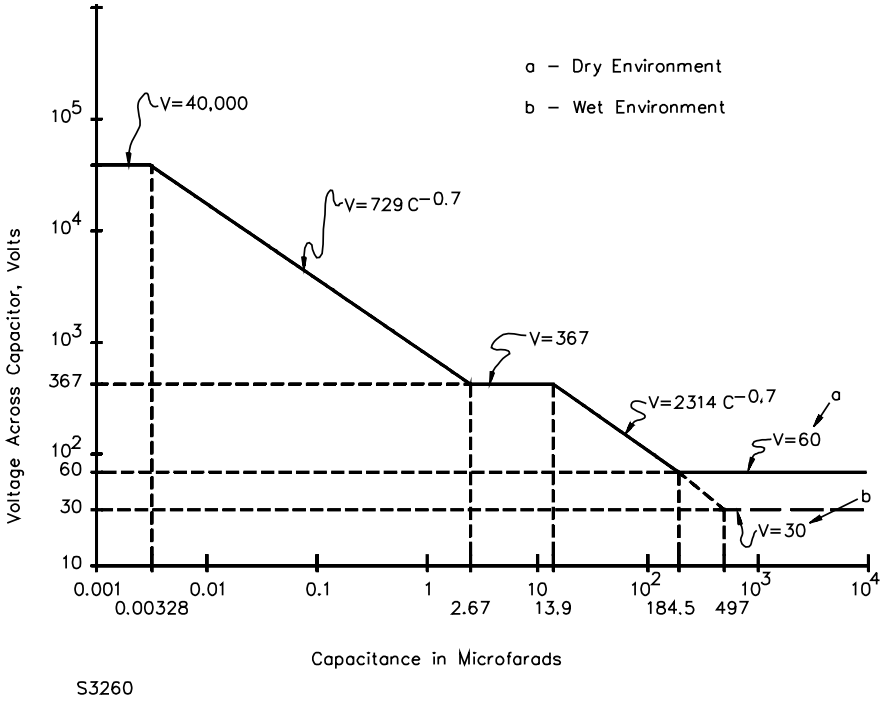
8.2.2 With reference to 8.2.1, a part involving a potential of more than 40 kilovolts peak is to be investigated to determine whether or not it involves a risk of electric shock.

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 m^3/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.

12.9 A bypass switch or maintenance bypass used to connect the protected load directly to the bypass source shall comply with requirements in the Standard for Transfer Switch Equipment, UL 1008.

Exception: A bypass switch or maintenance bypass tested in conjunction with the UPS is not required to comply with UL 1008. See 12.10, 52.12.1, and 52.12.2.

12.9 revised November 17, 1997

12.10 With reference to the requirement in the Exception to 12.9, solid state switches shall comply with the requirements in this standard. Mechanical and electromechanical switches shall comply with the appropriate requirements for switches such as in the Standard for General-Use Snap Switches, UL 20, the Standard for Industrial Control Equipment, UL 508, or other appropriate standards.

12.11 If a unit switch or circuit breaker is mounted such that movement of the operating handle between the on position and off position results in one position being above the other position, the upper position shall be the on position. This requirement does not apply to:

a) A switching device having more than one on position (such as a bypass switch);

b) A double throw switch;

c) A rotationally-operated switch; or

d) A rocker switch.

13 Disconnection Device

13.1 A disconnection device shall be provided for the output ac and dc power circuits of a fixed UPS, and a remote battery supply/cabinet assembly (see 13.4).

Exception No. 1: A UPS or battery supply having either a cord and plug or receptacle for connection to the output ac or dc circuit need not be provided with a disconnect device.

Exception No. 2: A UPS or battery supply provided with an instruction manual indicating that the disconnection means is to be provided by others need not be provided with a disconnect means. See 74.1.2(r).

13.2 The disconnection device shall:

a) Open all ungrounded conductors;

b) Consist of either a manually operated switch or circuit breaker;

c) Employ an operating handle that is either accessible from outside of the enclosure or located under a hinged cover not requiring a tool for opening; and

d) Be marked in accordance with 72.1.22.

13.3 If the operating handle of a disconnect device is operated vertically rather than rotationally or horizontally, the up position of the handle shall be the on position.

13.4 For a UPS investigated in combination with the remote battery supply intended to be used with the UPS, only one disconnection device need be provided for the battery supply circuit.

13.5 A battery supply for a UPS provided with a marking indicating that it is suitable for use in a computer room (see 72.1.27) shall incorporate a battery disconnect and a means for connection to the remote emergency power off circuit that disconnects the battery power source. The battery shall be disconnected within five minutes of the activation of the remote emergency power off circuit. See 70B.1.

Exception No. 1: A battery supply which meets the criteria of either (a) or (b) need not comply with this requirement:

a) The product of the open circuit voltage times the rating of the overcurrent protective device does not exceed 750 VA; or

b) Any resistive load cannot draw more than 750 VA for more than five minutes after the main power is disconnected (see 70A.1).

Exception No. 2: A disconnecting means shall not be required for power sources capable of supplying 750 volt-amperes or less derived from UPS equipment or from battery circuits integral to UPS equipment.

Added 13.5 effective February 1, 1999

14 Receptacles

14.1 A general-use attachment-plug receptacle in a unit shall be of the grounding type.

14.2 With reference to 14.1, if a grounding type receptacle is supplied from the secondary of a transformer:

a) The side of the secondary winding connected to the white or silver terminal of the receptacle shall be grounded in accordance with the requirements in 17.1, 17.2, and 17.4; and

b) The grounding terminal of the receptacle shall be conductively connected to the equipment grounding means in accordance with Section 19, Bonding of Internal Parts, and 18.14.

Exception: For an isolated-ground receptacle, the grounding terminal intended for connection to an insulated grounding conductor shall not be conductively connected to the equipment grounding means. See 14.4.

14.3 If a receptacle is supplied from the input ac supply circuit for the unit then, the white or silver terminal of the receptacle shall be connected to the grounded supply conductor, and the grounding terminal of the receptacle shall be conductively connected to the equipment grounding means in accordance with the requirements for bonding of internal parts specified in Section 19, Bonding of Internal Parts. See also 15.8.1 and 18.14.

14.4 With reference to the Exception to 14.2, a UPS provided with an isolated-ground receptacle shall comply with the following:

a) Provisions for permanent wiring connections shall be provided for the ac supply conductors; and

b) Provisions for connection of two equipment grounding conductors – one for grounding dead metal parts of the UPS specified in 18.1 and the other for grounding the grounding terminal of the isolated-ground receptacle – shall be provided. These provisions shall comply with the requirements in Section 18, Equipment Grounding.

14.5 A receptacle mounted on a raised outlet box cover shall be secured by at least two screws, or an equivalent means that reduces the likelihood of the receptacle loosening, turning, being pushed-back, or the like.

Added 14.5 effective February 1, 1999

15 Supply Connections

15.1 Fixed units

15.1.1 A fixed unit shall have provision for connection of a wiring system. This provision shall consist of:

a) Either wiring terminals as specified in 15.1.3 – 15.1.13, or wiring leads as specified in 15.1.3 and 15.1.14 – 15.1.19; and

b) A means for connection of cable or conduit as specified in 15.1.22.

Exception No. 1: The requirements described in 15.1.3 – 15.1.22 do not apply to the means for connection to accessible signal circuits complying with the requirements specified in Section 25, Accessible Signal Circuits.

Exception No. 2: The means for connection to an alternating current output power circuit of a UPS may consist of receptacles complying with the requirements specified in Section 14, Receptacles.

No Text on This Page

15.1.2 The requirement in 15.1.1 applies to the wiring connection means for the alternating current and direct current input and output power circuits of a unit. These connections are intended to be made in the field when the unit is installed.

15.1.3 A wiring terminal or lead shall be acceptable for the connection of a conductor having an ampacity based on Table 310-16 of the National Electrical Code, ANSI/NFPA 70-1993, of no less than 125 percent of the maximum current that the circuit will carry during rated conditions described in 44.1. For determining the appropriate column in Table 310-16, see 74.1.2(v) and (w).

Exception No. 1: For a UPS intended to be used with a remote battery supply and a remote battery supply or cabinet assembly (or both), a wiring terminal or lead for connection to the dc power circuit of a battery supply shall be acceptable for connection of a conductor having an ampacity of no less than 100 percent of the current that the circuit will carry while operating in the reserve mode at rated conditions, as described in 44.1(b), provided that the maximum allowable temperatures indicated in Table 45.1 are not exceeded during the temperature test specified in Section 45. See 71.4 and 72.1.14.

Exception No. 2: For a UPS having a recharging mode [see 44.1(a)] duration of less than 3 hours, the ampacity of the input alternating current terminals may be based on the input current measured during the Power Input Test specified in Section 44 as follows:

a) 125 percent of the input current required for the alternating current output load [see 44.1(d)]; plus

b) 100 percent of the input current required for battery charging [see 44.1(a) and (d)].

15.1.4 A wiring terminal shall comply with the requirement in 15.1.3 for a wire of each metal for which it is marked. See 72.1.9.

15.1.5 A wiring terminal shall be provided with a pressure terminal connector of other than the crimping type that is securely fastened in place – for example, firmly bolted or held by a screw.

Exception No. 1: A pressure terminal connector, including a crimping type, may be field-installed in accordance with 15.1.7.

Exception No. 2: A wire-binding screw may be employed at a wiring terminal intended for connection of a No. 10 AWG (5.3 mm^2) or smaller conductor if upturned lugs, a cupped washer, or the equivalent is provided to hold the wire in position.

15.1.6 A wiring terminal shall be prevented from turning or shifting in position by a means other than friction between surfaces. This may be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method.

Exception: A pressure terminal connector of the type that secures the wire by crimping and used in accordance with the requirements in 15.1.7 need not be prevented from turning provided that when the connectors are oriented in the position resulting in the least spacing between adjacent terminals and also between terminals and dead metal parts, the spacing complies with Section 23, Spacings.

15.1.7 In accordance with Exception No. 1 to 15.1.5, a pressure terminal connector need not be provided if the conditions in (a) – (e) are met:

a) One or more component terminal assemblies shall be available from the unit manufacturer or others, and they shall be specified in the instruction manual. See 74.1.2(b) and (c).

b) The fastening hardware such as a stud, nut, bolt, spring or flat washer, and the like, as required for an effective installation, shall either be:

1) Provided as part of the terminal assembly;

2) Mounted on or separately packaged with the unit; or

3) Specified in the instruction manual.

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

d) If the pressure terminal connector provided in a terminal assembly requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any necessary instructions shall be included in the assembly package or with the unit. See 74.1.2(d).

e) Installation of the pressure terminal connector in the intended manner shall result in a unit complying with the requirements of this standard.

15.1.8 An insulating base for support of a pressure terminal connector shall be subjected to the test described in Section 60, Strength of Terminal Insulating Base and Support Test.

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

Exception No. 1: A No. 8 (4.2 mm diameter) screw may be used at a terminal intended only for the connection of a No. 14 AWG (2.1 mm^2) conductor, or a No. 16 or 18 AWG (1.3 or 0.82 mm^2) control-circuit conductor.

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

15.1.10 A wire-binding screw shall thread into metal.

15.1.11 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 inch (1.27 mm) thick.

Exception: A terminal plate less than 0.050 inch (1.27 mm) thick is acceptable in a LVLE circuit or limited energy circuit (see 2.19 and 2.22) if the tapped threads have adequate mechanical strength to withstand the tightening torque specified in Table 15.1 without stripping.

Table 15.1
Tightening torque for wire-binding screws

Size of terminal screw, number	Wire sizes to be tested, AWG[a]	Tightening torque	
		Pound-inches	Newton meters
6	16 – 18 (ST)	12	1.4
8	14 (S) and 16 – 18 (ST)	16	1.8
10	10 – 14 (S) and 16 – 18 (ST)	20	2.3

[a] ST – stranded wire; S – solid wire.

15.1.12 There shall be two or more full threads in the metal of a terminal plate. The metal may be extruded at the tapped hole to provide at least two full threads.

Exception: Two full threads are not required for a terminal in a LVLE or limited-energy circuit (see 2.19 and 2.22) if a lesser number of threads results in a secure connection in which the threads will not strip when subjected to the tightening torque specified in Table 15.1.

15.1.13 A terminal for connection of a grounded conductor of an alternating current power circuit shall be identified as described in 72.1.12.

15.1.14 A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it will be connected, and shall not be smaller than No. 18 AWG (0.82 mm^2), for example, a No. 10 AWG (5.3 mm^2) or larger field-wiring lead is required for connection to a No. 6 AWG (13.3 mm^2) field-provided conductor. A field-wiring lead shall not be less than 6 inches (152.4 mm) long.

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

Exception No. 2: A lead may be more than two wire sizes smaller than the field-provided copper conductor to which it will be connected, but not smaller than No. 18 AWG (0.82 mm^2), if more than one factory-provided copper lead is intended for connection to the same field-provided lead, and the construction complies with the conditions in (a) – (c):

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

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

c) Instructions are provided in accordance with 74.1.2(e).

15.1.15 A field-wiring lead shall consist of general building wire, or other wiring if it has an insulation of:

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

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

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

15.1.16 A field-wiring lead shall be subjected to the test specified in 54.1.4.

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

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

b) A marking is provided on the unit in accordance with 72.1.25.

15.1.18 The free end of a field-wiring lead that will not be used in every installation, such as a tap for a multivoltage transformer, shall be insulated. For a grounding lead, see 18.8.

15.1.19 A field-wiring lead for connection of a grounded conductor shall be identified as described in 72.1.12.

15.1.20 A wiring compartment on a fixed unit shall be located so that wire connections therein will be accessible for inspection, without disturbing either factory or field connected wiring, after the unit is installed in the intended manner.

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

15.1.22 For a fixed unit intended for installation on a raised floor and having provision for entrance of field wiring through the bottom of the enclosure, the following requirements apply:

a) The bottom enclosure openings shall comply with 5.10.1; and

b) Conduit or knockout openings in accordance with 5.8.1 – 5.8.9 shall be provided.

15.2 Openings for conduit or cable connection

15.2.1 For a fixed unit, an opening or knockout complying with the requirements specified in 5.8.1 – 5.8.9 shall be provided for connection of conduit or cable wiring system.

Exception: A unit complying with the requirements specified in 5.8.7 and 5.8.8 need not be provided with an opening or a knockout.

15.3 Openings for class 2 circuit conductors

15.3.1 An opening for the entry of a conductor or conductors of a Class 2 circuit shall be provided with an insulating bushing. The bushing may be mounted in place in the opening or may be within the enclosure so that it may be properly mounted when the unit is installed.

Exception: The bushing may be omitted if the opening is acceptable for accommodating armored cable or conduit, and the installation instructions indicate that Class 1 wiring methods are to be used as indicated in 74.1.2(x).

15.3.2 A bushing of rubber or rubber-like material provided in accordance with 15.3.1 shall be at least 1/8 inch (3.2 mm) thick, except that it may be not less than 3/64 inch (1.2 mm) thick if the metal around the hole is eyeletted or similarly treated to provide smooth edges. A bushing shall be located so that it will not be exposed to oil, grease, oily vapors, or other substances having a deleterious effect on the material of the bushing. A hole in which such a bushing is mounted shall be free from sharp edges, burrs, projections, or the like, that may damage the bushing.

15.4 Cord-connected units

15.4.1 For a stationary unit, flexible cords and attachment plugs and receptacles shall be used for connection to the alternating current and direct current input and output power circuits. The requirements described in 15.4.2 – 15.4.10 do not apply to a Class 2 circuit or to an accessible signal circuit complying with the requirements in Section 25, Accessible Signal Circuits.

Exception No. 1: The means for connection to an alternating-current output circuit of a UPS may consist of:

a) Either wiring terminals as specified in 15.1.3 – 15.1.13, or wiring leads as specified in 15.1.3 and 15.1.14 – 15.1.19; and

b) Provision for connection of cable or conduit as specified in 15.2.1.

Exception No. 2: The means for connection to the direct-current input or output power circuit of a unit may consist of welding cable and an attachment plug and receptacle.

15.4.2 The cord shall be Type G, SJ, SJT, SJE, SJO, SJOO, SJTO, SJTOO, S, ST, SE, SO, SOO, STO, STOO, W, SV, SVE, SVEO, SVEOO, SJEOO, SEOO, SVT, or SVTO. The length of the cord used for the alternating current input circuit as measured from the face of the attachment plug to the point where the cord emerges from the unit shall be not less than 6 feet (1.8 m).

15.4.2 revised February 1, 1996

15.4.3 The voltage rating of a flexible cord shall be at least the rated voltage of the unit, and its ampacity shall be at least the current rating of the unit.

15.4.4 The attachment plug of a supply cord shall:

a) Have a current rating in accordance with 15.4.5; and

b) Have a voltage rating corresponding to the rated voltage of the unit.

15.4.5 With reference to 15.4.4(a), the current rating of an attachment plug for the alternating current input circuit shall not be less than 125 percent of the rated input alternating current. The current rating of an attachment plug for a battery supply circuit for a UPS used with a remote battery cabinet shall be at least the current rating of the battery supply circuit [see 71.4].

Exception: For a UPS having a recharging mode [see 44.1(a)] duration of less than 3 hours, the current rating of the attachment plug may be based on the input current measured during the Power Input Test specified in Section 44 as follows:

a) 125 percent of the input current required for the alternating-current output load [see 44.1(c) and (d)]; plus

b) 100 percent of the input current required for battery charging [see 44.1(a) or (d)].

15.4.6 The attachment plug shall be of the polarized type if the unit is not provided with a grounding type attachment plug.

15.4.7 If the unit can be adapted for use on two or more different voltages by field alteration of internal connections, the attachment plug provided with the unit shall be of a type required for the voltage and current for which the unit is connected when shipped from the factory and the unit shall be marked as described in 72.1.17.

Exception: A unit need not comply with this requirement if the unit is:

a) Equipped with an operator-adjustable voltage selector that complies with 52.13.1;

b) Provided with a detachable power-supply cord or complies with the Exception to 15.4.8; and

c) Marked in accordance with 72.1.20.

15.4.7 revised February 1, 1996

15.4.8 If a unit is intended for use with a detachable power supply cord, the cord shall be provided with the unit.

Exception: A unit marked in accordance with 72.1.23 and 74.1.2(n) need not comply with this requirement.

15.4.9 A unit having a rating of 208 volts single phase may be provided with an attachment plug, receptacle, or cord connector rated 250 volts if:

a) The test described in 52.13.2 is conducted; and

b) The marking specified in 72.2.21 – 72.2.23 is provided. See 15.4.10.

15.4.10 With reference to 15.4.9(b), the marking is not required for a unit complying with the test requirements in Sections 42 – 45 and 48, and if while energized from a 240 volt source of supply, the output voltage of the unit does not exceed its output voltage rating by more than 10 percent.

15.5 Strain relief

15.5.1 Strain relief shall be provided to reduce the risk of mechanical twisting or stress on a flexible cord or welding cable from being transmitted to terminals, splices, or interior wiring. See 54.1.1 and 54.1.3. The means for preventing twisting shall be evaluated by inspection. The tests described in 54.1.1 and 54.1.3 are to be conducted to evaluate the means for preventing stress.

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15.5.2 If a knot in a flexible cord serves as strain relief, the surfaces that the knot may contact shall be free from burrs, fins, sharp edges, and projections that may damage the cord.

15.5.3 Means shall be provided to prevent a flexible cord or lead from being pushed into the enclosure of an appliance through the cord-entry hole when such displacement results in:

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

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

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

d) Damaging internal connections or components.

To determine compliance, a flexible cord or lead shall be tested in accordance with the push-back relief test of 54.3.2.

15.5.3 revised January 11, 1999

15.6 Bushings

15.6.1 At the point at which a supply cord passes through an opening in a wall, barrier, or the overall enclosure, there shall be a bushing or the equivalent that is secured in place and that has a smooth, well-rounded surface against which the cord can bear.

15.6.2 Ceramic materials and some molded compositions are acceptable for insulating bushings, but bushings of wood or hot-molded shellac and tar compositions are not acceptable.

15.6.3 A bushing of the same material as is molded integrally with the supply cord is acceptable if the built-up section is not less than 1/16 inch (1.6 mm) thick at the point at which the cord passes through the enclosure.

15.7 Interconnections between sections

15.7.1 The means provided for external connection between sections of a unit or between units of a system shall comply with the requirements described in 15.7.2 – 15.7.11.

15.7.2 A flexible-cord or -cable assembly used for interconnection shall be of a type as specified in 15.4.2 and shall be provided with bushings and strain relief in accordance with 15.5.1 – 15.6.3.

Exception No. 1: The strain relief for wires and cables that are part of the secondary circuits mentioned in 24.4 – 24.12 shall comply with 54.1.2.

Exception No. 2: When an interconnecting cable is used, it shall be constructed of a thermoplastic or thermoset jacketed appliance wiring material, required for the maximum voltage, current, and temperature involved and shall be rated VW-1, FT-1 or better. The cable employed shall be classified for use for external interconnection of electronic equipment and equivalent to the flexible cords specified in 15.4.2.

15.7.2 revised January 5, 2000

15.7.3 Inserting a male connector in a female connector other than the one intended to receive it, misalignment of male and female connectors, and other manipulations of parts that are accessible to the operator shall not result in a risk of electric shock or electrical energy – high current levels to persons. See 15.7.5.

15.7.4 If either end of an interconnecting cable terminates in a connector having one or more exposed contacts, a risk of electric shock or electrical energy – high current levels shall not result between contacts and between earth ground and any contact that is exposed on either the connector or its receptacle while the connector is out of its receptacle. See 15.7.5 and 15.7.6.

15.7.5 Inclusion of an interlock circuit in the cable to de-energize the exposed contacts whenever an end of the cable is disconnected constitutes compliance with the requirement in 15.7.3 and 15.7.4.

15.7.6 With reference to 15.7.4, an attachment plug or a receptacle that is exposed and is used for a battery supply located in a remote cabinet shall comply with the following:

a) For 60 volts dc or less, the:

1) Contacts and associated live parts of the receptacle shall be recessed 1/16 inch (1.6 mm) minimum from the plane of the face of the receptacle body; and

2) Blades of the attachment plug shall be recessed 1/16 inch minimum from the plane of the blade opening of the plug body.

b) For more than 60 volts dc, accessibility of the receptacle contacts, attachment plug blades, and associated live parts shall comply with:

1) The accessibility requirements specified in the Standard for Attachment Plugs and Receptacles, UL 498; or

2) The accessibility requirements in 7.2, 7.4 – 7.6, and 7.12.

15.7.7 Unless acceptable cable assemblies are provided, each section of a unit shall be provided with acceptable field-wiring terminals or leads (see 15.1.4 – 15.1.19) to facilitate interconnection by means of permanently installed wiring.

15.7.8 Sections of a unit that are intended to be combined in field installations to form overall unified enclosures (modular units – see 5.2.1) may be acceptable if the modules provide complete enclosures or the equivalent that facilitate the routing or interconnecting cables or other wiring from one unit of the system to another. Such constructions shall provide substantially complete enclosures for all wiring.

15.7.9 If interconnection of sections of a unit involves Class 2 circuits, the Class 2 circuits may be terminated in field-wiring connections other than specified in 15.7.7, such as wire-wrap or crimp-on types, if the Class 2 circuits are permanently separated from all other circuits and if the mating parts and instructions for their method of attachment are provided.

15.7.10 A connector used for connection to an external control circuit shall comply with the requirements in the Standard for Electrical Attachment Plugs and Receptacles, UL 498.

Exception: Connectors used for connection to a low-voltage Class 2 circuit as described in 24.4 such as an RS232 data port connector are acceptable.

15.7.11 Sections of a unit interconnected by flexible metal conduit or flexible metal tubing shall be bonded together by an equipment grounding conductor. The size of the grounding conductor shall not be less than the circuit conductors contained within the conduit.

15.8 Identification

15.8.1 A unit rated as follows shall have the grounded conductor connected to the components, if provided, and as listed in 15.8.2(a) – (c):

a) 120 volts, 2-wire;

b) 120/240 volts, single-phase, 3-wire;

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c) 208Y/120 volts, two-phase, 3-wire;

d) 208Y/120 volts, three-phase, 4-wire;

e) 480Y/277 volts, three-phase, 4-wire in which the neutral is used as a circuit conductor;

f) 240/120 volts, three-phase, 4-wire in which the midpoint on one phase is used as a circuit conductor; or

g) 240 or 480 volts, three-phase, 3-wire, corner-grounded delta.

15.8.2 The following components, if provided, shall be connected to the grounded conductor of a unit rated as shown in 15.8.1:

a) The identified terminal or lead of a receptacle as specified in 14.2 and 14.3, as appropriate;

b) The screw shell of an Edison-base lampholder; and

c) The screw shell of an Edison-base fuseholder.

The grounded conductor of a fixed unit shall be connected to the field-wiring terminal intended for the connection of a grounded conductor (see 15.1.13) or shall be connected to the field-wiring lead intended for the connection of a grounded conductor (see 15.1.19). The grounded conductor of a stationary or portable unit shall be connected to the blade of the attachment plug intended for connection to the grounded supply conductor. A single-pole switch or single-pole overcurrent protective device, other than an automatic control without a marked off position shall be connected to the ungrounded conductor. See also 12.8.

Exception: The grounded conductor may be connected to a single-pole overcurrent protective device under the conditions described in Exception No. 2 of 28.1.8.

16 Wire Bending Space

16.1 A permanently connected unit employing pressure terminal connectors for field connection of circuits described in 15.1.2 shall be provided with space within the enclosure as specified in 16.3 – 16.7 for the installation of conductors including grounding conductors likely to be employed in the installation.

16.2 The conductor size used in judging the wiring space is to be based on the use of a conductor sized in accordance with 15.1.3.

16.3 Wire bending space for field installed conductors shall be provided opposite any:

a) Pressure wire connector as specified in 16.4 or 16.5; and

b) Opening or knockout for a conduit or wireway in a gutter as specified in 16.9.

16.4 If a conductor is likely to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 16.1. A wire is considered likely to enter or leave a top, back, bottom, or side surface if there is an opening or knockout for a wireway or conduit.

Table 16.1
Minimum wire-bending space for conductors through a wall opposite terminals in inches (mm)[a]

Wire size,		Wires per terminal (pole)[b]											
AWG or kcmil	(mm^2)	1			2			3			4 or more		
14 – 10 AWG	(2.1 – 5.3)	Not Specified			–			–			–		
8	(8.4)	1-1/2		(38.1)	–			–			–		
6	(13.3)	2		(50.8)	–			–			–		
4	(21.1)	3		(76.2)	–			–			–		
3	(26.7)	3		(76.2)	–			–			–		
2	(33.6)	3-1/2		(88.9)	–			–			–		
1	(42.4)	4-1/2		(114)	–			–			–		
0	(53.5)	5-1/2		(140)	5-1/2			7		(179)	–		
2/0	(67.4)	6		(152)	6			7-1/2		(191)	–		
3/0	(85.0)	6-1/2	[1/2][b]	(165)	6-1/2	[1/2][b]	(165)	8		(203)	–		
4/0	(107)	7	[1][b]	(179)	7-1/2	[1-1/2][b]	(191)	8-1/2	[1/2][b]	(216)	–		
250 kcmil	(127)	8-1/2	[2][b]	(216)	8-1/2	[2][b]	(216)	9	[1][b]	(229)	10		(254)
300	(152)	10	[3][b]	(254)	10	[2][b]	(254)	11	[1][b]	(279)	12		(305)
350	(177)	12	[3][b]	(305)	12	[3][b]	(305)	13	[3][b]	(330)	14	[2][b]	(355)
400	(203)	13	[3][b]	(330)	13	[3][b]	(330)	14	[3][b]	(355)	15	[3][b]	(381)
500	(253)	14	[3][b]	(355)	14	[3][b]	(355)	15	[3][b]	(381)	16	[3][b]	(406)
600	(304)	15	[3][b]	(381)	16	[3][b]	(406)	18	[3][b]	(457)	19	[3][b]	(483)
700	(355)	16	[3][b]	(406)	18	[3][b]	(457)	20	[3][b]	(508)	22	[3][b]	(559)
750	(380)	17	[3][b]	(432)	19	[3][b]	(483)	22	[3][b]	(559)	24	[3][b]	(610)
800	(405)	18		(457)	20		(508)	22		(559)	24		(610)
900	(456)	19		(483)	22		(559)	24		(610)	24		(610)
1000	(507)	20		(508)	–			–			–		
1250	(633)	22		(559)	–			–			–		
1500	(760)	24		(610)	–			–			–		
1750	(886)	24		(610)	–			–			–		
2000	(1013)	24		(610)	–			–			–		

[a] The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned may be given further consideration.

[b] Wire bending space shall be permitted to be reduced by the number of inches shown in brackets under the following conditions:

1. Only removable or lay-in wire connectors receiving one wire each are used (there may be more than one removable wire connector per terminal), and

2. The removable wire connectors can be removed from their intended location without disturbing structural or electrical parts other than a cover, and can be installed with the conductor in place.

16.5 If a conductor is not likely to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 16.2. The wire bending space is considered to be in accordance with Table 16.2 if:

a) A barrier is provided between the connector and the opening; or

b) Drawings are provided specifying that the conductors are not to enter or leave the enclosure directly opposite the wire connector. See Illustrations A, B, and C of Figure 16.1.

Table 16.2
Minimum width of gutter and wire-bending space for conductors through a wall not opposite terminals in inches (mm)[a]

Size of wire,		Wires per terminal (pole)									
AWG or kcmil	(mm^2)	1		2		3		4		5	
14 – 10 AWG	(2.1 – 5.3)	Not Specified		–		–		–		–	
8 – 6	(8.4 – 13.3)	1-1/2	(38.1)	–		–		–		–	
4 – 3	(21.1 – 26.7)	2	(50.8)	–		–		–		–	
2	(33.6)	2-1/2	(63.5)	–		–		–		–	
1	(42.4)	3	(76.2)	–		–		–		–	
1/0 – 2/0	(53.5 – 7.4)	3-1/2	(88.9)	5	(127)	7	(178)	–		–	
3/0 – 4/0	(85.0 – 107)	4	(102)	6	(152)	8	(203)	–		–	
250 kcmil	(127)	4-1/2	(114)	6	(152)	8	(203)	10	(254)	–	
300 – 350	152 – 177)	5	(127)	8	(203)	10	(254)	12	(305)	–	
400 – 500	(203 – 253)	6	(152)	8	(203)	10	(254)	12	(305)	14	(356)
600 – 700	(304 – 355)	8	(203)	10	(254)	12	(305)	14	(356)	16	(406)
750 – 900	(380 – 456)	8	(203)	12	(305)	14	(356)	16	(406)	18	(457)
1000 – 1250	(507 – 633)	10	(254)	–		–		–		–	
1500 – 2000	(760 – 1010)	12	(305)	–		–		–		–	

[a] The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned may be given further consideration.

16.6 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. See illustration D of Figure 16.1.

16.7 For a unit not provided with a conduit opening or knockout (see 5.8.7) the minimum wiring bending space mentioned in 16.4 – 16.6 shall be based on:

a) Any enclosure wall likely to be used for installation of the conduit; or

b) Only specific walls that are to be used as determined by a marking, drawing, or template furnished with the unit.

16.8 The distance mentioned in 16.3 – 16.5 is to be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. See illustrations A – C of Figure 16.1. The wire terminal is to be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it can assume without defeating any means provided to prevent turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or the like. 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. If a terminal is provided with one or more 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.

Figure 16.1
Wire bending space

Figure 16.1 revised November 17, 1997

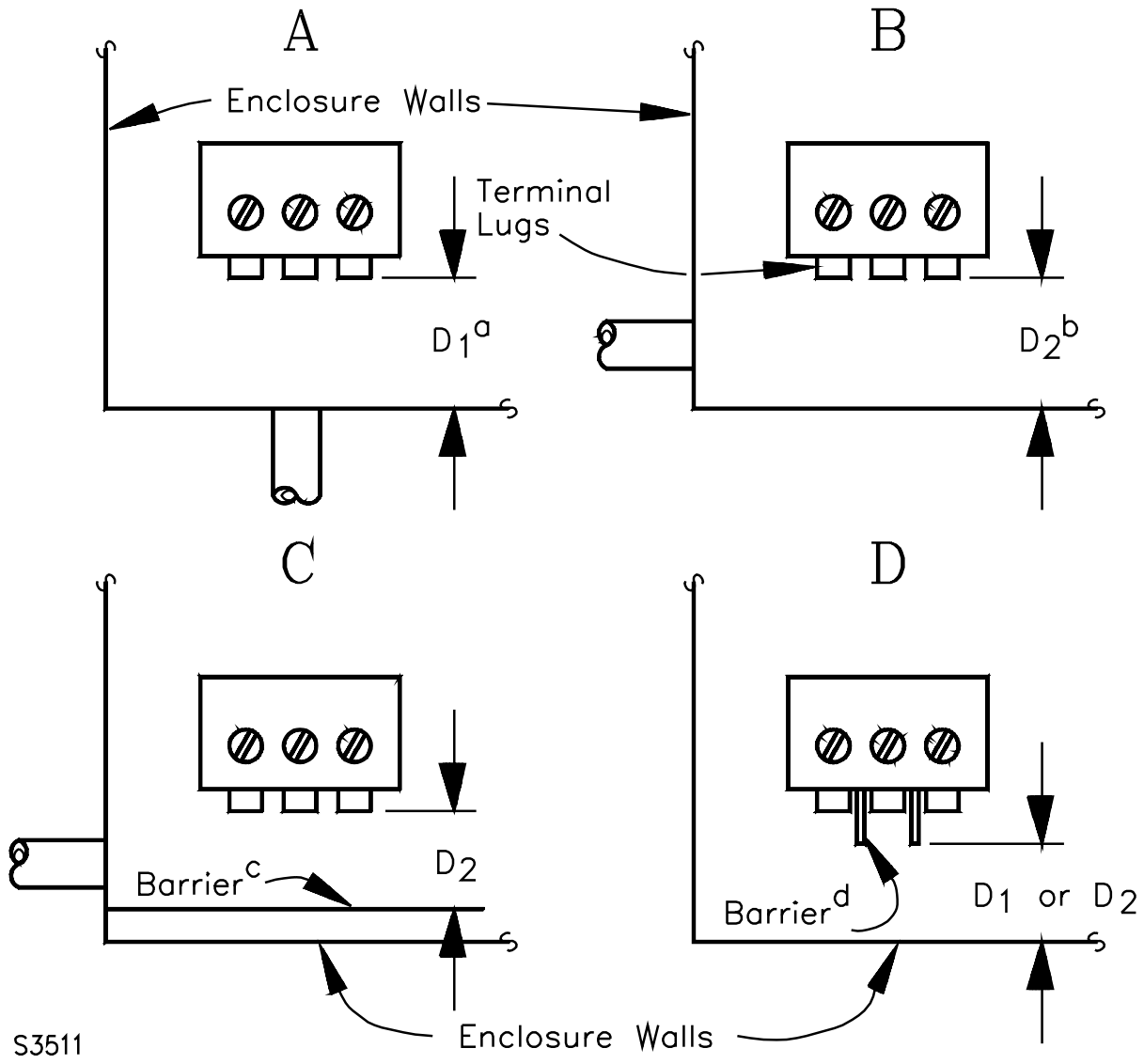

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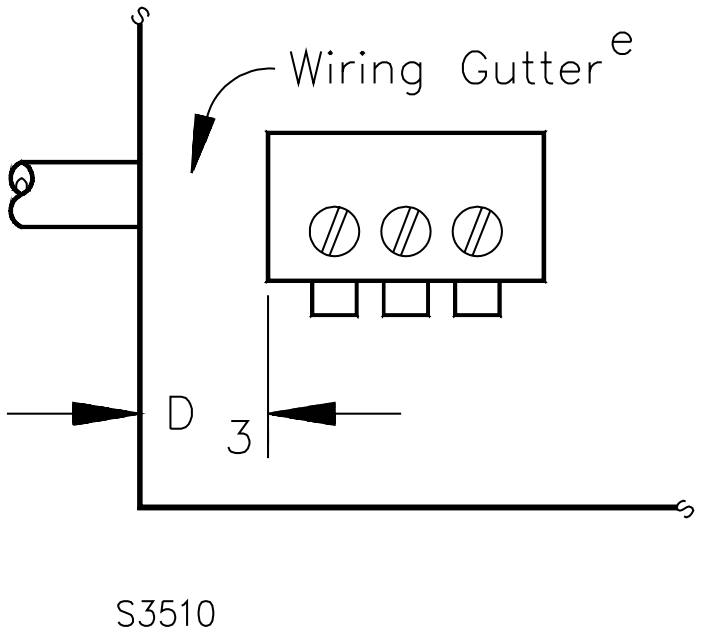
Figure 16.1 (Cont'd)

E



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D_1 is the distance between a wire connector or an adjacent barrier and the opposite wall that conductors are likely to pass through.

D_2 is the distance between a wire connector or an adjacent barrier and the opposite wall or barrier that conductors are not likely to pass through.

D_3 is the width of a wiring gutter having a side through which conductors are likely to pass through.

[a] A conduit opening or knockout is provided in the wall opposite the terminal lugs. D_1 shall not be less than the minimum wire bending space specified in Table 16.1.

[b] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. The wall opposite the terminal lugs either is not provided with a knockout or conduit opening or a marking is provided indicating that the conduit opening or knockout is not to be used. D_2 shall not be less than the minimum wire bending space specified in Table 16.2.

[c] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. In addition, a conduit opening or knockout is provided in the wall opposite the terminal lugs, however, a barrier preventing the use of the opening is provided. D_2 shall not be less than the minimum wire bending space specified in Table 16.2.

[d] When a barrier or other means is provided restricting bending of the conductor, the distance D_1 or D_2, as appropriate (see notes 1 – 3 above) is to be measured from the end of the barrier.

[e] A conduit opening or knockout is provided in a wiring gutter. The width of the gutter, D_3, shall not be less than the minimum wire bending space specified in Table 16.2.

16.9 The width of a wiring gutter in which one or more knockouts are provided shall be large enough to accommodate (with respect to bending) conductors of the maximum size likely to be used at that knockout. The values of the minimum acceptable width of a wiring gutter, with respect to conductors entering a knockout, are the same as the values of minimum acceptable bending space given in Table 16.2. See illustration E of Figure 16.1.

Exception: The wiring space is not prohibited from being less than the required minimum width when:

a) Knockouts are provided elsewhere that are in compliance with these requirements;

b) The wiring space at such other point or points is of a width that accommodates the conductors in question; and

c) The knockout or knockouts at such other points are capable of being used in the intended wiring of the unit.

16.9 revised January 11, 1999

17 Output Circuit Grounding

17.1 The requirements for circuit grounding specified in 17.2 – 17.8 apply to the output circuit of fixed units and of stationary units having grounding type receptacles for the output alternating current power connections.

17.2 An output alternating current power circuit shall be grounded when:

a) The circuit has no electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another wiring system (see 17.3);

b) The circuit is rated 50 – 600 volts; and

c) The circuit is as described, but not limited to those in (1) – (3). See Section 250-5(b) of the National Electrical Code, NFPA 70-1996, for other circuits:

1) A circuit that is grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts. This requires that one conductor of each of the following circuits be grounded:

i) 120 volts, 2-wire;

ii) 240/120 volts, single-phase, 3-wire;

iii) 208/120 volts, two-phase, 3-wire;

iv) 208/120 volts, three-phase, 4-wire.

2) A circuit nominally rated 480 wye/277 volts, 3-phase, 4-wire in which the neutral is used as a circuit conductor.

3) A circuit-nominally rated 240/120 volts, 3-phase, 4-wire in which the midpoint of one phase is used as a circuit conductor.

For other units, an output alternating current power circuit complying with (a) shall not be grounded unless the construction complies with the requirements specified in 17.4 and 17.7.

Exception: The output alternating current circuit of a stationary UPS that is not a separately derived source during the normal mode of operation is not required to be grounded in the reserve mode of operation.

17.2 revised November 17, 1997

17.3 The condition specified in 17.2(c)(1)(i) applies to all modes of operation of the unit including recharging, reserve, bypass, and normal modes as defined in 44.1 (a) – (d).

17.3 revised November 17, 1997

17.4 With reference to 17.2, the conductor to be grounded shall be as follows:

a) Single-phase alternating current system, 2-wire – one conductor.

b) Single-phase alternating current system, 3-wire – the neutral conductor.

c) Multiphase alternating current system having one wire common to all phases – the common conductor.

d) Multiphase alternating current system where one phase is used as in (b) above – the neutral conductor.

17.5 Grounding of the circuits mentioned in 17.2 – 17.4 shall be made by a bonding jumper connected between the grounded conductor referenced in 17.4 and to:

a) The enclosure of a metal-enclosed unit; or

b) The metal chassis that is bonded to the equipment grounding conductor or terminal of a nonmetallic enclosed unit. See 17.6.

Exception: The following provisions may be provided to allow the circuit to be grounded in the field:

a) A field-wiring terminal intended for use with a conductor size specified in Column 4 of Table 17.1 and identified in accordance with 72.1.12 shall be connected to the circuit by a bonding jumper of a size not less than specified in Column 4 of Table 17.1; and

b) A marking identifying the circuit as a separately derived source and referencing the instruction manual in accordance with 72.1.28.

17.6 The size of the bonding jumper specified in 17.5 shall be, based on the current rating of the circuit, not less than the value specified in Column 4 of Table 17.1.

17.7 A fixed unit shall be provided with a terminal that complies with 15.1.4 – 15.1.13 for connection of the grounding electrode conductor to the metal enclosure or equipment grounding conductor described in 17.5(a) and (b). The terminal shall be:

a) Capable of securing a conductor size, based on the maximum current rating of the circuit, as specified in Column 3 of Table 17.1; and

b) Marked as described in 72.1.13.

17.8 For an alternating current output circuit of a unit having a polarized receptacle, lead, or terminal identified as a grounded circuit (see 72.1.12) that is not grounded at the unit itself because of an electrical connection to supply conductors originating in another wiring system [see 17.2(c)(1)] a potential involving a risk of electric shock shall not exist between ground and the grounded circuit contact, terminal, or lead. Compliance with this requirement is to be determined by the test specified in 51.1.

Exception: The test described in 51.1 is not required if the ac input neutral and ac output neutral conductors are solidly connected together, that is, no electronic components connected between the neutral conductors.

Table 17.1
Size of circuit bonding, equipment-grounding, and grounding electrode conductors[a]

Column 1	Column 2				Column 3				Column 4			
	Minimum size of equipment grounding or bonding conductor AWG or kcmil (mm^2)[c]				Minimum size of grounding electrode conductor AWG or kcmil (mm^2)				Minimum size of output circuit bonding jumper AWG or kcmil (mm^2)[f]			
Maximum current rating[b] (amperes)	Copper		Aluminum or copper-clad aluminum		Copper		Aluminum or copper-clad aluminum		Copper		Aluminum or copper-clad aluminum	
20	12	(3.3)	10	(5.3)	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
60	10	(5.3)	8	(8.4)	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
90	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
100	8	(8.4)	6	(13.3)	6	(13.3)	6	(13.3)	6	(13.3)	4	(21.2)
150	6	(13.3)	4	(21.2)	6	(13.3)	4	(21.2)	6	(13.3)	4	(21.2)
200	6	(13.3)	4	(21.2)	4	(21.2)	2	(33.6)	4	(21.2)	2	(33.6)
300	4	(21.2)	2	(33.6)	2	(33.6)	1/0	(53.5)	2	(33.6)	1/0	(53.5)
400	3	(26.7)	1	(42.4)	1/0[d]	(53.5)	3/0[d]	(85.0)	1/0[d]	(53.5)	3/0[d]	(85.0)
500	2	(33.6)	1/0	(53.5)	2/0	(67.4)	4/0	(107.2)	1/0	(53.5)	3/0	(85.0)
600	1	(42.4)	2/0	(67.4)	2/0	(67.4)	4/0	(107.2)	2/0	(67.4)	4/0	(107.2)
800	1/0	(53.5)	3/0	(85.0)	3/0	(85.0)	250	(127)	2/0	(67.4)	4/0	(107.2)
1000	2/0	(67.4)	4/0	(107.2)	3/0	(85.0)	250	(127)	3/0	(85.0)	250	(127)
1200	3/0	(85.0)	250	(127)	3/0	(85.0)	250	(127)	250[e]	(127)	250	(127)
1600	4/0	(107.2)	350	(127)	3/0	(85.0)	250	(127)	300[e]	(152)	400[e]	(203)
2000	250	(127)	400	(203)	3/0	(85.0)	250	(127)	400[e]	(203)	500[e]	(253)
2500	350	(177)	600	(304)	3/0	(85.0)	250	(127)	500[e]	(253)	700[e]	(355)
3000	400	(203)	600	(304)	3/0	(85.0)	250	(127)	600[e]	(304)	750[e]	(380)
4000	500	(253)	800	(405)	3/0	(85.0)	250	(127)	700[e]	(380)	1000[e]	(508)
5000	700	(355)	1200	(608)	3/0	(85.0)	250	(127)	900	(456)	1250	(635)
6000	800	(405)	1200	(608)	3/0	(85.0)	250	(127)	1200	(608)	1500	(759)

[a] See Table 17.2 for equivalent area of bus.

[b] Maximum ampere rating of the input circuit overcurrent protective device described in 52.1.6 or the output circuit overcurrent protective device described in 28.3.1 – 28.4.4.

[c] The equipment grounding conductor in the cord for a portable or stationary unit may be the same size as the current-carrying conductors.

[d] If the wire terminal connectors for the input or output circuit conductors, as appropriate, are rated for two No. 3/0 AWG copper or two No. 250 kcmil aluminum conductors but will not accept a No. 600 kcmil conductor, these values may be reduced to No. 2 AWG copper or No. 1/0 AWG aluminum.

[e] The cross section may be reduced to 12.5 percent of the total cross section of the largest input or output circuit conductor, as appropriate, of the same material (copper or aluminum) for any phase on units rated 1200 amperes and above. This applies when the cross section of the circuit conductors is limited by the wire terminal connectors provided.

[f] The bonding jumper for a stationary unit may be the same size as the current-carrying conductors of the output circuit.

Table 17.2
Equivalent cross-sectional areas of wires and buses

Table 17.2 revised January 11, 1999

Wire size (AWG or kcmil)	Minimum cross section of bus	
	Inch^2	(mm^2)
8	0.013	8.39
6	0.021	13.55
4	0.033	21.29
3	0.041	26.45
2	0.052	33.55
1	0.066	42.58
0	0.083	53.55
2/0	0.105	67.74
3/0	0.132	85.16
4/0	0.166	107.10
250	0.196	236.45
300	0.236	152.28
350	0.275	177.42
400	0.314	202.58
500	0.393	253.55
600	0.471	303.87
700	0.550	364.84
750	0.589	380.00
800	0.628	405.16
1000	0.785	506.45
1200	0.942	607.73
1250	0.981	632.90
1500	1.178	760.00

18 Equipment Grounding

18.1 There shall be provisions for grounding all dead metal parts of a unit that are exposed or that may be contacted by a person during intended operation or adjustment and that are likely to become energized as a result of electrical malfunction.

18.2 The provisions for equipment grounding specified in 18.1 shall be provided for each wiring system to be connected to the:

a) Alternating current input supply; and

b) Alternating current output circuit.

Exception: Accessible signal circuits described in Section 25 need not have provisions for equipment grounding.

18.3 To determine whether a part is likely to become energized, factors such as construction, the proximity of wiring, and the results of a dielectric voltage-withstand test (conducted after the appropriate overload, endurance, and abnormal tests) are to be evaluated.

18.4 The grounding means for fixed equipment shall consist of an equipment-grounding terminal or lead.

18.5 An equipment-grounding terminal or lead-grounding point shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection. To reduce the likelihood of inadvertent loosening, the head of the screw or bolt shall not be accessible from outside of the enclosure.

Exception: The head of a double-nut secured bolt or screw may be accessible.

18.6 An equipment-grounding connection shall penetrate a nonconductive coating, such as paint or vitreous enamel.

18.7 An equipment-grounding point shall be located so that the grounding means is not likely to be inadvertently removed during servicing.

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

18.9 An equipment-grounding lead shall be a size specified in Column 2 of Table 17.1. The lead shall have a free length of at least 6 inches (152 mm) and the surface of the insulation shall be green with or without one or more yellow stripes. No other lead in a field-wiring compartment or visible to the installer shall be so identified.

Exception: The color coding requirement does not apply to low-voltage Class 2 circuits provided the low-voltage leads are:

a) Located remote from the line-voltage connections and the segregation complies with the requirements in Section 23, Separation of Circuits; or

b) Marked in accordance with 72.1.26.

18.10 The equipment-grounding conductor of a power-supply cord shall be connected to the grounding blade of a grounding attachment plug and shall be connected to dead metal parts within the frame or enclosure by means of a screw not likely to be removed during ordinary servicing not involving the power-supply cord. An external force applied to the power-supply cord shall not transmit stress to the equipment-grounding connection on the frame or enclosure before the line-voltage connections are broken.

18.11 An equipment-grounding conductor shall not be spliced.

18.12 An equipment-grounding connection, equipment-grounding conductor, enclosure, frame, component mounting panel, or any other part connected to earth ground shall not carry current except during an electrical malfunction. See 24.1.

Exception: A line bypass capacitive impedance circuit for a radio frequency signal circuit or a transient voltage surge suppressor need not comply.

18.13 A grounded circuit conductor shall not be connected to any equipment-grounding or bonding circuit in a unit.

Exception: The output circuit of a unit as described in 17.1 and 17.2 may be connected to an equipment-grounding or bonding circuit.

18.14 A soldering lug, a connection means that depends on solder, a screwless (push-in) connector, a quick-connect, or other friction-fit connector shall not be used for equipment-grounding.

Exception: A quick-connect terminal that is additionally secured by soldering may be used for connection of an equipment-grounding conductor of a power-supply cord to dead metal parts within the unit.

18.15 The equipment-grounding terminal shall be capable of securing a conductor of a size acceptable for the application in accordance with Column 2 of Table 17.1 and shall be constructed in accordance with the requirements specified in 15.1.4 – 15.1.12.

18.16 A wire-binding screw employed for the connection of a field-installed equipment grounding conductor shall have a green colored head that is either hexagonal, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be marked as described in 72.1.10.

18.17 If two or more units are interconnected electrically and one of them is grounded, they shall be bonded together, such as by means of a conductor included in an interconnecting cable or by a conductive mechanical means, including the use of starwashers or the equivalent (see 19.7 – 19.11).

19 Bonding of Internal Parts

19.1 On a UPS having provisions for grounding (see 18.1) all exposed dead metal parts that are likely to become energized through electrical fault that involves a risk of electric shock or electrical energy – high current levels, shall be conductively connected to the equipment grounding means.

19.2 In a unit having provisions for grounding, all uninsulated metal parts of the enclosure, motor frames and mounting brackets, component mounting brackets, capacitors, and other electrical components that involve a risk of electric shock or electrical energy – high current levels shall be bonded for grounding if they may be contacted by the user or inadvertently contacted by the serviceman.

Exception: A metal part as described in (a) – (g) need not be bonded for grounding:

a) An adhesive-attached metal foil marking, a screw, a handle, or the like, that is located on the outside of an enclosure or cabinet and isolated from electrical components or wiring by grounded metal parts so that they are not likely to become energized.

b) An isolated metal part, such as a magnet frame and an armature, a small assembly screw, or the like, that is positively separated from wiring and uninsulated live parts.

c) A panel or cover that does not enclose uninsulated live parts if wiring is positively separated from the panel or cover so that it is not likely to become energized.

d) A panel or cover that is insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 1/32 inch (0.8 mm) thick and secured in place.

e) An isolated metal part that is mounted on a printed-wiring board (such as transformers and choke cores and heat sinks).

f) An isolated metal part that is marked in accordance with 72.2.15.

g) A capacitor sleeved with insulating tubing complying with 23.2.2.

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

a) The connector is not likely to be displaced;

b) The terminal has the dimensions specified in Table 19.1; and

c) The component is limited to use on a circuit having a branch-circuit protective device rated 20 amperes or less.

19.4 Metal-to-metal piano-type hinges may be considered as a means for bonding a door for grounding.

19.5 If the continuity of the grounding system relies on the dimensional integrity of a nonmetallic material, the material shall be acceptable for the purpose when investigated for creep in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. See also 19.9.

Table 19.1
Quick-connect terminals for bonding internal parts

Nominal size of terminal, inches (mm)					
Width		Length		Thickness	
0.187	(4.7)	1/4	(6.4)	0.020	(0.5)
0.187	(4.7)	1/4	(6.4)	0.032	(0.8)
0.205	(5.2)	1/4	(6.4)	0.032	(0.8)
0.250	(6.4)	5/16	(8.0)	0.032	(0.8)

19.6 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 painting, galvanizing, plating, or equivalent means. A separate bonding conductor or strap shall:

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

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; and

c) Not be spliced.

19.7 The bonding shall be by a positive means, such as by clamps, rivets, bolted or screwed connections, or by welding, soldering, or brazing with materials having a softening or melting point greater than 455°C (850°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 similar material, other than as indicated in 19.9.

19.8 With reference to 19.7, if penetration of a nonconductive coating cannot be determined by examination, a Grounding Impedance Test, Section 55, shall be conducted.

19.9 A connection that depends upon the clamping action exerted by rubber or similar material may be acceptable if it complies with the requirements in the Bonding Conductor Test, Section 62, for bonding conductors 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 are likely to 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 it being reassembled in its intended position.

19.10 A separate component-bonding conductor shall either:

a) Not be smaller than the size specified in Column 2 of Table 17.1, (see 19.11);

b) Not be smaller than the conductor supplying the component; or

c) Comply with the requirements in Section 62, Bonding Conductor Test.

19.11 With reference to Column 2 of Table 17.1, if more than one size branch-circuit overcurrent device is involved, the size of the bonding conductor is to be based on the rating of the overcurrent device intended to provide ground-fault protection for the component bonded by the conductor. For example, if a motor is individually protected by a branch-circuit overcurrent device smaller than other overcurrent devices used with the UPS, a bonding conductor for that motor is sized on the basis of the overcurrent device intended for ground-fault protection of the motor.

20 Internal Wiring

20.1 Wires

20.1.1 The internal wiring of a UPS shall be rated for the particular application with respect to the temperature and voltage, exposure to oil or grease, and other conditions of service to which the wiring can be subjected.

20.1.2 With respect to 20.1.1, the effects of vibration, impact, and exposure are to be considered for wires smaller than No. 24 AWG (0.21 mm^2).

20.1.3 All wiring shall be polyvinyl chloride (PVC), polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), or neoprene insulated, or shall comply with the vertical wire flame test requirements in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, as evidenced by a surface marking ″VW-1.″

20.1.4 Helical wraps and other continuous forms of harnessing shall be classed V-2 or less flammable when tested in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception No. 1: A harness need not be classed V-2 or less flammable if, when tested as an assembly, the assembly is classed V-2 or less flammable.

Exception No. 2: Lacing tape, twine, individual cable clamps, and noncontinuous cable ties need not be classed V-2 or less flammable.

20.1.4 revised January 11, 1999

20.1.5 Wiring that extends from the enclosure to a hinged door or other part that is subject to movement in use other than installation and servicing shall be stranded and the arrangement shall preclude twisting or stressing of conductors as a result of the movement. The wiring shall be routed or protected to reduce the likelihood of damage to the insulation. The conductors shall be:

a) Of a jacketed type, such as Type SJ, SJO, SJT, or SVT; and

b) Provided with strain relief so that stress will not be transmitted to terminals or splices.

Exception No. 1: The conductors of a low-voltage, limited-energy circuit described in 2.22 need not comply.

Exception No. 2: A bonding lead used for grounding a door need not be jacketed.

Exception No. 3: Wiring of a type other than those mentioned in 20.1.5 that is subject to motion, and any supplementary insulation provided on the wire may be subjected to a flexing test to determine the acceptability for the application. See 54.2.1.

20.1.5 revised February 1, 1996

20.1.6 The length of a power-supply cord inside a UPS shall be limited to that needed for electrical connections.

20.2 Protection of wiring

20.2.1 Internal wiring shall not be accessible when judged in accordance with Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts and User Servicing, Section 7.

Exception: Internal wiring may be accessible if it is located and secured within the enclosure so that it is not likely to be subjected to stress or mechanical damage.

20.2.2 Wires within an enclosure, compartment, raceway, or the like shall be located or protected to reduce the risk of unintentional contact with any sharp edge, burr, fin, moving part, or the like that may damage the conductor insulation.

20.2.3 Internal wiring shall be so routed and secured that neither it nor related electrical connections are likely to be subjected to stress or mechanical damage.

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

20.2.5 A bushing used on other than smooth, rounded surfaces of a hole through which wires pass shall be of material that has mechanical and heat-resistant properties acceptable for the application – such as porcelain, phenolic, fiber at least 3/64 inch (1.2 mm) thick, a material complying with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C (see 35.2) or smooth, rounded metal. A soft-rubber bushing or the like is not acceptable for other than low-voltage wiring (see 15.3.2) unless the material has been evaluated and found to be acceptable for the purpose.

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

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

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

Exception: Auxiliary mechanical protection is not required for conductors having cross-linked synthetic insulation.

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

21 Current-Carrying Parts

21.1 General

21.1.1 A current-carrying part shall be of silver, copper, a copper-base alloy, stainless steel, aluminum, or other materials acceptable for the application.

Exception: Plated steel may be used for secondary-circuit parts and for some primary-circuit parts (such as for capacitor terminals where a glass-to-metal seal is necessary and for leads or threaded studs of semiconductor devices). Blued steel or steel with equivalent corrosion resistance can be used for the current-carrying arms of mechanically or magnetically operated leaf switches and within a motor and its governor, motor terminals included, or where the temperature is in excess of 100°C (212°F), but not elsewhere.

21.1.2 An uninsulated live part and a component that has uninsulated live parts shall be secured to the base or mounting surface so that they cannot turn or shift in position when a displacement occurs which may result in a reduction of spacings below the minimum required values specified in Section 23, Spacings.

21.2 Bus bars

21.2.1 Each bus bar shall be plated at each joint with tin, silver, nickel, or cadmium.

Exception No. 1: A welded or brazed joint need not be plated.

Exception No. 2: A copper bus bar need not be plated if the current at the joint is 600 amperes or less.

Exception No. 3: Other coatings may be used for aluminum bus bars if investigated for the application in accordance with the requirements for current-carrying parts described in Section 70, Bus Bar Tests.

Exception No. 4: A bus bar provided with a suitable oxide inhibiting compound over the joint surfaces need not be plated. See 21.3.2.

21.2.2 The bending of a bus bar shall not result in visible cracks, but roughening or slight surface crazing is acceptable.

21.2.3 Each riveted joint connection shall have a spring washer at one end and either a spring washer or a flat washer at the other end. See 21.2.5 and 21.2.6.

Exception No. 1: A connection rated 225 amperes or less employing only copper bus bars need not comply.

Exception No. 2: Other constructions employing a rivet may be accepted if they are investigated in accordance with the applicable requirements in Section 70, Bus Bar Tests.

21.2.4 Each joint connection shall employ a spring washer at one end of a bolt. See 21.2.6.

Exception No. 1: A spring washer may be replaced with a split ring lock washer and flat washer if each bus in the joint is copper or if each aluminum bus in the joint has a tensile yield strength of at least 20,000 psi (138 MPa).

Exception No. 2: A flat washer, a split-ring lock washer, or a bolthead that complies with 21.2.5 may be used in place of a spring washer if the joint does not include any aluminum or if aluminum bolts are used with aluminum bus bars.

Exception No. 3: Other constructions may be accepted if they are investigated in accordance with the applicable requirements in Section 70, Bus Bar Tests.

21.2.5 The flat washer mentioned in 21.2.3 and 21.2.4 shall have a thickness of at least one-sixth that of the diameter of the rivet shank or bolt and shall have an outer diameter at least 150 percent of the rivet shank or bolt and not less than the outer diameter of any adjacent spring washer.

21.2.6 A spring washer as mentioned in 21.2.3 and 21.2.4 is a dished washer of stainless, or hardened and tempered steel, having an outer diameter not less than 150 percent of the bolt diameter, a thickness not less than one-eighth of the bolt diameter, and dished not less than 3-1/2 percent of the bolt diameter.

21.2.7 Unless investigated for such use, a bolted connection between two bus bars or between a bus bar and another current-carrying part shall not depend on the dimensional integrity of a thermoplastic material.

21.2.8 Insulation over bus bars such as tape or tubing as described in 23.2.2 and 23.2.4 shall not be provided over a bolted joint so that tightening of the joint can be accomplished without removal of the insulation.

21.2.9 The current density of a bus bar shall not be more than that indicated in Table 21.1 or 21.2.

Exception No. 1: A bus bar having characteristics that will not result in maximum bus bar temperatures exceeding the values specified in Table 45.1 may have a current density exceeding that of Tables 21.1 and 21.2.

Exception No. 2: A bus bar contained in a unit having forced air ventilation that will not result in maximum bus bar temperatures exceeding the values specified in Table 45.1 may have a current density exceeding that of Tables 21.1 and 21.2.

21.2.10 The cross section of a bus as covered in Table 21.1 or 21.2 may be reduced by not more than 5 percent due to rounding, shaping, or dimensional tolerances.

21.2.11 Part of the bus material may be removed for slots or holes (whether used or not) provided that:

a) The remaining material at any cross section along the length of the bus bar has at least 70 percent of the required ampacity in accordance with Table 21.1 or Table 21.2 and 21.2.10; and

b) The remaining metal in any 6-inch (152-mm) length of bus is at least 93 percent of the metal of a bus having the required ampacity in accordance with Table 21.1 or Table 21.2 and 21.2.10. For example, a 1-inch (25.4-mm) wide bus could have 9/32 inch (7.1 mm) holes on 1-inch centers or a 4-inch (102-mm) wide bus could have 13/32-inch (10.3-mm) wide slots 3.2 inches (81.3 mm) long every 6 inches.

Exception: The above limitations do not apply to a bus bar having characteristics that will not result in maximum bus for temperatures exceeding the values specified in Table 45.1 under the test conditions indicated in Section 45, Temperature Test.

21.2.12 The limitations on current density mentioned in Tables 21.1 and 21.2 do not apply to:

a) A connecting strap, bus, or the like comprising a part of a circuit breaker, switch, or fuseholder employed in the unit; and

b) A portion of a strap, bus, jumper, or the like adjacent and connected to a terminal of a switch, circuit breaker, or fuseholder, but not more than 1 inch (25.4 mm) from the terminal, if a reduced cross section in that portion is necessary because of the recessing of the terminal or because of barriers adjacent to it.

21.3 Live heat sinks

21.3.1 A current-carrying, aluminum heat sink shall be plated, conductive anodized, iridated or the equivalent at surfaces contacting the solid state component. This requirement does not apply to a live heat sink that is not used to conduct current.

Exception No. 1: A heat sink provided with a suitable oxide inhibiting compound over the heat sink surfaces contacting the solid state component. See 21.3.2.

Exception No. 2: A heat sink subjected to the heat cycling tests described in Section 66, Heat Sink Temperature Cycling Test.

21.3.2 The suitability of an oxide inhibiting compound referenced in Exception No. 1 to 21.3.1 is to be judged by tests indicating that:

a) The compound is stable at both elevated and low temperatures; and

b) The thermal conductivity of the heat sink/solid state component junction is not adversely affected by temperature cycling.

Table 21.1
Ampacity of single or multiple bus bars and clamped joints

Bus bar material[a]	Current	Current density in amperes per square inch (6.45 cm^2)	
		Bus bar cross section	Contact area at clamped joints
Copper	0 – 600 amperes	1000[c]	200
Copper	Over 600	1000[c]	200[d,e]
Aluminum[b]	Any	750[c]	200[d,e]

[a] Multiple bus bars in parallel shall be of the same material.
[b] Minimum conductivity of 55 percent of International Annealed-Copper Standard.
[c] See also Table 21.2 for 800 ampere maximum single bus bars.
[d] See 21.1.1, 21.2.10 – 21.2.12.
[e] Joints bolted and plated with silver, tin, nickel, or cadmium.

Table 21.2
Rating and sizes of single bus bars – 800 amperes maximum[a,d]

Current rating in amperes	Copper bus				Aluminum bus[c]			
	Bus size[b]		Cross section		Bus size[b]		Cross section	
	Inches	mm	In.^{2}	mm^2	Inches	mm	In.^{2}	mm^2
225	0.125 by 0.875	3.2 by 22.2	0.109	70.3	0.250 by 0.875	6.4 by 22.2	0.219	141.3
400	0.250 by 1.500	6.4 by 38.1	0.375	242.0	0.250 by 2.000	6.4 by 50.8	0.500	322.6
600	0.250 by 2.000	6.4 by 50.8	0.500	322.6	See Table 21.1	See Table 21.1	0.800	518.1
800	0.250 by 3.000	6.4 by 76.2	0.750	483.9	See Table 21.1	See Table 21.1	1.067	688.4

[a] See 21.2.10 – 21.2.12. For multiple buses in parallel, refer to Table 21.1. The minimum contact area at a clamped joint shall provide not less than 1 square inch (6.5 cm^2) per 200 amperes.

[b] A bus bar having other dimensions may also be acceptable if it has not less than the cross-sectional area specified in the table and if it has equivalent rigidity.

[c] Minimum conductivity of 55 percent of International Annealed-Copper Standard.

[d] Bolted joints and bus bars plated with silver, tin, nickel, or cadmium.

22 Electrical Connections

22.1 The requirements described in 22.2 – 22.7 apply to connections of internal wiring that are factory installed in the UPS.

22.2 A splice or connection shall be mechanically secure and shall make acceptable electrical contact.

22.3 A soldered connection is considered to be mechanically secure when the lead is:

a) Wrapped one full turn around a terminal;

b) Bent at a right angle after being passed through an eyelet or opening, except on printed-wiring boards where components are properly inserted or secured (as in a surface mounted component) and wave-or lap-soldered; or

c) Twisted with other conductors.

22.4 When stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire cannot contact other uninsulated conductive parts. This can be accomplished by use of pressure terminal connectors, soldering lugs, crimped eyelets, soldering of all strands together, or by any other equivalent means.

22.5 A nominal 0.110-inch (2.8 mm), 0.125-inch (3.2-mm), 0.187-inch (4.7-mm), 0.205-inch (5.2-mm), or 0.250-inch (6.4 mm) wide quick-connect terminal shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310. Other sizes of quick-connect terminals shall be investigated with respect to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rises; all tests shall be conducted in accordance with UL 310.

22.6 An open-end spade lug is not acceptable unless an additional means, such as upturned ends on the lug or bosses or shoulders on the terminal, is provided to hold the lug in place if the binding screw or nut loosens.

22.7 A splice shall be provided with insulation equivalent to that of the wires involved unless permanent spacings will be maintained between the splice and other metal parts. An acceptable insulation over the splice may consist of:

a) A splicing device such as a pressure wire connector may be employed if insulated acceptably for the voltage and temperature the device is to be subjected.

b) Insulating tubing or sleeving used to cover a splice shall be used in accordance with 23.2.2.

c) Two layers of thermoplastic tape, or two layers of friction tape, or one layer of friction tape and one layer of rubber tape, may be used on a splice if the voltage involved is less than 250 volts. Thermoplastic tape wrapped over a sharp edge is not acceptable.

Exception: A splicing device, insulating tubing, sleeving, or tape need not be used on splices within coil windings. See 26.2.1 – 26.2.3.

23 Spacings

23.1 General

23.1.1 The spacings for a UPS intended for use in a general environment shall not be less than the applicable values specified in Table 23.1. Spacings for a unit intended for use in a controlled environment (see 2.12 and 23.1.3) shall not be less than the applicable values specified in Table 23.2. For the purpose of this requirement, a general environment is considered to be an environment other than a controlled environment.

Exception No. 1: The spacing requirements of 23.1.1 shall be waived if the rotary UPS complies with 23.2.1 and if liners and barriers are used.

Exception No. 2: The spacing requirements of 23.1.1 shall not apply to the area between adjacent foils on printed-wiring boards provided with a conformal coating complying with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. See 23.1.2.

Exception No. 3: On printed-wiring boards having a flammability classification of V-0 in accordance with UL 94, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, and constructed from a base material having a minimum Comparative Tracking Index (CTI) rating of 100 and 175 volts (as determined by UL 746C, Polymeric Materials – Use in Electrical Equipment Evaluations) for controlled and general environments respectively, spacings (other than spacings to ground, between primary and secondary circuits, between the battery supply circuit and other circuits, and at field wiring terminals) are not specified between traces of different potential connected in the same circuit if:

a) The spacings are adequate to comply with the requirements in Section 61, Evaluation of Reduced Spacings or Printed-Wiring Boards; or

b) An analysis of the circuit indicates that no more than 12.5 milliamperes of current will flow between short-circuited traces having reduced spacings.

Exception No. 4: For multilayer-printed wiring boards, the minimum spacing between adjacent internal foils of opposite polarity and between an internal foil and a plated-through hole is 1/32 inch (0.79 mm). If these foils are in circuits described in 23.1.12 or 23.1.13, no spacing is specified.

Exception No. 5: The spacing requirements in Tables 23.1 and 23.2 may not apply to inherent spacings of a component such as a switch, lampholder, power switching semiconductor, or a motor. See 23.1.7.

Exception No. 6: Spacings within a transformer shall be provided in accordance with Table 26.2 at locations that are not insulated, including those with film-coated magnet wire.

Exception No. 7: Spacing requirements do not apply between adjacent terminals of a power switching semiconductor device including the connection points of the terminals of the device.

23.1.1 revised January 11, 1999

23.1.2 With reference to Exception No. 2 to 23.1.1 concerning conformal coatings, minimum spacings between adjacent foils are based on voltage transient and dielectric voltage-withstand tests in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluation, UL 746C. A conformal coating on printed wiring boards is not considered as insulation in lieu of spacings between a foil on a printed wiring board and uninsulated live metal parts of opposite polarity or to dead metal parts.

23.1.2.1 As an alternative to the spacing requirements of Table 23.1 or Table 23.2, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, may be used. If UL 840 is used, then the following considerations shall apply:

a) The spacing requirements of UL 840 shall not be used for field wiring terminals and spacings to a dead metal enclosure;

b) If a UPS employs a voltage limiting device for application of the requirements in UL 840, the device shall comply with the Standard for Transient Voltage Surge Suppressors, UL 1449; and

c) Permanently connected UPS shall be considered overvoltage category 3, and cord-connected UPS with surge suppressors shall be considered overvoltage category 2. An overvoltage category is the grouping of products based on a typical installed location with respect to overvoltage protection and available energy as defined in UL 840.

23.1.2.1 added February 1, 1996

23.1.3 Units investigated for use in a controlled environment indicated in 23.1.1 shall be marked as described in 72.1.29.

Exception: A unit employing a hermetically sealed enclosure, encapsulation, or conformal coating need not comply with this requirement.

23.1.4 For a unit intended for use in a controlled environment, a spacing between an uninsulated live part and a metal enclosure or other accessible dead metal part may be less than the value specified in the fourth column of Table 23.2 but not less than the values specified in the second and third columns of Table 23.2, if the unit enclosure complies with the Mechanical Strength Test for Metal Enclosures, Section 60.

23.1.5 If an uninsulated live part is not rigidly secured in position by means other than friction between surfaces or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that, for any position resulting from turning or other movement of the parts in question, at least the minimum required spacings will be maintained.

23.1.6 With reference to 23.1.5, a properly applied lock washer is considered as an acceptable method of rigidly securing a part.

23.1.7 Inherent spacings of the components mentioned in Exception No. 5 of 23.1.1 shall comply with the requirements for the component in question if the spacings are less than the values specified in this standard. Spacings from such components to another component and to the enclosure shall comply with the appropriate spacings specified in this standard.

23.1.8 With respect to judging spacings, an uninsulated live part is considered to be at opposite polarity to uninsulated live parts in another circuit. Spacings are to be based on the highest of the circuit voltages. See 47.2.1 – 47.2.3.

23.1.9 Film-coated wire is considered to be an uninsulated live part in judging spacings.

23.1.10 Spacings at field-wiring terminals are to be measured with conductors installed in the terminals. The gage of these conductors is to be based on the rating of the circuit containing the terminals. See 15.1.3.

23.1.11 Spacings between uninsulated live parts of different potential and between such parts and dead metal that may be grounded in service are not specified for parts of LVLE circuits in accordance with 2.22 nor in accessible signal circuits described in Section 25, Accessible Signal Circuits.

23.1.12 Spacings between uninsulated live parts of different potential and between such parts and dead metal that may be grounded in service are not specified for parts of limited-energy circuits in accordance with 2.19. Spacings in these circuits exceeding 30 volts rms (42.4 volts peak) or 60 volts dc are judged by the applicable dielectric voltage-withstand test described in Section 47, Dielectric Voltage-Withstand Test. Also see 50.1.

Table 23.1
Spacings for units intended for use in a general environment

Table 23.1 revised February 1, 1996

Potential involved, volts rms (peak)	Minimum spacings, inch (mm)		
	Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[a,f]		Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[b]
	Through air	Over surface	Shortest distance
0 – 50 (0 – 70.7)	1/16 (1.6)[c,d]	1/16 (1.6)[c,d]	1/16 (1.6)[c]
Greater than 50 to 150 (70.7 to 212.1)	1/8 (3.2)[c,d]	1/4 (6.4)[d]	1/4 (6.4)
Greater than 150 to 300 (212.1 to 424.2)	1/4 (6.4)	3/8 (9.5)	1/2 (12.7)
Greater than 300 to 600 (424.2 to 848.4)	3/8 (9.5)	1/2 (12.7)	1/2 (12.7)
Greater than 600 to 3000 (848.4 to 4242.0)	3/4 (19.1)[e]	3/4 (19.1)[e]	3/4 (19.1)

[a] For printed-wiring boards, see Exception Nos. 2 – 4 in 23.1.1.

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

[c] The spacing between field-wiring terminals of opposite polarity and the spacing between a field-wiring terminal and a grounded dead metal part shall not be less than 1/4 inch (6.4 mm).

[d] At closed-in points only, such as a screw and washer construction of an insulated stud mounted in metal, a spacing of 3/64 inch (1.2 mm) is acceptable.

[e] Between uninsulated high-voltage parts and the following:

1) Uninsulated high-voltage parts of opposite polarity or different potentials,

2) Earth-grounded metal parts,

3) Uninsulated primary-circuit parts,

4) Insulated primary-circuit parts,

5) Insulated high-voltage parts of opposite polarity, or of different potentials.

[f] Spacings are to be applied between uninsulated live parts of enclosure-mounted components and the metal mounting surface where deformation of the enclosure is not likely to reduce spacings between the live parts and the enclosure.

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Table 23.2
Spacings for units intended for use in a controlled environment

Table 23.2 revised January 11, 1999

Potential involved, volts rms (Peak)	Minimum Spacings, Inch (mm)		
	Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[a,d]		Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[b]
	Through air	Over surface	Shortest distance
0 – 50 (0 – 70.7)	3/64 (1.2)[c]	3/64 (1.2)[c]	1/16 (1.6)[c]
Greater than 50 to 150 (70.7 to 212.1)	1/16 (1.6)[c,e]	1/16 (1.6)[c,e]	1/4 (6.4)
Greater than 150 to 300 (212.1 to 424.2)	3/32 (2.4)[c,e]	3/32 (2.4)[c,d,e]	1/2 (12.7)
Greater than 300 to 600 (424.2 to 848.4)	3/8 (9.5)	1/2 (12.7)	1/2 (12.7)
Greater than 600 to 3000 (848.4 to 4242.0)	3/4 (19.1)[f]	3/4 (19.1)[f]	3/4 (19.1)[f]

[a] For printed-wiring boards, see Exception Nos. 2 – 4 in 23.1.1.

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

[c] The spacing between field-wiring terminals of opposite polarity and the spacing between a field-wiring terminal and a grounded dead metal part shall not be less than 1/4 inch (6.4 mm).

[d] On printed-wiring boards, their connectors and board-mounted electrical components, wired on the load side of line filters or similar-voltage-peak-reduction networks or components or both, a minimum spacing of 0.023 inch (0.58 mm) plus 0.0002 inch (0.005 mm) per volt peak shall be maintained over surface and through air between uninsulated live parts and any other uninsulated conductive part (live or dead) not of the same polarity.

[e] At closed-in points only, such as a screw and washer construction of an insulated stud mounted in metal, a spacing of 3/64 inch (1.2 mm) is acceptable.

[f] Between uninsulated high-voltage parts and the following:

1) Uninsulated high-voltage parts of opposite polarity or different potentials,

2) Earth-grounded metal parts,

3) Uninsulated primary-circuit parts,

4) Insulated primary-circuit parts,

5) Insulated high-voltage parts of opposite polarity, or of different potentials.

23.1.13 Spacings within the following circuits that are not safety circuits are not specified:

a) Secondary circuits supplied by a transformer winding of less than 200 volt-amperes or at a potential of 100 volts or less; and

b) Battery circuits at a potential of 100 volts or less. See 23.1.14.

The spacings in these circuits shall be judged on the basis of the Dielectric Voltage-Withstand Test, Section 47. (See 50.1).

23.1.14 With reference to 23.1.13, spacings within a circuit derived from a battery supply rated over 100 volts are not specified provided that the voltage within the circuit is limited to 100 volts or less by a regulating network complying with the requirement in 24.11.

23.1.15 The acceptability of spacings between live and dead metal parts connected to the enclosure within an instrument shall be judged by conducting the applicable dielectric voltage-withstand test described in Section 47, Dielectric Voltage-Withstand Test.

Exception: A meter complying with the requirements in the Standard for Electrical Analog Instruments – Panelboard Types, UL 1437 need not be subjected to a dielectric voltage-withstand test.

23.2 Insulation barriers

23.2.1 An insulating liner or barrier of material such as vulcanized fiber may be employed in lieu of required spacings mentioned in Exception No. 1 to 23.1.1 but not as the sole support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current provided that it is not less than 0.028 inch (0.71 mm) thick and it is so located that it will not be adversely affected by arcing. Other insulating materials used as a barrier or as either direct or indirect support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 1: Vulcanized fiber not less than 0.013 inch (0.33 mm) thick may be used:

a) In conjunction with an air spacing of not less than 50 percent of the minimum acceptable through air spacing; and

b) Between a heat sink and a metal mounting surface, including the enclosure, of an isolated secondary circuit rated 50 volts rms or less.

Exception No. 2: Mica not less than 0.006 inch (0.165 mm) may be used as insulation between a heat sink and a live case of a semiconductor device.

23.2.2 Other than as indicated in 23.2.3, insulating tubing complying with the requirements in the Standard for Extruded Insulating Tubing, UL 224 may be used as insulation of:

a) A conductor including bus bars in lieu of the minimum acceptable spacings; and

b) A capacitor case in lieu of bonding the case for grounding, providing that the following conditions are met:

1) The conductor is not subjected to compression, repeated flexure, or sharp bends;

2) The conductor or case covered with the tubing is well rounded and free from sharp edges;

3) The tubing is used in accordance with the manufacturer's instructions; and

4) The conductor or case is not subjected to a temperature or voltage higher than that for which the tubing is rated.

23.2.3 Insulating tubing complying with UL 224, the Standard for Extruded Insulating Tubing, shall not be used as insulation over a bolted joint of a bus bar as provided in 21.2.8.

23.2.4 A wrap of thermoplastic tape, complying with the requirements in the Standard for Insulating Tape, UL 510 may be used if all of the following conditions are met:

a) The wrap is no less than 0.013 inch (0.33 mm) thick, is applied in two or more layers, and is used in conjunction with no less than one-half the required through air spacing;

b) The wrap is no less than 0.028 inch (0.72 mm) thick when used in conjunction with less than one-half the required through air spacing;

c) Its temperature rating is no less than the maximum temperature observed during the Temperature Test of Section 45;

d) The tape is not subject to compression;

e) The tape is not wrapped over a sharp edge; and

f) The tape is not wrapped over a bolted bus bar joint (see 21.2.8).

24 Control Circuits

24.1 A LVLE circuit as described in 2.22 or a limited-energy circuit as described in 2.19 may be connected to a single-point reference ground.

24.2 Except as indicated in 24.3, a LVLE circuit (see 2.22) need not be investigated. Printed-wiring boards and insulated wire used in such circuits shall be types that are required for the application. See 20.1.1, 20.1.4, and 34.1.

24.3 Safety circuits shall be judged by the requirements for primary circuits.

24.4 A control circuit, including associated electronic components on printed-wiring boards, that does not extend out of the unit need not be investigated if the maximum voltage and current are limited as specified in (a) and (b):

a) The voltage limits specified in Table 8.1; and

b) 8 amperes for 0 – 42.4 volts peak ac, or 0 – 30 volts dc, or amperes equal to 150 divided by the maximum voltage for 30 – 60 volts dc. See 24.5.

Printed-wiring boards, insulated wires, and motors used in such circuits shall be types that are required for the application. See 20.1.1, 20.1.3, 30.1, 30.2, and 34.1.

Exception: The value of current specified in (b) may be exceeded if the circuit includes an overcurrent protection device as described in 24.8 and 24.9.

24.5 With reference to the current specified in 24.4(b), the maximum current is to be measured under any condition of loading including short circuit using a resistor that is to be continuously readjusted during the 1-minute period to maintain maximum load current, but not exceeding the value indicated in (b).

24.6 With reference to the voltage limit specified in 24.4(a), measurement is to be made with the unit connected to the voltage specified in 41.1 and with all loading circuits disconnected. If a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement is to be made from either end of the winding to the tap.

24.7 If the control circuit mentioned in 24.4 is not limited as to available short-circuit current by the construction of a transformer but the circuit includes either one or more resistors, a fuse, a nonadjustable manual-reset protective device, or a regulating network (see 24.11) the circuits in which the current is limited in accordance with 24.8, 24.9, or 24.10 need not be investigated.

24.8 A fuse or circuit-protective device provided in the control circuit used to limit the current in accordance with 24.7 shall be rated or set at not more than the values specified in Table 24.1.

24.9 A fuse or circuit protective device may be connected in the primary of a transformer to limit the current in accordance with 24.7 provided that the protection is equivalent to that specified in 24.8 as determined by conducting the Overcurrent Protection Calibration Test, Section 56.

24.10 One or more resistors or a regulating network used to limit the current in accordance with 24.7 shall be such that the current under any condition of load including short circuit does not exceed the values indicated in 24.4(b).

24.11 If a regulating network is used to limit the voltage or current in accordance with 24.4 – 24.10, and the performance may be affected by malfunction, either short circuit or open circuit, of any single component – excluding a resistor – the network shall comply with the following:

a) The environmental tests mentioned in 29.6; and

b) Critical components shall be derated in accordance with 29.8.

24.12 In a circuit of the type described in 24.7, the secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited shall be judged under the applicable requirements in this standard.

Table 24.1
Rating for secondary fuse or circuit protector

Circuit voltage (volts, rms)	Maximum overcurrent protection (amperes)
20 or less	5
More than 20 but not greater than 60	100/V[a]

[a] V is the maximum output voltage, regardless of load, with the primary energized in accordance with 41.1.

25 Accessible Signal Circuits

25.1 The requirements in 25.2 and 25.3 apply to accessible signal circuits having provision for external connections such as RS232 communication ports and the like.

25.2 A signal circuit that extends out of a unit shall be isolated from internal circuits having a voltage considered to involve a risk of electric shock (as determined in accordance with Electric Shock, Section 8) by any of the following or the equivalent:

a) An optical isolator having an isolation voltage rating of not less than the dielectric voltage-withstand test potential required in 47.3.1 and complying with the requirements in the Standard for Optical Isolators, UL 1577;

b) An isolation transformer complying with the requirements in the Standard for Class 2 and Class 3 Transformers, UL 1585;

c) An isolation transformer complying with the requirements in 26.1.3 – 26.2.4;

d) An electro-mechanical relay complying with the requirements in the Standard for Industrial Control Equipment, UL 508; or

e) A voltage regulating network is acceptable if:

1) The voltage being isolated is not derived from the a-c input circuit; and

2) The network does not show a risk of electric shock at the external signal circuits (as determined in accordance with Electrical Shock, Section 8) as a result of a failure mode and effect analysis in accordance with the method described in the Standard for Tests for Safety Related Controls Employing Solid-State Devices, UL 991.

25.3 The maximum voltage and current available from an accessible signal circuit shall comply with the requirements in 24.4 – 24.11.

25.4 The maximum power available from an accessible signal circuit that employs an overcurrent protection device to limit the current as described in the Exception to 24.4 shall not exceed the values specified in Table 25.1.

Table 25.1
Maximum power of accessible signal circuits

Circuit voltage volts, rms	Maximum power, volt-amperes
15 or less	350
More than 15 but not greater than 60	250

26 Transformers

26.1 General

26.1.1 A transformer coil, unless inherently moisture resistant, shall be treated with an insulating varnish and baked, or otherwise impregnated to exclude moisture or acid vapor. Film-coated magnet wire is considered moisture resistant.

26.1.2 A thermal cutoff or other device employed to reduce the risk of fire or electric shock due to overheating of a transformer during abnormal operation shall comply with the requirements applicable to such a device in addition to the applicable requirements in this standard. For example, a thermal cutoff shall comply with the applicable requirements in this standard and those in the Standard for Thermal Cutoffs for Use in Electrical Appliances and Components, UL 1020.

26.1.3 A transformer used where isolation is required in accordance with 38.7.1, or to supply an accessible signal circuit as described in Section 25 shall have its primary winding electrically isolated from its secondary winding and shall be constructed as specified in 26.2.1 – 26.2.4 so that there is no electrical connection – under normal and overload conditions – between the primary and secondary windings, between the primary winding and the core, or between separate adjacent secondary windings, if such connection may result in a risk of fire or electric shock.

26.1.4 With reference to the requirement in 26.1.3, a transformer complying with the requirements in either of the following standards is considered to comply with this requirement:

a) Class 2 and Class 3 Transformers, UL 1585.

b) Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411.

26.2 Coil insulation

26.2.1 A transformer winding including the start, all taps, finish, and crossover leads up to the point where insulated leads are provided shall be constructed, if used, as specified in Table 26.1.

26.2.2 Insulating material, such as outer-wrap and crossover-lead insulation, employed to reduce the risk of live parts from becoming accessible through openings in the outer enclosure in accordance with Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 7, shall comply with note A or C of Table 26.1.

Table 26.1
Transformer insulation

Insulation required		Type of insulation
1.	Insulation between the primary wires of opposite polarity and between secondary wires of opposite polarity having a potential greater than 30 volts, rms (42.4 volts peak)	a, b, c, or d
2.	Insulation between the primary and any secondary winding	a, b, c, or d
3.	Insulation between any winding or lead connections and dead metal parts	b, c, d, e, f, or g
4.	Insulation between the crossover leads and (1) the turns of a different winding, (2) the metal enclosure of a unit, or (3) the core	a, d, e, g, or h

a) Electrical grade paper that is waxed or otherwise treated to retard the absorption of moisture and that has a total thickness of not less than 0.028 inch (0.71 mm); polyethylene terephthalate film, not less than 0.007 inch (0.178 mm) thick; or aramid paper, not less than 0.0085 inch (0.203 mm) thick.

b) A thermoplastic or thermoset coil form not less than 0.028 inch thick.

c) A material having a thickness less than 0.028 inch may be used provided that it is equivalent to note A or B and the material has a minimum dielectric breakdown strength of 5000 volts for the thickness used as determined by the test described in Section 69, Tests on Transformer Insulating Materials.

d) Spacings specified in either Table 23.2, if applicable, or Table 26.2 may be used in place of the specified insulation.

e) Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.013 inch (0.33 mm) if used in conjunction with an air spacing of one-half that specified in note D.

f) Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.028 inch if the insulation is in contact with the enclosure.

g) A material having a thickness less than that specified in notes E and F may be used, provided that it is equivalent to notes E and F and the material has a minimum dielectric breakdown strength of 2500 volts for the thickness used for note E and 5000 volts for the thickness used for note F as determined by the test described in Section 69.

h) Any type and thickness of insulation in addition to the magnet wire coating, or a through air spacing less than that specified in Table 26.2 may be used between a crossover lead and the winding to which it is connected if the construction complies with either of the following:

1) The coil withstands the appropriate dielectric withstand potential described in 47.3.1 and 47.3.2. The potential is to be applied between the coil leads with the crossover lead cut at the point where it enters the inner layer.

2) The coil withstands the induced potential described in 47.5.2 and 47.5.5.

Table 26.2
Spacings within a transformer[b]

Minimum spacing through air and over surface, inch (mm)	
Potential involved, volts	**Between any uninsulated live part and an uninsulated live part of opposite polarity, or the core[a]**
0 – 50	3/64 (1.2)
Greater than 50 to 125	1/16 (1.6)
Greater than 125 to 250	3/32 (2.4)
Greater than 250 to 600	1/4 (6.4)

[a] Includes turns of a coil having a magnet wire coating.
[b] This table applies only to transformers that are treated with an insulating varnish and baked or otherwise impregnated.

26.2.3 A flanged bobbin-wound transformer shall be constructed so as to maintain physical separation between the primary and secondary windings. Physical separation may be accomplished by employing a 3-flange bobbin for winding the primary and secondary windings adjacent to each other. As an alternative, a telescoping bobbin construction, with each section containing an individual winding, may be used where the primary winding is wound over the secondary winding or the secondary winding over the primary winding. The bobbin insulation shall comply with note A, B, C, or D of Table 26.1.

Exception No. 1: A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation is acceptable if:

a) The tape insulation complies with note A or C of Table 26.1;

b) The tape insulation provides a continuous overlap on the bobbin flanges;

c) The transformer complies with the tests described in the Flanged Bobbin Transformer Abnormal Test, Section 53 (see 26.2.4); and

d) The transformer complies with the induced potential tests described in 47.5.1 – 47.5.5.

Exception No. 2: A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation is acceptable if:

a) The tape insulation complies with note A or C of Table 26.1;

b) The coils are layer wound; and

c) All windings have end turns that are retained by a positive means and the spacing between end margins of the primary and secondary windings comply with Table 26.1(d).

Exception No. 3: A transformer complying with the requirements in either the Standard for Class 2 and Class 3 Transformers, UL 1585, or the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television Type Appliances, UL 1441 is considered to comply with this requirement.

26.2.3 effective December 6, 1994

26.2.4 With reference to (c) in Exception No. 1 to 26.2.3, the Flanged Bobbin Transformer Test, Section 53, is not required if the transformer:

a) Is supplied from a LVLE circuit in accordance with 2.22, or a limited energy circuit in accordance with 2.21; or

b) Complies with the requirements in 24.4 – 24.12.

27 Separation of Circuits

27.1 Factory wiring

27.1.1 Insulated conductors of different circuits (see 27.1.2) within a UPS, including wires in a terminal box or compartment, shall be either separated by barriers or segregated and shall be so separated or segregated from uninsulated live parts connected to different circuits.

Exception: For insulated conductors of different circuits, if each conductor is provided with insulation acceptable for the highest of the circuit voltages, no barriers or segregation are necessary.

27.1.2 For the purpose of the requirement in 27.1.1, different circuits include:

a) Circuits connected to the primary and secondary windings of an isolation transformer;

b) Circuits connected to different isolated secondary windings of a multi-secondary transformer;

c) Circuits connected to secondary windings of different transformers;

d) Input and output circuits of an optical isolator;

e) AC input power and output AC power circuits;

f) AC input power and DC power circuits; and

g) AC output power and DC power circuits.

Exception: Power circuits specified in (e), (f), and (g) that are derived from the taps of an autotransformer or the like which do not provide isolation are not considered to be different circuits.

27.1.3 Segregation of insulated conductors may be accomplished by clamping, routing, or an equivalent means that will maintain permanent separation from insulated and uninsulated live parts and from conductors of a different circuit.

27.2 Separation barriers

27.2.1 A barrier used to provide separation between the wiring of different circuits shall be:

a) Grounded metal or insulating material complying with the requirements for flammability classification of internal materials specified in Section 36, Flammability Classification of Internal Materials, and no less than 0.028 inch (0.71 mm) thick; and

b) Supported so that it cannot be readily deformed so as to defeat its purpose.

27.2.2 A barrier used to provide separation between field wiring of one circuit and field or factory wiring or uninsulated live parts of another circuit shall be spaced no more than 1/16 inch (1.6 mm) from the enclosure walls and interior mechanisms, component-mounted panels, and other parts that serve to provide separated compartments.

27.3 Field wiring

27.3.1 The equipment shall be constructed so that a field-installed conductor of a circuit shall be separated as specified in 27.3.2 or separated by barriers as specified in 27.2.1 and 27.2.2 from:

a) Factory-installed conductors connected to any other circuit, unless the conductors of both circuits will be insulated for the maximum voltage of either circuit.

b) An uninsulated live part of another circuit and from an uninsulated live part if short circuit with it could result in a risk of fire, electric shock, electrical energy involving high current levels, or injury to persons.

c) Field-installed conductors connected to any other circuit unless:

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

2) Both circuits will be insulated for the maximum voltage of either circuit.

Exception: A field-installed conductor need not be separated from a field wiring terminal of a different circuit if the field wiring will be insulated for the maximum voltage of either circuit and both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3.

27.3.2 Separation of a field-installed conductor from another field-installed conductor and from an uninsulated live part connected to another circuit can be accomplished by locating an opening in the enclosure for the conductor opposite to the conductor terminal so that, when the installation is complete, the conductors and parts of different circuits are separated by a minimum of 1/4 inch (6.4 mm). In determining whether a UPS having such openings complies with this requirement, it is to be wired as in service including 6 inches (152.4 mm) of slack in each conductor within the enclosure. No more than average care is to be exercised in routing the wiring and stowing the conductor slack into the wiring compartment.

27.3.3 With reference to 27.3.2, if the number of openings in the enclosure does not exceed the minimum required for the proper wiring of the UPS, and if each opening is located opposite a set of terminals, it is to be assumed that a conductor entering an opening will be connected to the terminal opposite that opening. If more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than the one opposite the terminal to which it is intended to be connected and the likelihood of it contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit is to be investigated.

28 Overcurrent Protection

28.1 General

28.1.1 An overcurrent protective device, the intended functioning of which requires renewal, replacement, or resetting, shall be accessible:

a) From outside of the enclosure; or

b) Behind a hinged cover (see 5.3.1).

Exception: A protective device that would ordinarily be unknown to the user because of its location and omission of reference to the device in the operating instructions provided with the unit need not be accessible.

28.1.2 With reference to the requirement in 28.1.1, a control-circuit fuse is not considered to require renewal as an intended function provided the fuse and the load are contained within the same enclosure.

28.1.3 The screw shell of a plug-type fuseholder and the contacts including associated live parts that can be contacted by the probe illustrated in Figure 7.1 of an extractor-type fuseholder shall be connected toward the load.

Exception: The screwshell shall not be connected toward the load if the screwshell is in accordance with (c) of Exception No. 2 to 28.1.8.

28.1.4 A fuse and a fuseholder shall have voltage and current ratings acceptable for the circuit in which they are connected. A fuseholder shall be of the cartridge, plug, or extractor type. Plug fuses are not acceptable in a circuit rated more than 125 volts or 125/250 volts, 3-wire.

Exception: Fuses intended to be replaced by only service personnel (see Section 39, Protection of Service Personnel) may be bolted in place.

28.1.5 A plug-type fuseholder shall be of the Type S construction.

28.1.6 A circuit breaker or supplementary protector shall be connected to open all ungrounded conductors of the circuit. Multipole circuit breakers and supplementary protectors shall be the common trip type.

Exception: Single-pole circuit breakers and supplementary protectors with handle ties, the combination of which complies with the applicable requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489, and the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077 respectively, may be used as the protection for each ungrounded conductor supplying line-to-line connected loads of equipment rated for connection to a grounded:

a) Single-phase circuit;

b) 3-wire direct-current circuit; or

c) Circuit that is connected to a 4-wire 3-phase, or 5-wire 2-phase system with a grounded neutral.

28.1.6 revised January 5, 2000

28.1.7 A UPS shall be marked in accordance with 72.2.12 if it is provided with overcurrent protection consisting of an interchangeable fuse and if the fuse is:

a) Accessible to the user; or

b) Used to comply with the requirements in this standard.

28.1.8 An overcurrent protective device shall not be connected in the grounded (neutral) side of the line.

Exception No. 1: Additional overcurrent protection may be provided in the grounded side of the supply circuit provided that the protective device simultaneously disconnects the grounded and ungrounded conductors of the supply circuit.

Exception No. 2: A unit may incorporate a single-pole overcurrent protective device connected in the grounded (neutral) side of the line provided:

a) The grounded circuit conductor is not depended upon to carry a current imbalance such as is likely in a UPS supplied by a 3-phase, 4-wire or a single-phase, 3-wire system;

b) Each ungrounded circuit conductor is provided with an overcurrent protective device having a current rating no higher than that of the overcurrent protective device in the grounded circuit conductor;

c) The screw shell of a plug fuseholder and the accessible contact of an extractor fuseholder located in the grounded circuit conductor is connected toward the grounded supply line; and

d) The unit is marked in accordance with 72.2.19.

28.1.9 Temperature or current-sensitive devices such as temperature limiting thermostats, thermal cutoffs, appliance protectors, fuses, circuit breakers, or the like that are relied upon to comply with the Abnormal Tests, Section 52, shall comply with the requirements for such devices.

28.1.10 Overcurrent protection employing solid state component circuitry used for protection of circuits described in (a) – (c) shall comply with the requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489.

a) Control circuits per 28.2.1 – 28.2.7.

b) Output alternating current power circuits per 28.3.1 – 28.3.5.

c) Battery supply circuits for fixed units per entries 3 and 4 in Table 28.2.

Exception No. 1: Overcurrent protection whose performance is not affected by malfunction, either by short circuit or open circuit, of any single component need not comply with these requirements.

Exception No. 2: A solid state overcurrent protection circuit provided in addition to other overcurrent protection devices such as a fuse or circuit breaker that is suitable for the application need not comply with these requirements.

28.1.10 revised January 5, 2000

28.2 Control circuits

28.2.1 A control circuit that extends from the UPS to a remote control panel, status panel, or the like shall be protected in accordance with 28.2.2 – 28.3.5 to reduce the risk of fire and electric shock that may result from overload and short circuit conditions.

28.2.2 The overcurrent protective device specified in 28.2.1 shall be a circuit breaker or fuse that is either:

a) Acceptable for branch circuit use; or

b) A supplementary type.

If the protective device consists of a fuse, the UPS shall be marked in accordance with 72.2.12.

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28.2.3 A Class 1 power-limited circuit, in accordance with the National Electrical Code, ANSI/NFPA 70-1993, used to supply an external control circuit shall be supplied from a source having a rated output of no more than 30 volts and 1000 volt-amperes. If the source is other than a transformer, the circuit shall be protected by an overcurrent protection device rated no more than 167 percent of the volt-ampere rating divided by the rated voltage. The overcurrent device shall not be interchangeable with overcurrent devices of higher ratings.

28.2.4 An external control circuit derived from a Class 2 transformer described in 2.10 need not be provided with overcurrent protection specified in 28.2.1.

28.2.5 An external control circuit derived from the secondary of a transformer other than that described in 28.2.3 and 28.2.4 shall be provided with overcurrent protection in accordance with 28.2.6 and 28.2.7. For transformers not having a rating, the rated primary or secondary current mentioned in 28.2.6 and 28.2.7 is to consist of the maximum current during normal operation of the unit.

28.2.6 Except as described in 28.2.7, a transformer used to supply a control circuit shall be provided with overcurrent protection in the primary circuit rated as indicated in Table 28.1.

Exception: If the rated primary current of the transformer is 9 amperes or more and 125 percent of this current does not correspond to a standard rating of fuse or circuit breaker, the next higher standard rating of protective device may be used. Standard ratings of protective devices are specified in Section 240-6 of the National Electrical Code, ANSI/NFPA 70-1993.

Table 28.1
Primary overcurrent protection for control circuit transformers

Rated primary current, amperes	Maximum rating of overcurrent device, percent of transformer primary current rating
Less than 2	300
2 or more, less than 9	167
9 or more	125

28.2.7 If a control circuit is derived from the secondary of a transformer that is provided with primary circuit overcurrent protection rated at no more than 250 percent of the rated primary current of the transformer, additional overcurrent protection is not required in the primary circuit provided that the secondary circuit is protected at no more than 125 percent of the rated secondary current of the transformer.

Exception No. 1: If the rated secondary current of the transformer is 9 amperes or more and 125 percent of this current does not correspond to a standard rating of fuse or circuit breaker, the next higher standard rating of protective device may be used in the secondary circuit. Standard ratings of protective devices are specified in Section 240-6 of the National Electrical Code, ANSI/NFPA 70-1993.

Exception No. 2: If the rated secondary current of the transformer is less than 9 amperes, the overcurrent protection in the secondary circuit may be rated or set at no more than 167 percent of the rated secondary current.

28.3 Output alternating current power circuits

28.3.1 An alternating current output power circuit shall be provided with overcurrent protection for all ungrounded conductors as described in 28.3.3 – 28.3.5. The voltage rating of the overcurrent protection shall not be less than the rating of the circuit with which it is used. The overcurrent protection device shall be a circuit breaker or a fuse acceptable for use as branch circuit protection.

Exception No. 1: Overcurrent protection need not be provided with a UPS having provision for permanent wiring connection of the output circuit and provided with an instruction manual indicating that the overcurrent protection is to be provided by others. See 74.1.2(t).

Exception No. 2: Overcurrent protection need not be provided with a UPS whose output current is limited by construction of the transformer, one or more resistors, or a regulating network complying with 24.11 to not more than 110 percent of the:

a) Rated output current; or

b) The output receptacle rating.

Exception No. 3: An appliance protector having a short circuit interrupting rating not less than the maximum fault current available from the UPS and complying with the requirements in the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077, may be used in the output circuit of a UPS supplied by the power conversion portion of a UPS in lieu of a branch circuit protection fuse or circuit breaker.

Exception No. 4: A fuse having a short-circuit interrupting rating not less than the maximum fault current available from the UPS and complying with the requirements in the Standard for Fuses for Supplementary Overcurrent Protection, UL 198G, may be used in the output circuit of a UPS supplied by the power conversion portion of a UPS in lieu of a branch circuit protection fuse or circuit breaker.

Exception No. 5: For cord-connected units, output overcurrent protection may be the branch circuit protection intended for the input circuit if the attachment plug and the output receptacle have identical ratings. If the attachment plug and the output receptacle do not have identical ratings, then branch circuit protection shall be required for the output.

28.3.1 revised February 1, 1996

28.3.2 The voltage rating mentioned in 28.3.1 for a 3-phase circuit shall be based on the phase-to-phase voltage.

28.3.3 For a UPS having provision for permanent wiring connection of the alternating current output power circuit, the rating of the overcurrent protection shall not exceed the ampacity of the conductors intended to be connected to the UPS as determined in accordance with 15.1.3.

28.3.4 For a UPS provided with a cord and receptacle for connection of the alternating current output power circuit, the rating of the overcurrent protection shall not exceed the ampacity of the conductors as determined from Table 400-5 in the National Electrical Code, ANSI/NFPA 70-1993.

28.3.5 If a UPS includes one or more attachment-plug receptacles for connections to the ac output circuit, overcurrent protection shall be provided for each receptacle. A single overcurrent protection device whose rating does not exceed the ampere rating of any receptacle connected to it may be used if all receptacles are connected in parallel.

Exception No. 1: Two or more 15 ampere rated receptacles may be protected by a 20 ampere overcurrent protection device.

Exception No. 2: A stationary unit having an input ac attachment plug that has both a current and voltage rating not exceeding the current and voltage rating of any of the output ac receptacles need not be provided with overcurrent protection.

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Exception No. 3: A unit having provisions for permanent input wiring connections need not be provided with overcurrent protection provided that the current and voltage ratings of the output a-c receptacles are not less than the current and voltage ratings of the intended input branch circuit overcurrent protection device. See 52.1.6.

28.4 Battery supply circuits

28.4.1 A battery supply circuit shall be provided with overcurrent protection complying with the requirements described in 28.4.2 – 28.4.4.

28.4.2 The battery supply circuit shall be provided with acceptable rated dc overcurrent protection to reduce the risk of fire and electric shock resulting from overload or short-circuit conditions. The protective device shall be located adjacent to the battery connecting means before any component which may fail short-circuited such as capacitors, solid-state devices, or the like.

28.4.3 The type and location of the overcurrent protective device shall be as indicated in Table 28.2.

Table 28.2
Battery supply overcurrent protection

Location and/or type of battery supply		Overcurrent protective device	
		Type	Location
1.	Within UPS	Note 1 or 2	UPS
2.	Stationary remote cabinet	Note 1 or 2	Battery cabinet, see note 3
3.	Fixed remote cabinet	Note 2	Battery cabinet, see note 3
4.	Remote battery room	Notes 2 and 4	UPS, see note 5

NOTES

1 Supplementary appliance type.

2 Circuit breaker or fuse suitable for branch circuit protection.

3 A battery supply cabinet assembly investigated by itself shall contain the indicated overcurrent protective device. For a UPS investigated in combination with the battery supply intended for use with the UPS, the overcurrent protection is required only in the battery supply cabinet. For a UPS investigated without the battery supply cabinet assembly, the UPS shall also employ the indicated overcurrent protective device.

4 In accordance with 74.1.2(m), the instruction manual for a UPS having an input ac rating of 5 kilovolt-amperes or larger shall indicate the rating of the overcurrent protective device.

5 Overcurrent protection need not be provided if the instruction manual contains the statement indicated in 74.1.2(s).

28.4.4 The rating of the overcurrent protective device employed in a UPS having an integral battery supply shall be such as to protect against conditions described in 52.1.3(a) – (d). For a fixed UPS that is to be used with a fixed remote battery supply, the rating of the overcurrent protective device shall be based on the ampacity of the conductors intended to be connected between the UPS and battery supply as determined from the requirement described in 15.1.3 under reserve mode operating conditions – see 44.1(b).

28.5 Inverter storage capacitors

28.5.1 A UPS shall be protected against a surge current flowing into the discharged main storage inverter capacitors that may be caused by inadvertent closing of a manually operated battery disconnect switch when the UPS is not operating. Compliance with this requirement is to be judged by conducting the test described in 52.7.1. A UPS having a disconnect switch or a control circuit preventing closure of the disconnect switch under the above conditions need not be subjected to the test.

29 Backfeed Protection

29.1 A UPS shall be provided with backfeed protection to prevent a potential involving a risk of electric shock (see Electric Shock, Section 8) from being present on its input ac terminals during interruption of the input ac power.

29.2 With reference to the requirement in 29.1, performance of the protection is to be judged by conducting the Backfeed Protection Test, Section 48.

29.3 The protection mentioned in 29.1 shall employ an automatic switching device having air-gap contacts such as an electromechanical relay for preventing a potential involving a risk of electric shock from appearing on the input terminals. A unit provided with a remote shunt-trip circuit breaker, which will open the input ac circuit when the input ac power is interrupted, complies with this requirement. If the remote shunt-trip circuit breaker is not provided with the unit, then a marking as described in 72.1.33 shall be provided.

Exception: An electronic control employing a solid state power switching component and subjected to the tests described in 29.6 may be provided in lieu of an air-gap contact device.

29.3 revised February 1, 1996

29.3.1 The backfeed protection for a stationary UPS, with an output that is not a separately derived system, shall:

a) Open or de-energize all supply conductors; or

b) Make the blades of the supply cord inaccessible when the supply cord is removed from the receptacle.

Exception: This requirement does not apply to a stationary UPS provided with a single output receptacle.

Added 29.3.1 effective November 17, 2000

29.4 With reference to 29.3, the conditions described in either (a) or (b) resulting from a short-circuit failure of a solid-state component during the normal mode of operation (see 44.1) that is used for isolation between the input-ac terminals and the inverter is considered to comply with the requirement in 29.3.

a) Operation of an input-ac, overcurrent-protective device; or

b) Shut-down of the inverter.

29.4 revised February 1, 1996

29.5 The control circuit for the backfeed protection mentioned in 29.3 is to be subjected to a failure mode and effect analysis in accordance with the method described in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. This analysis is to cover all modes of operation except for the reserve mode (see 44.1). If this analysis indicates that either opening or shorting of a component such as a transistor, triac, SCR, capacitor, resistor or the like will cause a potential involving a risk of electric shock to appear on the input ac terminals during the test conditions described in Section 48, Backfeed Protection Test, the environmental tests specified in 29.6 shall be conducted.

29.6 If it is determined that environmental tests in accordance with the Exception to 29.3 or with 29.5 are necessary, the protection control is to be subjected to the following tests in accordance with the method described in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991:

a) Transient Overvoltage Test

b) Ramp Voltage Test

c) Electromagnetically Susceptibility Tests

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d) Electrostatic Discharge Test

e) Thermal Cycling Test

f) Humidity Test for a UPS intended for a general environment

g) Effects of Shipping and Storage Test

Before and after each test, the control is to be checked for normal operation by conducting the Backfeed Protection Test, Section 48. See 29.7 and 29.8.

29.7 The following test parameters are to be used in the investigation of the control covered by 29.6 for compliance with the Standard for Tests for Safety-Related Controls Employing Solid State Devices, UL 991:

a) Electrical supervision of critical components is permitted;

b) Audibility is an acceptable trouble indicator for an electrical supervision circuit;

c) A field strength of 3 volts per meter (0.91 volts per foot) is to be used for the Radiated EMI Test; and

d) Exposure Class H5 is to be used for the Humidity Test.

29.8 Critical components identified by the failure mode and effect analysis mentioned in 29.5 shall be derated in accordance with the Electronic Reliability Design Handbook, Military Handbook Number 338-1A, 1988.

30 Motors

30.1 Each motor shall be protected from overheating due to any condition of load up to and including stalled rotor.

Exception No. 1: A motor used for air-handling only by means of a fan or blower attached directly to the shaft need be protected only against locked-rotor conditions.

Exception No. 2: A shaded-pole motor having a difference of 1 ampere or less between no-load and locked-rotor currents and having a 2 to 1 or smaller ratio between locked-rotor and no-load currents need be protected only against locked-rotor conditions.

Exception No. 3: A motor connected to a LVLE circuit as described in 2.22 need not be protected.

30.2 The protection required by 30.1 shall be accomplished by:

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

b) Impedance protection complying with requirements in UL 2111, the Standard for Overheating Protection for Motors; or

c) Other protection that tests show is equivalent to the protection specified in (a) or (b).

31 Capacitors

31.1 The materials and construction of a capacitor, its case, or both shall be such that emission of flame from the enclosure of the UPS during malfunction of the capacitor cannot occur. See 31.3.

31.2 The materials and construction of a capacitor or its case within a UPS shall be such that pressures capable of causing injury to persons cannot develop in the capacitor in the event of malfunction of the capacitor or the circuit in which it is connected. See 31.3.

31.3 Compliance with the requirements described in 31.1 and 31.2 shall be determined by the abnormal tests specified in 52.7.1 and 52.10.1 – 52.11.2.

31.4 Under both normal and abnormal conditions of use, including internal shorting of the capacitor, a capacitor containing oil that is more combustible than askarel shall not result in a risk of fire or electric shock and shall be constructed to reduce the risk of expelling dielectric medium from the enclosure of the UPS. See 31.5 and 31.6.

31.5 With reference to the requirement in 31.4, a capacitor complying with the requirements for protected oil-filled capacitors in the Standard for Capacitors, UL 810, is considered to be constructed to reduce the risk of expelling the dielectric medium.

31.6 With reference to 31.4, a unit having a capacitor other than that described in 31.5 shall be provided with a complete noncombustible bottom panel below the capacitor.

Exception No. 1: A ventilated, bottom-panel construction complying with either Exception No. 2 or 3 to 5.10.1 need not comply with this requirement.

Exception No. 2: A ventilated, bottom-panel construction complying with the capacitor fault test described in 52.8.1.

31.7 A means such as a bleeder resistor shall be provided to drain the charge stored in a capacitor so that it does not provide a risk of electric shock or a risk of electrical energy – high current level. A risk of shock is considered to exist if the voltage across the capacitor exceeds the limits specified in 8.2.1. A risk of electrical energy – high current level – is considered to exist if the stored energy exceeds 20 joules as determined by the following equation:

$$J = 5 \times 10^{-7} CV^2$$

in which:

C is in microfarads; and

V is in volts.

Exception No. 1: The requirement does not apply if a tool is necessary to remove a panel to reach the capacitor and the UPS is marked as specified in 72.2.13.

Exception No. 2: The requirement does not apply if the unit is marked in accordance with 72.2.14.

Exception No. 3: The requirement does not apply if:

a) The capacitor terminals and all parts connected to these terminals are insulated to reduce the likelihood of contact of these terminals and parts by the serviceman; and

b) A cautionary marking per 72.2.24 is provided.

31.8 Capacitors connected across an input ac circuit shall comply with the requirements for across-the-line capacitors in the:

a) Standard for Across-the-Line, Antenna-Coupling, and Line-By-Pass Capacitors for Radio- and Television-Type Appliances, UL 1414; or

b) Standard for Electromagnetic-Interference Filters, UL 1283.

Exception: A capacitor subjected to a dielectric voltage-withstand test in accordance with Test No. 5 itemized in Table 47.1 need not comply with this requirement.

32 Resistors

32.1 The assembly of a power resistor, such as a wire-wound type requiring a separate support, shall be reliable. The resistor shall be prevented from loosening or rotating by a means other than friction between surfaces.

32.2 An assembly employing lock washers is considered to comply with the requirement in 32.1.

33 Lampholders

33.1 A lampholder shall be constructed or installed so that uninsulated live parts, other than a screw shell, may not be unintentionally contacted by persons removing or replacing the lamp during intended service.

33.2 A medium-base screw-shell lampholder shall not be used in a circuit involving a potential of more than 150 volts.

34 Printed-Wiring Boards

34.1 A printed-wiring board shall comply with the requirements in the Standard for Printed-Wiring Boards, UL 796, and shall be classed V-0, V-1, or V-2 in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: A printed-wiring board located outside an enclosure, such as in an external control circuit, and located in a LVLE circuit or a limited-energy circuit described in 2.22 need not be classed as minimum V-2.

34.1 revised January 11, 1999

34.2 A resistor, capacitor, inductor, or other part that is mounted on a printed-wiring board to form a printed-wiring assembly shall be secured so that it cannot be displaced to cause a risk of electric shock or fire by a force likely to be exerted on it during assembly, intended operation, or servicing of the power supply.

34.3 Consideration is to be given to a barrier or a partition that is part of the unit assembly and that provides mechanical protection and electrical insulation of a component connected to the printed-wiring board.

35 Insulating Materials

35.1 An insulating material used for supporting live parts and a barrier material shall be moisture-resistant and not be adversely affected by the temperature and stresses to which it will be subjected under conditions of use.

35.2 A material that is used for the direct support of an uninsulated live part shall comply with the Relative Thermal Index (RTI), Hot Wire Ignition (HWI), High-Current Arc Resistance to Ignition (HAI), and Comparative Tracking Index (CTI) values indicated in Table 35.1 and determined in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. A material is considered to be in direct support of an uninsulated live part if:

a) It is in direct physical contact with the uninsulated live part; and

b) It serves to physically support/maintain the relative position of the uninsulated live part.

Exception No. 1: A generic material complying with the thickness and RTI in Table 35.2 is considered suitable for the direct support of uninsulated live parts without additional evaluation.

Exception No. 2: A material without HWI Performance Level Category (PLC) value or with HWI PLC value higher (worse) than the HWI required by Table 35.1 may alternatively be subjected to the End-Product Abnormal Overload Test per UL 746C.

Exception No. 3: A material without HAI PLC value or with HAI PLC value higher (worse) than the HAI required by Table 35.1 may alternatively be subjected to the End-Product Arc Resistance Test per UL 746C.

Exception No. 4: A material that is used in devices that do not incorporate contacts need not comply with the HAI PLC requirements.

Exception No. 5: A material that is used in devices that incorporate contacts but is not used within 1/2 inch (12.7 mm) of the contacts need not comply with the HAI PLC requirements.

Exception No. 6: A material without CTI PLC value or with CTI PLC value higher (worse) than the CTI required by Table 35.1 may alternatively be subjected to the End-Product Arc Resistance Test per UL 746C.

Exception No. 7: A material without CTI PLC value or with CTI PLC value higher (worse) than the CTI required by Table 35.1 shall be considered in compliance with the CTI PLC requirement if:

a) It has a High-Voltage-Arc Tracking (HVTR) PLC value of 1 or lower (better); or

b) The over surface spacings between the uninsulated live parts are at least 1/2 inch (12.7 mm).

Exception No. 8: A printed-wiring board evaluated to UL 796, Printed-Wiring Boards, is considered to be suitable for the direct support of uninsulated live parts without additional evaluation.

35.2 revised February 1, 1996

Table 35.1
Minimum material characteristics necessary for the direct support of uninsulated live parts

Table 35.1 revised January 11, 1999

UL 94 Flame Class	RTI Elec	HWI[b]	HAI[b]	CTI[c]
-HB	a	2	1	4
V-2	a	2	2	4
V-1	a	3	2	4
V-0	a	4	3	4

[a] The electrical RTI value of a material is to be determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B by test or by use of the generic RTI table. This material characteristic is dependent upon the minimum thickness at which the material is being used and shall not be exceeded during the Temperature Test of Section 45.

[b] The HAI and HWI Performance Level Category (PLC) value of a material is to be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used.

[c] The CTI PLC value of a material is to be determined by test in accordance with UL 746A. This material characteristic is not dependent upon the minimum thickness at which the material is being used.

Table 35.2
Generic materials considered suitable for the direct support of uninsulated live parts[a]

Table 35.2 added February 1, 1996

Generic material	Thickness, inches (mm)		RTI, °C
Diallyl Phthalate	0.028	(0.71)	105
Epoxy	0.028	(0.71)	105
Melamine	0.028	(0.71)	130
Melamine-Phenolic	0.028	(0.71)	130
Phenolic	0.028	(0.71)	150
Unfilled Nylon	0.028	(0.71)	105
Unfilled Polycarbonate	0.028	(0.71)	105
Urea Formaldehyde	0.028	(0.71)	100
Any cold-molded composition (i.e. concrete)	No Limit		No Limit
Ceramic, Porcelain & Slate	No Limit		No Limit

[a] Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Test of Section 45.

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

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

36 Flammability Classification of Internal Materials

36.1 General

36.1.1 The requirements in 36.1.2, 36.1.3, and 36.2.1 apply to a unit provided with a marking indicating that it is suitable for use in a computer room. See 72.1.27.

36.1.2 All combustible material used within an enclosure of a unit, including the case material of batteries used in a UPS having an integral battery supply and in remote battery cabinets investigated under the requirements of this standard, shall be classed as V-2, HF-2, VTM-2, or less flammable in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception No. 1: A motor, relay, capacitor, semiconductor, transformer, switch, insulating tubing, or tape need not comply. Other electrical components need not be classed as V-2, HF-2, or less flammable if they comply with the flammability class applicable to the component.

Exception No. 2: Indicator lamps and lenses need not be classed as V-2, HF-2, or less flammable.

Exception No. 3: A component, except a printed-wiring board, within a circuit described in 24.4 – 24.12 need not be classed as V-2, HF-2, or less flammable.

Exception No. 4: The following nonelectrical components need not be classed as V-2, HF-2, or less flammable if they are isolated from uninsulated electrical parts that involve a risk of fire by either at least 0.5 inch (12.7 mm) of air or by a solid partition of material classed as V-1 or less flammable:

a) A gear, cam, belt, bearing, strain-relief bushing, and other parts that contribute negligible fuel;

b) Tubing or duct for air handling systems classed as HB or less flammable; and

c) Foamed plastics classed as HBF or less flammable.

Exception No. 5: A component within a UPS that has a volume of no more than 2 cubic feet (0.057 m^3) need not be classed as V-2, HF-2, or less flammable if the component is contained within a metal enclosure having no ventilation openings.

Exception No. 6: Materials need not be classed as V-2, HF-2, or less flammable if they comply with the enclosure flammability 3/4-inch (19-mm) flame test described in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 7: An integrated circuit package, transistor package, opto-isolator package, capacitor, and other parts of similar size are exempt from the flammability classification of V-2 if the parts are mounted on material of at least the flammability classification of V-1.

Exception No. 8: A component within a UPS that has a volume of less than 0.125 cubic inches (2.05 cm^3) and a maximum dimension of 2 inches (50.8 mm) need not comply with this requirement.

36.1.2 revised January 11, 1999

36.1.3 Materials used for barriers shall be classed as V-2 or less flammable in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: Barrier materials need not be classed as V-2 or less flammable if they comply with the enclosure flammability 3/4-inch (19-mm) flame test described in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

36.1.3 revised January 11, 1999

36.2 Air filters

36.2.1 Air filters for use in cooling systems shall comply with the requirements in the Standard for Air Filter Units, UL 900, or shall be constructed of materials classed V-2 or HF-2 or less flammable in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception No. 1: This requirement does not apply to air filters in closed systems. A closed system is defined as that which, although not necessarily air-tight, is not intended to be vented outside the enclosure.

Exception No. 2: This requirement does not apply to air filters located external to the enclosure and constructed of materials classed HB or HBF or less flammable.

36.2.1 revised January 11, 1999

37 Adhesives

37.1 An adhesive that is relied upon to reduce a risk of fire, electric shock, or injury to persons shall comply with the requirements for adhesives in the Standard for Polymeric Materials – Use in Electrical Evaluations, UL 746C.

37.2 The requirement in 37.1 also applies to an adhesive used to secure a conductive part, including a nameplate, that may, if loosened or dislodged:

a) Energize an accessible dead metal part;

b) Make a live part accessible;

c) Reduce spacings below the minimum acceptable values; or

d) Short-circuit live parts.

38 Battery Supplies

38.1 General

38.1.1 The battery supply intended to be used with a UPS shall be provided with the UPS and comply with the requirements in 38.2.1 – 38.6.1.

Exception: Either the batteries or the battery cabinet need not be furnished with the following types of products [see 38.1.2 and 74.1.2(p)]:

a) A fixed UPS; and

b) A stationary UPS having an input rating of more than 20 amperes or 125 volts ac.

38.1.2 With reference to the requirements in the Exception to 38.1.1, a battery supply contained in a remote cabinet that is investigated by itself, that is, it is not included in the investigation of a UPS, shall comply with the requirements in 38.2.1 – 38.6.1 and other applicable requirements in this standard.

38.2 Enclosure

38.2.1 Vented batteries shall be contained in a separate enclosure or compartment (see 38.2.2) from the power conversion portion of the UPS. This requirement does not apply to valve-regulated batteries. See 2.4 and 2.5.

38.2.2 With reference to 38.2.1, vented batteries may be contained in the overall enclosure of the UPS, provided that a barrier, partition, or the equivalent is used to inhibit the passage of hydrogen gas from the battery area to the area of the enclosure containing the electronic components, switches, contactors, and controls used in the power conversion portion of the UPS.

38.2.3 The interior of a metallic enclosure or compartment housing a vented battery shall be protected by two coats of acid (or alkali, as applicable) resistant paint, two coats of enamel individually baked on, or the equivalent.

38.2.4 A polymeric enclosure or compartment housing a vented battery, such as a lead-acid storage battery, shall be constructed of materials resistant to corrosion by acids or alkalis, as applicable.

38.2.5 The enclosure or compartment housing a vented battery shall be constructed so that spillage or leakage of the electrolyte from one battery will be contained within the enclosure and prevented from:

a) Reaching the outer surfaces of the UPS where contact with the user is possible;

b) Contaminating adjacent electrical components or materials; and

c) Bridging required electrical spacings. See Stability Test, Section 63.

38.3 Battery mounting

38.3.1 A battery shall be so located and mounted that the terminals of cells will be prevented from coming into contact with terminals of adjacent cells, or with metal parts of the battery compartment, as the result of shifting of the battery.

38.3.2 To reduce the risk of leakage of the electrolyte as a result of damage to the battery case by a battery mounting means, a battery mounting means shall not cause undue stress to the battery case. See 38.3.3 and 38.3.4.

38.3.3 A battery mounting means that consists of a bracket, strap, or the like that extends around the top and/or sides of the battery shall not cause undue compression to the walls of the battery. The types of brackets or straps indicated in (a) – (c) are considered acceptable. Other constructions may be accepted if they are determined to be equivalent:

a) A bracket or strap constructed of a nonrigid polymeric material;

b) A metal bracket or strap with a flexible, foamed material or the like between the bracket or strap and the battery walls; and

c) A metal bracket, which when tightened as intended, provides a clearance, minimum not specified, between the bracket and the battery walls. See 38.3.4.

38.3.4 When determining the adequacy of the clearance for the mounting means described in 38.3.3(c), the following factors shall be taken into consideration:

a) Dimensional tolerances of the bracket and overall dimensions of the battery case;

b) The overall dimensions of the battery may increase slightly after use; and

c) The need for a restraining means for use during shipping if the clearance of the mounting means permits excessive movement of the battery.

38.4 Enclosure ventilation

38.4.1 The requirements in 38.4.2 – 38.4.5 apply to units having vented batteries.

38.4.2 The enclosure or compartment housing a vented battery where gassing is possible during heavy discharge, overcharging, or similar type of usages shall be vented. The means of venting shall provide air flow throughout the compartment in order to reduce the risk of buildup of pressure or accumulation of a gas mixture, such as hydrogen-air, involving a risk of injury to persons.

38.4.3 Arcing parts, such as the contacts of switches, circuit breakers, and relays, shall not be located in the enclosure or compartment housing a vented battery described in 38.4.2, nor shall the enclosure or compartment vent into closed spaces where such parts are located. For purposes of this requirement, fuses and connectors do not contain arcing parts. Battery or compartment monitoring sensors (such as temperature sensors and the like) may be located in the enclosure or compartment.

38.4.4 If the gas mixture is lighter than air (such as hydrogen-air), the requirement of 38.4.2 may necessitate locating additional ventilation openings in the uppermost portions of the battery enclosure or compartment where such a gas mixture may accumulate.

38.4.5 With reference to 38.4.4, the venting means shall prevent hydrogen concentrations in excess of 2 percent by volume. If the adequacy of the ventilation required in 38.4.2 is not obvious, a determination shall be made by measurement of gas concentration in accordance with Battery Compartment Ventilation Test, Section 57. A lead-acid battery at full charge, when most of the charging energy goes into gas, will generate approximately 1 cubic foot of hydrogen gas per cell for each 63 ampere-hours of input. See 52.9.3.

38.5 Batteries

38.5.1 A vented battery or a valve-regulated battery provided with a UPS or battery cabinet shall comply with the applicable requirements for batteries in the Standard for Emergency Lighting and Power Equipment, UL 924.

38.5.2 A metal case or container of a battery, such as an alkaline battery, shall be insulated or spaced away from contact with uninsulated live parts of the UPS if such contact may result in a short circuit.

38.5.3 An enclosure or compartment housing batteries employing metal containers or cases that are conductively connected to a battery electrode shall be such that the batteries are insulated or spaced from each other, or otherwise physically arranged, to prevent short-circuiting of part or all of the battery supply after installation in a UPS.

38.5.4 A battery that requires the addition of water shall employ a means to determine the fluid level.

38.6 Overcurrent protection

38.6.1 A battery supply shall be provided with overcurrent protection in accordance with 28.4.1 – 28.4.4.

38.7 Isolation

38.7.1 A UPS having a battery supply rated 60 volts, dc (maximum rectifier output voltage) or less shall incorporate transformer isolation as specified in 26.1.3 between the input ac circuit and the battery circuit.

Exception: A UPS provided with (a) and (b) need not comply with this requirement:

a) Guarding of the battery terminals to reduce the likelihood of unintentional contact with the battery terminals by service personnel (see Section 39, Protection of Service Personnel); and

b) A marking as described in 72.2.20.

39 Protection of Service Personnel

39.1 The requirements in this section apply only to service personnel who may find it necessary to reach over, under, across, or around uninsulated electrical parts or moving parts to make adjustments or measurements while the UPS is energized. For requirements covering accessibility of live parts for protection of users, refer to Section 7.

39.2 Live parts shall be so arranged and covers so located as to reduce the risk of electric shock or electrical energy – high current levels while covers are being removed and replaced.

39.3 An uninsulated live part involving a risk of electric shock or electrical energy – high current levels and a moving part that involves a risk of injury to persons shall be located, guarded, or enclosed so as to reduce the likelihood of unintentional contact by service personnel adjusting or resetting controls, or the like, or performing mechanical service functions that may be performed with the equipment energized, such as lubricating a motor, adjusting the setting of a control with or without marked dial settings, resetting a trip mechanism, or operating a manual switch.

39.4 Live parts involving a risk of electric shock or electrical energy – high current levels – located on the back side of a door shall be either guarded or insulated to reduce the likelihood of unintentional contact of the live parts by service personnel.

39.5 A component that may require examination, resetting adjustment, servicing, or maintenance while energized shall be so located and mounted with respect to other components and with respect to grounded metal parts that it is accessible for electrical service functions without subjecting the serviceperson to the risk of electric shock, electrical energy – high current, or injury to persons by adjacent moving parts. Access to a component shall not be impeded by other components or by wiring.

39.6 For an adjustment that is to be made with a screwdriver or similar tool when the unit is energized, the requirement in 39.5 necessitates that protection be provided so that inadvertent contact with adjacent uninsulated hazardous live parts involving a risk of electric shock is not likely, taking into consideration that misalignment of the tool with the adjustment means may result when an adjustment is attempted. This protection may be provided by:

a) Location of the adjustment means away from uninsulated hazardous live parts; or

b) A guard to reduce the likelihood of the tool from contacting uninsulated live parts.

39.7 A live heat sink for a solid-state component, a live relay frame, and the like, involving a risk of electrical shock or electrical energy – high current levels, which may be mistaken for dead metal, shall be guarded to reduce the risk of unintentional contact by the serviceperson or be marked in accordance with 72.2.6.

Exception: A heat sink mounted on a printed-wiring board need not comply with this requirement.

39.8 Moving parts that can cause injury to persons and that must be in motion during service operations not involving the moving parts shall be located or protected so that unintentional contact with the moving parts is not likely.

39.9 A functional attachment that is made available or recommended by the manufacturer for use with the basic unit shall be included in the evaluation of the unit. Unless the manufacturer recommends the use of two or more attachments at the same time, only one attachment at a time is to be evaluated with the unit.

39.10 Whether a guard, a release, an interlock, or the like is required and whether such a device is adequate shall be determined from an investigation of the complete unit, its operating characteristics, and the likelihood of a risk of injury to persons resulting from a cause other than gross negligence. The investigation shall include consideration of the results of breakdown or malfunction of any component; but not more than one component at a time, unless one event contributes to another. If the investigation shows that breakdown or malfunction of a particular component can result in a risk of injury to persons, that component shall be investigated for reliability.

40 Harmonic Distortion

40.1 The output voltage harmonic distortion from a UPS is to be measured as described in Section 49, Harmonic Distortion Test. If the levels specified in 49.1 are exceeded (including the acceptable cases stated in Exceptions No. 1 – No. 4) the Load Temperature Test of Section 46 shall be conducted.

Exception No. 1: The output voltage distortion levels of 49.1 may be exceeded if the unit complies with all of the following requirements:

a) The electrical input rating is a nominal 240 V and 6 A, or a nominal 120 V and 12 A, or less; and

b) The output voltage distortion exceeding the levels of 49.1 occurs only during reserve mode operation, and the unit is not capable of providing rated output for more than 30 minutes, with the provision for powering the unit from external batteries, under reserve mode with fully charged batteries.

Exception No. 2: The output voltage distortion levels of 49.1 may be exceeded if the unit is intended for use with a specific product load, and if the unit is marked in accordance with 72.1.30. Additionally, the instruction manual shall contain the information described in 74.1.2(ad) when a specific type of device is used. The temperature on the load shall not exceed the allowable values applicable to the load equipment involved during the Load Temperature Test of Section 46.

Exception No. 3: The output voltage distortion levels of 49.1 may be exceeded if the unit is intended for use with a generic type of device, and the unit is marked in accordance with 72.1.31. The Load Temperature Test of Section 46 shall be conducted using representative samples of the end use products supplied by a sinusoidal voltage source, and by the UPS output under the mode which results in the worst case harmonic voltage distortion.

Exception No. 4: The output voltage distortion levels of 49.1 may be exceeded if the temperatures measured on the loads supplied by the nonsinusoidal waveform do not exceed the temperatures measured using the sinusoidal waveform by more than 5°C (9°F), and do not exceed the allowable values applicable to the load equipment involved. If representative products are used, a sufficient number of products shall be tested to allow temperature measurements of the components mentioned in 46.2(b)(1) – (5).

Exception No. 5: The Harmonic Distortion Test of Section 49 and the Load Temperature Test of Section 46 need not be conducted if the unit is intended for use with Cable TV and is marked as described in 72.1.32.

40.1 revised February 1, 1996

PERFORMANCE

41 General

41.1 A representative sample of a unit is to be subjected to the tests described in Sections 42 – 68. Unless otherwise specified, all tests are to be conducted at the applicable voltage specified in Table 41.1.

Exception: A test voltage of not less than 90 percent of the values specified in Table 41.1 may be used provided that the unit will deliver rated output power at the reduced test voltage.

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Table 41.1
Values of test voltages

Rated voltage	Test voltage
Less than 110	Rated voltage[a]
110 – 120	120
121 – 219	Rated voltage[a]
220 – 240	240
241 – 253	Rated voltage[a]
245 – 277	277
278 – 439	Rated voltage[a]
440 – 480	480
481 – 525	Rated voltage[a]
526 – 600	600

[a] A unit marked with an operating voltage range shall comply with the requirements in Sections 42 – 68 while connected to a source of voltage adjusted to any value within the specified range.

41.2 A unit marked with one frequency rating is to be tested at that frequency. For a unit marked with a dual frequency rating such as 50/60 hertz or a frequency range such as 50 – 60 hertz, tests are to be conducted at any frequency covered by the marking.

Exception: For a unit marked with a dual frequency rating or a frequency range, the Power Input Test of Section 44, the Temperature Test of Section 45, and the Transformer Burnout Test specified in 52.2.1 – 52.2.3 are to be conducted at the lowest frequency.

41.3 Average reading instruments are to be used during the Power Input Test of Section 44 for output current and voltage measurements of either half-wave or full-wave rectifier circuits.

42 Leakage Current Test

42.1 The leakage current from parts that are accessible to the user (see Section 7, Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts – and User Servicing) of a stationary unit rated 250 volts or less, when tested in accordance with 42.2 – 42.6, shall not be more than 0.75 milliampere.

Exception: A unit that is required to have primary-circuit filtering to meet the applicable electromagnetic compatibility (EMC) regulations may have higher leakage current levels at accessible parts provided that the unit complies with the following:

a) Leakage current does not exceed 5.0 milliampere and the unit complies with the grounding requirements in Section 18, Equipment Grounding; or

b) Leakage current does not exceed 5 percent of the input current determined in accordance with Section 44, Power Input Test, and all of the following conditions are met:

1) The unit complies with the grounding requirements in Section 18, Equipment Grounding;

2) The unit, including one having more than one voltage rating, is provided with an attachment plug of other than a parallel blade configuration rated 15 amperes, 125 volts or a T-blade configuration rated 20 amperes, 125 volts for all voltage ratings;

3) Provision is made for connecting together and earth-grounding all the metal frames of the unit in the system; and

4) The installation instructions comply with the requirements in 74.1.2(j).

42.2 All exposed conductive surfaces are to be tested for leakage currents. The leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one surface to another if simultaneously accessible. Parts are considered to be exposed surfaces unless guarded by an enclosure considered acceptable for protection to reduce the risk of electric shock as defined in Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 7. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These requirements do not apply to exposed output terminals operating at voltages less than 30 volts rms (42.4 volts peak) or 60 volts dc or less.

42.3 If a conductive surface other than metal is used for the enclosure or a part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 by 20 centimeters in contact with the surface. If the surface is less than 10 by 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the unit.

42.4 The measurement circuit for leakage current is to be as illustrated in Figure 42.1. The measurement instrument is defined in (a) – (c). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument. The meter used need not have all the attributes of the defined instrument.

a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad;

b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor; and

c) Over a frequency range of 0 – 100 kilohertz, the measurement circuit is to have a frequency response (ratio of indicated to actual value of current) that is equal to the ratio of the impedance of a 1500-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 0.5 or 0.75 milliampere, the measurement is not to have an error of more than 5 percent at 60 hertz.

42.5 Leakage current is to be measured between the following points:

a) Between the grounding conductor and the grounded supply conductor for a unit having all accessible surfaces bonded together and connected to the grounding conductor;

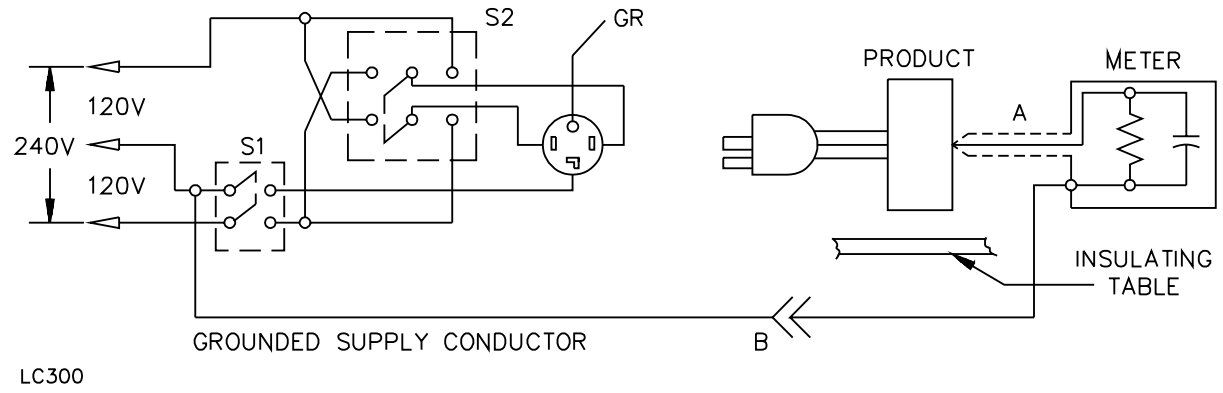
b) Between one accessible part of a unit to another that are not bonded together; and

c) Between the grounded conductor and an accessible part on a unit not having a grounding conductor.

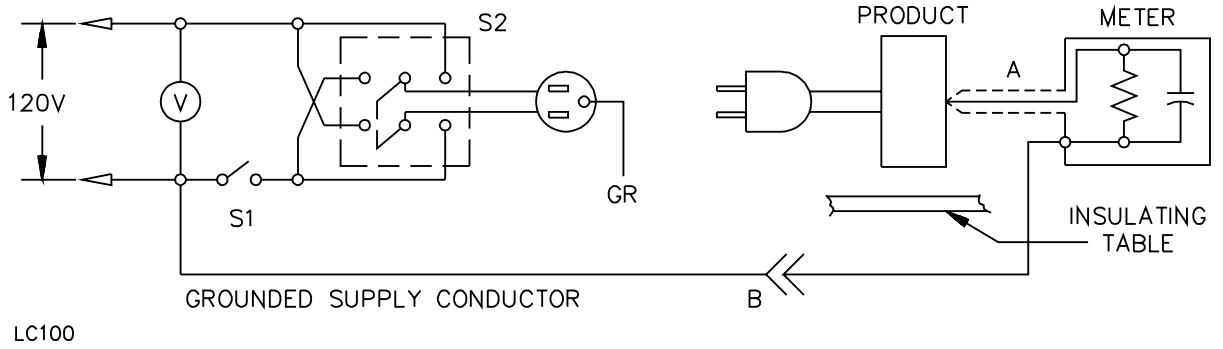
For a unit having exposed conductive surfaces other than metal, between the points mentioned in (b) and (c) above. See 42.3.

Figure 42.1
Leakage current measurement circuit

Figure 42.1 revised November 17, 1997

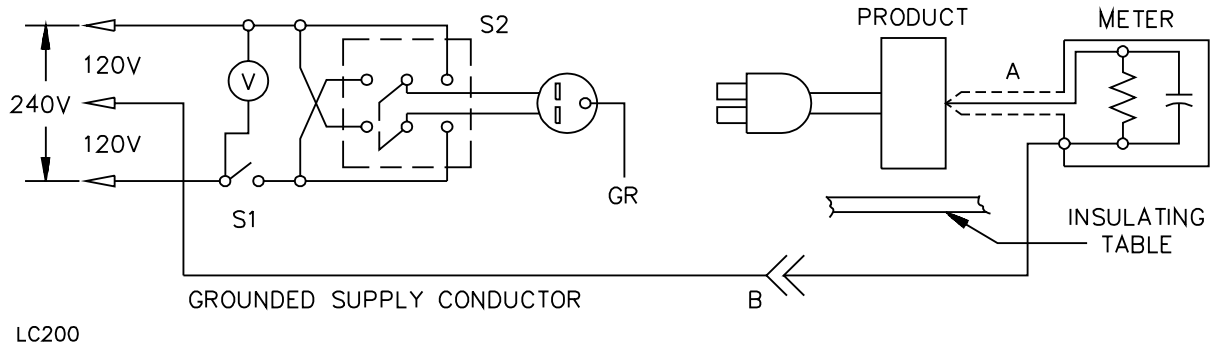


LC300



LC100

42.6 A sample of the unit is to be tested for leakage current starting with the as-received condition (the



Note:

A – Probe with shielded lead.

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

as-received condition is without prior energization except as may occur as part of the production-line testing) but with the grounding conductor, if any, open at the attachment plug. The supply voltage is to be adjusted to the test voltage specified in 41.1. The test sequence, with reference to the measuring circuit, Figure 42.1, is to be as follows:

a) With switch S1 open, the unit is to be connected to the measuring circuit. The leakage current is to be measured using both positions of switch S2 for each mode of operation described in 44.1(a) – (c). During these modes of operation, the UPS switching devices are to be placed in all of their operating positions.

b) Switch S1 is then to be closed, energizing the unit, and within 5 seconds the leakage current is to be measured using both positions of switch S2 for each mode of operation described in 44.1(a) – (c). During these modes of operation, the UPS switching devices are to be placed in all of their operating positions.

c) The leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in making this measurement. Thermal stabilization is considered to be obtained by operation as in the normal temperature test.

42.7 In general, the complete leakage current test program as described in 42.6 is to be conducted without interruption for other tests. With the concurrence of those concerned, the leakage current tests may be interrupted to conduct other nondestructive tests.

43 Leakage Current Test Following Humidity Conditioning

43.1 A stationary unit rated 250 volts or less shall comply with the requirements for leakage current in 42.1, following exposure to air having a relative humidity of 88 ±2 percent at a temperature of 32 ±2°C (90 ±4°F).

Exception: A unit marked in accordance with 72.1.29 need not be subjected to a leakage current test after humidity conditioning.

43.2 To determine whether a unit complies with the requirement in 43.1, a sample of the unit is to be heated to a temperature just above 34°C (93°F) to reduce the likelihood of condensation of moisture during conditioning. The heated sample is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 43.1. Immediately following the conditioning, the sample is to be removed from the humidity chamber and tested unenergized as described in 42.6(a). The sample is then to be energized and tested as described in 42.6(b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

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44 Power Input Test

44.1 When a unit is connected to a supply adjusted to the test voltage specified in 41.1 and supplying rated output under each of the conditions described in (a) – (d), the input current shall not be more than 110 percent of the rated value. See 71.1 and 71.3.

a) Recharging Mode – The UPS is to receive power from the utility line while delivering maximum rated alternating current power, and battery charging current. See 44.4.

b) Reserve Mode – For a UPS used with a remote battery, while simulating utility power outage, the inverter portion of the UPS is to receive power from either a fully charged battery bank or an external dc source of supply and allowed to deliver maximum rated alternating current power. The input dc current is to be measured.

c) Bypass Mode – The transfer switch is to be positioned such as to allow the utility power for the output load to bypass the rectifier/charger and inverter sections of the UPS and be delivered directly to the load adjusted to draw maximum rated alternating current power.

d) Normal Mode – With a fully charged battery, the UPS is to receive power from the primary or normal power source and deliver maximum rated alternating current power.

44.2 With reference to 44.1, the current in each phase and also the current in the neutral for a 3-phase, 4-wire UPS are to be measured. The input current of a UPS is to be measured using a true rms ammeter.

44.3 With reference to 44.1, if the power factor rating of alternating current output (see 71.1) is unity, a resistive load is to be used. For other UPS, a resistive-reactive load is to be used to allow the UPS to deliver power at minimum rated power factor rating.

44.4 With reference to 44.1(a), the battery charging circuit is to be connected to:

a) A resistive-capacitive (rc) load having capacitance of 1000 microfarads per output dc ampere rating of the battery supply;

b) A battery supplemented with a resistive load bank; or

c) If requested by the manufacturer, a battery having an ampere-hour and voltage rating corresponding to that which is intended to be used with the UPS.

If a battery load is to be used as described in (c), then the battery is to be prepared for charging by first connecting it to the proper load and then discharging it to the low-voltage disconnect (LVD) potential, or 80 percent of the float charging voltage rating of the battery for a UPS having a low-voltage disconnect lockout, at a rate not exceeding the discharge rate assigned by the battery manufacturer.

45 Temperature Test

45.1 Under each of the modes described in 44.1(a) – (d), the UPS shall not reach a temperature at any point high enough to:

a) Cause a risk of fire;

b) Damage any material used;

c) Cause a protective device to operate; or

d) Exceed the temperature limits specified in Table 45.2.

During this test, the ambient temperature is to be as specified in 45.12.

Exception: The conditions of a mode need not be included if a circuit analysis indicates that such conditions are covered by those of another mode included in the test.

45.2 During the temperature test, the temperature of a surface that may be contacted by the user shall not be more than the value specified in Table 45.1. If the test is conducted at a room temperature of other than 25°C (77°F), the results are to be corrected to that temperature.

Exception: A unit may exceed the temperature limits specified in the third item in Table 45.1 if it is:

a) A fixed unit so that it is not likely to be contacted by people;

b) Marked as required by 72.2.7; and

c) Provided with instructions as specified in 74.1.2(i).

Table 45.1
Maximum surface temperatures

Location	Composition of surface[a]			
	Metal		Nonmetallic	
Handles or knobs that are grasped for lifting, carrying, or holding	50°C	(122°F)	60°C	(140°F)
Handles or knobs that are contacted but do not involve lifting, carrying, or holding; and other surfaces subject to contact and user maintenance	60°C	(140°F)	85°C	(185°F)
Surfaces subject to casual contact[b]	70°C	(158°F)	95°C	(203°F)

[a] A handle, knob, or the like made of a material other than metal that is plated or clad with metal having a thickness of 0.005 inch (0.127 mm) or less is considered to be, and is judged as, a nonmetallic part.

[b] See Exception to 45.2.

45.3 With reference to 45.1, the test conditions for a UPS having a 120/240 volt, single-phase output shall include maximum unbalanced load capability of the UPS in accordance with the marking described in 71.5(b).

45.4 With reference to 45.1, an external dc source other than a battery supply may be used to supply the inverter during the reserve and normal modes.

45.5 For a fixed unit, the ampacity of the conductors connected to the field wiring terminals or leads shall be in accordance with the value determined by the requirement described in 15.1.3.

45.6 With reference to 45.1, a unit having voltage adjustment taps for intended use shall operate within the temperature limits at the setting representing the most severe loading condition as determined by an analysis of the circuit.

45.7 A unit intended for mounting or support in more than one position, or in a confined location, is to be tested in a manner representing the most severe conditions. An adjacent mounting or supporting surface is to consist of 1-inch thick trade-size soft-pine boards.

45.8 Unless investigated and found acceptable, see the Exception to 9.3 and 81.1, a supporting means formed of rubber or neoprene material is to be removed prior to the test. If the supporting means has a metal insert, such as a screw or rivet, the test is to be conducted with the unit supported by the metal insert. At the request of the manufacturer, the test may be conducted without any means of support.

45.9 A thermocouple junction and the adjacent thermocouple lead wires are to be held securely in good thermal contact with the surface of which the temperature is being measured. Usually, adequate thermal contact will result from securely taping or cementing the thermocouple in place. If a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

45.10 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, except that the resistance method may be used for a coil that is inaccessible for mounting thermocouples, such as a coil:

a) Immersed in sealing compound;

b) Wrapped with thermal insulation; or

c) Wrapped with more than two layers of material such as cotton, paper, or rayon more than 1/32 inch (0.8 mm) thick.

In a motor, the thermocouple is to be mounted on the integrally applied insulation of the coil wire.

45.11 The temperature of a winding is determined by the resistance method by comparing the resistance of the winding at a temperature to be determined with the resistance at a known temperature according to the formula:

$$T = \frac{R}{r}(k + t) - k$$

in which:

T is the temperature of the winding in degrees C;

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

r is the resistance of the coil at the beginning of the test in ohms;

t is the room temperature in degrees C at the beginning of the test; and

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum. Values of the constant k for other conductors are to be determined.

The winding is to be at room temperature at the start of the test.

45.12 All temperature limit values in Table 45.2 are based on an assumed ambient temperature of 25°C (77°F). However, with correction of temperature measurements, tests may be conducted in other ambients as described in Table 45.3.

45.13 If a unit is rated for an ambient temperature higher than 25°C (77°F), the rating shall be indicated in the instruction manual in accordance with 74.1.2 (o).

45.14 Thermocouples are to consist of wires not larger than No. 24 AWG (0.21 mm^2) and not smaller than No. 30 AWG (0.05 mm^2). When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ a temperature-indicating instrument with thermocouples consisting of No. 30 AWG iron and constantan wire. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary. The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform with the requirements for special thermocouples as listed in the Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA MC96.1-1982.

45.14 revised January 5, 2000

45.15 A temperature is considered to be constant when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 15 minutes, indicate no increase greater than 2°C (4°F).

Table 45.2
Temperature limits

Materials and Components		Degrees °C	Degrees °F
A.	MOTORS		
	1. Class A insulation systems on coil windings of motors having a diameter of more than 7 inches (178 mm):		
	a. In an open motor:		
	Thermocouple method	90[a]	194[a]
	Resistance method	100	212
	b. In a totally enclosed motor:		
	Thermocouple method	95	203
	Resistance method	105	221
	2. Class A insulation systems on coil windings of motors having a diameter of 7 inches (178 mm) or less:		
	a. In an open motor:		
	Thermocouple or resistance method	100	212
	b. In a totally enclosed motor:		
	Thermocouple or resistance method	105	221
	3. Class B insulation systems on coil windings of motors having a diameter of more than 7 inches (178 mm):		
	a. In an open motor:		
	Thermocouple method	110[a]	230[a]
	Resistance method	120	248
	b. In a totally enclosed motor:		
	Thermocouple method	120	248
	Resistance method	125	257
	4. Class B insulation systems on coil windings of motors having a diameter of 7 inches (178 mm) or less:		
	a. In an open motor:		
	Thermocouple or resistance method	120	248
	b. In a totally enclosed motor:		
	Thermocouple or resistance method	125	257
B.	COMPONENTS		
	1. Capacitors:		
	a. Electrolytic types	65[b]	149[b]
	b. Other than electrolytic	90[b]	194[b]
	3. Field Wiring Terminals	75[c]	167[c]
	4. Vulcanized fiber employed as electric insulation	90	194
	5. Plated bus bar	90[d]	194[d]
	6. Unplated bus bar and a joint	75[d]	167[d]

Table 45.2 Continued on Next Page

Table 45.2 Continued

Materials and Components	Degrees	
	°C	°F
7. Relays, solenoids, and the like:		
a. Class 105 coil insulation systems:		
Thermocouple method	90[a]	194[a]
Resistance method	110	230
b. Class 130 coil insulation systems:		
Thermocouple method	110[a]	230[a]
Resistance method	120	248
8. Transformer insulation systems:		
a. Class 105:		
Thermocouple method	90[a]	194[a]
Resistance method	95	203
b. Class 130:		
Thermocouple method	110[a]	230[a]
Resistance method	120	248
c. Class 155:		
Thermocouple method	135[a]	275[a]
Resistance method	140	284
d. Class 180:		
Thermocouple method	150[a]	302[a]
Resistance method	160	320
e. Class 200:		
Thermocouple method	165[a]	329[a]
Resistance method	175	347
f. Class 220:		
Thermocouple method	180[a]	356[a]
Resistance method	190	374
9. Phenolic composition employed as electrical insulation or as a part the deterioration of which would result in a risk of fire or electric shock	150[e]	302[e]
10. Wood and other combustible material	90	194
11. Rubber- or thermoplasit-insulated wire and cord	60[e,f]	140[e,f]
12. Other types of insulated wires	g	g
13. A surface upon which a stationary UPS may be mounted in service, and surfaces that may be adjacent to the UPS when so mounted	90	194
14. Any point on or within a terminal box or compartment of a fixed UPS on which field-installed conductors may rest	60[c]	140[c]
15. Thermoplastic sealing compound	h	h

Table 45.2 Continued on Next Page

Table 45.2 Continued

Materials and Components	Degrees	
	°C	°F
16. Selenium rectifier	75[l,e]	167[l,e]
17. Power semiconductor	j	j
18. Printed-wiring board	k	k

[a] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature measured by means of a thermocouple may be 5°C (9°F) higher than that specified if the temperature of the coil as measured by the resistance method is not more than that specified.

[b] A capacitor that operates at a temperature of more than 65°C (149°F) for electrolytic and more than 90°C (194°F) for other types may be judged on the basis of its marked temperature limit.

[c] The temperature observed on the terminals and at points within a terminal box of a UPS may exceed the values specified but shall not attain a temperature higher than the temperature marking required in 74.1.2(w) and (v).

[d] For a bus bar having a current density in accordance with 21.2.9, it is not necessary to measure the temperature since it is considered to have characteristics which will result in temperatures not exceeding the indicated values.

[e] The temperature limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has been investigated and found to have acceptable heat-resistant properties.

[f] A short length of rubber- or thermoplastic-insulated cord inside the UPS may be exposed to a temperature of more than 60°C (140°F) if supplementary insulation acceptable for the measured temperature and of adequate dielectric properties is employed on each individual conductor.

[g] The maximum allowable temperature is not to exceed the temperature limit of the wire except as noted in footnote g.

[h] The sealing compound temperature limit is 15°C (27°F) less than the softening point of the compound as determined in accordance with the test method for Vicat Softening Temperature of Plastics, ASTM D1525-1991.

[i] A temperature limit of 85°C (185°F) is acceptable if the stack assembly is insulated with phenolic composition or other insulating material suitable for a temperature of 150°C (302°F).

[j] For a power-switching semiconductor and the like, the temperature limit on the case is the maximum case temperature recommended by the semiconductor manufacturer.

[k] For a printed-wiring board, the temperature limit is the specified limit of the board.

Table 45.3
Temperature measurement correction

Ambient temperature rating of unit	Test ambient temperature	Correction of observed temperature
1. 25°C (77°F)	Range of 10 – 40°C (50 – 104°F)	See note a(1)
2. Range of 25 – 40°C (77 – 104°F)	Range of 20 – 40°C (68 – 104°F)	See note a(2)
3. Above 40°C (104°F)	Rated ambient[b]	c

[a] Correction of temperature, as determined by (1) or (2), shall not exceed the temperature limit specified in Table 45.2:

1 If the test ambient temperature is lower than 25°C (77°), an observed temperature is to be corrected by addition of the difference between 25°C (77°F) and the test ambient temperature. If the test ambient temperature is higher than 25°C (77°), an observed temperature is to be corrected by subtraction of the difference between 25°C (77°F) and the test ambient temperature.

2 If the test ambient temperature is lower than the rated ambient temperature, an observed temperature is to be corrected by addition of the difference between the rated ambient temperature and the test ambient temperature. If the test ambient temperature is higher than the rated ambient temperature, an observed temperature is to be corrected by subtraction of the difference between the rated ambient temperature and the test ambient temperature.

[b] Allowable tolerances are:

Minus – not less than 5°C (9°F) below rated ambient.

Plus – not specified.

[c] If the test ambient temperature equals rated ambient, no correction is to be made, and an observed temperature shall not exceed the temperature limit specified in Table 45.2. If the test ambient temperature is other than rated ambient, correction is to be made as described in a(2).

46 Load Temperature Test

46.1 In accordance with the Exceptions to 40.1, the tests described in 46.2 – 46.3 are to be conducted to investigate the acceptability of output voltage harmonic distortion exceeding the levels specified in 49.1.

46.1 effective January 19, 1996

46.2 The load is to be energized from the following sources, one at a time:

a) The ac output of the UPS while the input of the UPS is connected to a supply adjusted to the test voltage in 41.1; and

b) A utility source of sinusoidal voltage adjusted to the same rms value as obtained from the output of the UPS during the test mentioned in (1). While energized from each source, temperatures of components that may be affected by harmonic voltages are to be measured as described in Section 45, Temperature Test. Such components include, but are not limited to, those described in (1) – (5):

1) Linear transformer winding;

2) DC filter capacitor in a switch-mode power supply;

3) Across-the-line capacitor in an electromagnetic interference (EMI) filter;

4) Continuous duty capacitor start motor winding; and

5) Continuous duty shaded pole motor winding.

The maximum temperatures obtained while the load is supplied from the UPS shall not exceed by more than 5°C (9°F) the corresponding maximum temperatures obtained when the load is supplied from the utility source.

46.2 effective January 19, 1996

46.3 If the output voltage distortion of the unit varies with the amount of load connected to the UPS, the condition of loading resulting in the highest level of distortion is to be used for this test. To accomplish this, it may be necessary to connect other loads in parallel with the load under test.

46.3 effective January 19, 1996

47 Dielectric Voltage-Withstand Test

47.1 General

47.1.1 The test potential mentioned in 47.3.1 and 47.4.1 may be obtained from any convenient source having a capacity of at least 500 volt-amperes. The capacity may be lower if a meter is located in the output circuit, and the test potential is maintained except in case of breakdown. The voltage of the source is to be continuously adjustable. Starting at zero, the applied potential is to be increased at a rate of approximately 200 volts per second until the required test value is reached.

47.1.2 A direct-current potential may be used for an ac circuit, and if used, a test potential of 1.414 times the appropriate rms value of alternating-current voltage specified in 47.3.1 and 47.4.1 is to be applied.

47.1.3 Printed-wiring assemblies and other electronic-circuit components that would be damaged by application of the test potential or that may short-circuit the test potential are to be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand tests are made. A representative subassembly may be tested instead of an entire unit. Semiconductor devices in the unit may be individually shunted before the test is made to avoid destroying them in the case of a malfunction elsewhere in the secondary circuits.

47.2 Maximum-voltage measurements

47.2.1 The maximum voltage used as a basis for the calculation of the dielectric voltage-withstand test potentials specified in 47.3.1 and 47.4.1 and the determination of the minimum spacings specified in Section 23, Spacings, shall be determined in accordance with 47.2.2 and 47.2.3.

47.2.2 A connector or comparable part that is likely to be disconnected during intended operation is to be both connected and disconnected during the test so that the maximum voltage can be obtained.

47.2.3 If a complex voltage is present, the peak value of the voltage is to be measured and this value is to be used for calculation of the dielectric voltage-withstand potential and determination of the minimum spacings. For a sinusoidal or a direct current voltage, the rms or average values respectively is to be measured.

47.3 AC and DC power circuits

47.3.1 While at operating temperature, the ac and dc power circuits of a UPS shall withstand without breakdown the application of an essentially sinusoidal potential (see 47.1.2) of 1000 plus twice rated voltage (see 47.3.2) at a frequency in the range of 40 – 70 hertz applied for 1 minute at the points indicated in Table 47.1 and Figure 47.1.

Exception No. 1: For a dc circuit, either an alternating-current or a direct-current potential may be used. If an alternating current potential is used, the potential is to be the value indicated above, divided by 1.414.

Exception No. 2: A dc circuit having a potential of 30 volts or less need not be tested.

47.3.2 With reference to 47.3.1, the test potential between ac power circuits and dead metal parts is to be based on the phase-to-ground voltage rating. The test potential for other points involving the ac power circuit is to be based on the phase-to-phase voltage rating or the voltage rating of the other circuit, if applicable, whichever is greater.

Figure 47.1
Dielectric voltage-withstand test

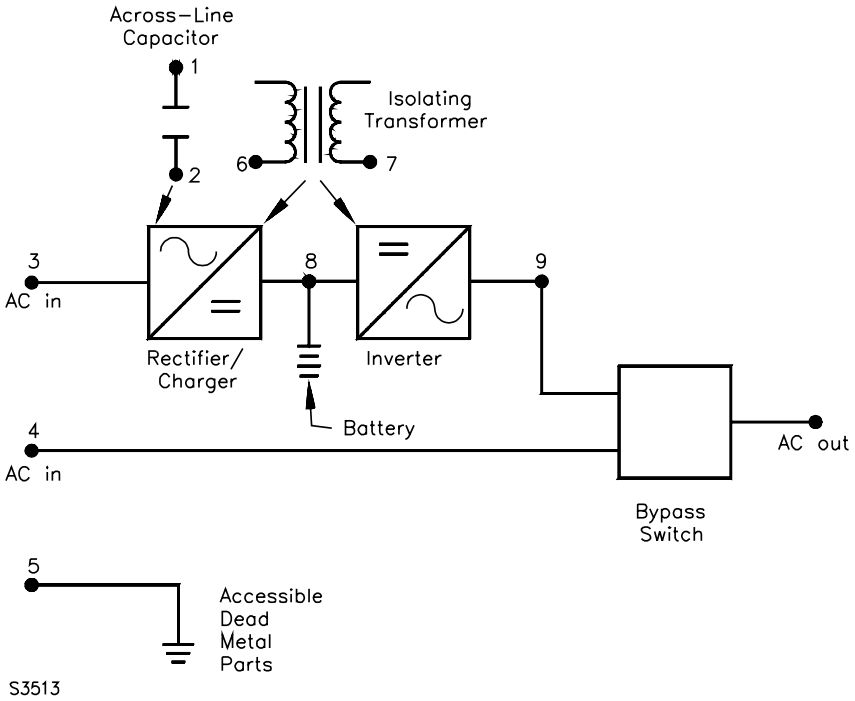


Table 47.1
Dielectric voltage-withstand test

Test no.	Potential applied across	
	Points shown in Figure 47.1[a]	Circuit parts
1	3, 9 to 5	ac circuits to dead metal parts
2	8 to 5	dc circuits to dead metal parts
3[b]	3, 9 to 8	ac circuits to dc circuits
4[c]	6 to 7	primary winding to secondary winding
5[d]	1 to 2	across capacitor terminals

[a] Points separated by a comma are to be connected together.

[b] Applicable only to units required to have isolation per 38.7.1.

[c] Applicable only to isolating-type transformers.

[d] Applicable to:

1) Capacitors that are connected directly across the input ac line prior to a transient suppressive device, a rectifier or similar network, and

2) Line-bypass capacitors connected between the line and the enclosure or between line and dead metal parts.

This test is not required for a capacitor complying with the Standard for Across-the-Line, Antenna-Coupling, and Line-by-Pass Capacitors for Radio- and Television-Type Appliances, UL 1414, or Standard for Electromagnetic-Interference Filters, UL 1283.

47.4 Secondary circuits

47.4.1 Each secondary circuit other than a power circuit covered in 47.3.1 and 47.3.2 shall withstand for 1 minute without breakdown the application of a test potential:

a) Between primary and secondary circuits;

b) Between secondary circuits and grounded metal with grounding connections, if any, disconnected; and

c) Between isolated secondary windings of transformers.

The unit shall be at operating temperature during the test. The test potential shall be as indicated in Table 47.2.

47.5 Induced potential

47.5.1 If an isolating power transformer is to be tested in accordance with Exception No. 4 to 52.2.1, the test described in 47.5.2 – 47.5.5 is to be conducted.

Table 47.2
Magnitude of test potential for secondary circuits

Maximum voltage in the circuit[a,b]	Test potential
30 (42.4 peak), 60 dc, or less	No test
More than 30 (42.4 peak) but not more than 333.3 (471.3 peak) or more than 60 dc	Ten times maximum voltage in circuit (maximum of 1000 volts rms)
More than 333.3 (471.3 peak) but not more than 1000 (1414 peak)	Three times maximum voltage in circuit
More than 1000 (1414 peak)	1750 volts plus 1.25 times voltage in circuit

[a] Where the peak voltage is greater than 120 percent of 1.414 times the rms voltage, the circuit shall be tested as if the voltage were peak voltage divided by 1.414.
[b] Values are rms unless otherwise indicated.

47.5.2 The primary winding of the transformer is to be subjected to an alternating potential of twice the rated voltage with the ends of all other windings opened. The potential is to be applied for 7200 cycles or for 60 seconds, whichever is less. An essentially sinusoidal source is to be used, and the frequency of the service may be in the range of 120 – 1000 hertz if necessary to prevent saturation of the core.

47.5.3 Primary- and secondary-circuit wiring connected to the transformer is to be disconnected for this test.

47.5.4 A 3-phase transformer may be tested with a single phase voltage. The voltage mentioned in 47.5.2 is to be applied successively across each primary winding.

47.5.5 While in the heated condition obtained during the transformer overload test, the test voltage required in 47.5.2 is to be initiated at one-fourth or less of the full value and brought up gradually to the full value in not more than 15 seconds. After being held for the time specified, the voltage is to be reduced slowly, but within 5 seconds, to one-fourth of the maximum value or less, and the circuit opened. The results are acceptable if there is no dielectric breakdown.

48 Backfeed Protection Test

48.1 General

48.1.1 A UPS shall not allow a potential involving a risk of electric shock to be present on the input ac terminals during the reserve mode operation [see 44.1(b)] when subjected to the test described in 48.1.2.

48.1.2 While simulating utility power outage or disconnection of an input ac power supply cord of a stationary UPS, the inverter of the UPS is to receive power from a fully charged battery bank and the UPS is to be allowed to:

a) Operate with no load connected to the output ac terminals; and

b) Deliver maximum rated output alternating current into a load as described in 44.3.

The electric energy available at the input terminals or attachment plug blades of the UPS shall not produce a risk of electric shock (see Section 8, Electric Shock).

48.1.3 With reference to the requirement in 48.1.2, voltage is to be measured:

a) From each input terminal or attachment plug blade to ground; and

b) Across the input terminals or attachment plug blades.

48.2 Electromagnetic interference filters

48.2.1 For a stationary UPS having an electromagnetic interference (EMI) filter capacitor, the peak supply voltage shall not exceed the voltage in Table 8.2 (stored energy shock hazard) corresponding to the capacitance between any two terminals – blades of an attachment plug – and any terminal and earth ground.

Exception: For a UPS having a path for discharging the capacitor, compliance with this requirement may be determined by connecting the filter and discharge means to a dc source of supply adjusted to 1.414 times the input ac voltage rating of the UPS followed by measuring either the voltage or current 5 seconds after disconnecting the filter from the dc source. The voltage shall not exceed the values indicated in Table 8.1.

49 Harmonic Distortion Test

49.1 When tested as described in 49.3, the total rms of the harmonic voltages, excluding the fundamental, delivered by a UPS shall not exceed 30 percent of the fundamental rms output voltage, and the rms voltage of any single harmonic shall not exceed 15 percent of the fundamental rms output voltage.

Exception: The specified output voltage distortion levels may be exceeded if the UPS complies with Section 46, Load Temperature Test.

49.1 effective January 19, 1996

49.2 If the inverter portion of the UPS does not operate to supply output during the normal mode of operation, the UPS is to be operating in reserve mode during this test.

49.2 effective January 19, 1996

49.3 With reference to the requirement in 49.1, the UPS is to be connected to an adjustable resistive load at rated power. The measurements are to be made at open circuit and with the UPS delivering 25, 50, 75, and 100 percent of rated power.

49.3 effective January 19, 1996

50 Volt-Ampere Capacity Measurement

50.1 If necessary to determine volt-ampere capacity of a transformer winding for judging compliance with other requirements in this standard [see 2.19, 23.1.12, and 23.1.13(a)] the capacity is to be measured by replacing the intended load on that winding with a variable resistor that has been set to maximum resistance. A thermal protector or an overcurrent protective device, if provided, is to be shunted. A wattmeter is to be connected to measure power dissipated by the resistor. The assembly is to be energized with the test voltage specified in Table 41.1. The variable resistor is to be continuously adjusted to dissipate maximum power, and the power value is to be measured after 1 minute of operation or just prior to opening the winding, whichever occurs first. This value is considered to be the winding capacity. For a multi-secondary winding, one winding is to be loaded and tested at a time, that is, while measuring the output of a particular winding, other windings are to be open circuited.

51 Neutral to Ground Potential Measurement Test

51.1 In accordance with 17.8, a UPS having a grounding type receptacle or a lead or terminal identified as a grounded circuit that is not grounded at the unit itself is to be subjected to this test. Under the recharging, reserve, bypass, and normal modes of operation (see 44.1), the UPS is to:

a) Operate with no load connected to the output ac terminals; and

b) Deliver maximum rated output alternating current into a load as described in 44.3.

The electric energy available between the grounded conductor of the ac output circuit and ground shall not produce a risk of electric shock (see Section 8, Electric Shock).

52 Abnormal Tests

52.1 General

52.1.1 A UPS shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons (see 52.1.3) when subjected to the tests specified in 52.1.2 – 52.13.2. Separate samples may be used for conducting these tests.

52.1.2 Following each test, Dielectric Voltage-Withstand Test in Section 47 is to be conducted. The potential is to be applied across the points indicated in Table 52.1.

Exception: More than one abnormal test may be conducted on a sample, and the dielectric voltage-withstand test may be conducted after completion of all abnormal tests.

52.1.3 A risk of fire, electric shock, or injury to persons is considered to exist if:

a) Flame, burning oil, or molten metal is emitted from the enclosure of the UPS as evidenced by ignition, glowing, or charring of the cheesecloth or tissue paper;

b) The insulation breaks down when tested in accordance with 52.1.2 or live parts are made accessible (see Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts – and User Servicing, Section 7);

c) Cracking, rupturing, or bursting of the battery case or cover, if such damage may result in user contact with battery electrolyte;

d) Explosion of the battery supply if such explosion may result in a risk of injury to persons; or

e) A backfeed potential involving a risk of electric shock (see Electric Shock, Section 8) being present on the input ac terminals or attachment plug blades as a result of the Component Short- and Open-Circuit Test (see 29.5, 48.1.1 – 48.1.3, and 52.10.1).

52.1.4 During these tests the UPS is to be placed on a softwood surface covered with a white tissue paper and a single layer of cheesecloth is to be draped loosely over the entire enclosure. The cheesecloth is to be untreated cotton cloth running 14 – 15 yards per pound (28 – 30 m^2/kg), and having, for any square inch (6.45 cm^2), a count of 32 threads in one direction and 28 in the other direction.

Exception No. 1: Units not having any bottom openings need not be placed on a softwood surface covered with tissue paper.

Exception No. 2: When it is impractical to drape the entire UPS, cheesecloth may be placed only over all ventilating openings.

Table 52.1
Dielectric voltage-withstand test following abnormal tests

Test no.	Points shown in Figure 47.1[a]	Circuit parts
1[b]	3 to 8 and 9 to 8	ac power circuits to battery power circuits
2	3, 8, and 9 to 5	ac and dc power circuits to accessible to dead metal parts
3[c]	6 to 7	Primary to secondary winding of isolating transformer
4[d]	4 to 9	Inverter input to bypass ac input circuit

[a] Points separated by a comma are to be connected together.

[b] Applicable only to a UPS required to have isolation per 38.7.1.

[c] Conduct only after following tests: Transformer Burnout (52.2.1 – 52.2.3), Transformer Overload (52.3.1 – 52.3.5), Short Circuit (52.5.1 and 52.5.2), and Flanged Bobbin Transformer Abnormal (Section 53).

[d] Conduct only on an air-gap type bypass switch after Load Transfer Test (52.12.1 and 52.12.2). For solid state bypass switch, see 52.12.3.

52.1.5 For a unit having supporting feet made of rubber or neoprene material, the requirement in 45.8 shall apply.

52.1.6 The supply circuit is to have branch circuit overcurrent protection, the size of which equals 125 percent of the input current rating (20-ampere minimum), except where this value does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating shall be used. The test voltage and frequency are to be adjusted to the values specified in 41.1 and 41.2.

Exception: If a marking on the product indicates the use of branch circuit protection exceeding 125 percent of the input current, such protection shall be used.

52.1.7 The enclosure of the unit is to be connected directly to ground.

52.1.8 Each test is to be continued until further change as a result of the test condition is not likely. If an automatically reset protector functions during a test, the test is to be continued for 7 hours. If a manual reset protector functions during a test, the test is to be continued until the protector is operated for 10 cycles using the minimum resetting time, but not at a faster rate than 10 cycles of operation per minute. The following are considered as an acceptable termination of the test:

a) Opening or shorting of one or more components such as capacitors, diodes, resistors, solid state devices, printed-wiring board traces, or the like;

b) Opening of the intended branch circuit overcurrent protection device described in 52.1.6 (see 52.1.9); or

c) Opening of an internal fuse.

Exception No. 1: If the manually reset protector is a circuit breaker that complies with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489, it is to be operated for 3 cycles using the minimum resetting time but not at a rate faster than 10 cycles of operation per minute.

Exception No. 2: A manual reset protector that becomes inoperative in the open condition may be operated fewer than 10 cycles, but not less than 3 cycles.

52.1.8 revised January 5, 2000

52.1.9 With reference to 52.1.8 (b), if the branch circuit overcurrent protection device terminates the test, the instruction manual shall contain the information specified in 74.1.2 (ab).

52.2 Transformer burnout test

52.2.1 An adjustable resistive load is to be connected directly to the secondary winding of each transformer and adjusted to result in the load condition described in (a), (b), or (c). Opening of the intended branch circuit overcurrent protection device described in 52.1.6 or an internal overcurrent protection device connected in the primary-winding circuit is an acceptable termination of this test.

a) For a transformer having a single isolated secondary winding, the load is to be adjusted to result in maximum volt-ampere output but not resulting in more than three times the maximum normal alternating current to flow in the primary winding.

b) For a transformer having multiple isolated secondary windings, each secondary winding is to be tested separately; that is, with the winding under test loaded with an alternating current equal to three times the rms value of the secondary current flowing through that winding during maximum normal operation of the unit and the other isolated windings, each loaded with an alternating current equal to the rms value of the secondary current flowing through their respective windings during maximum normal operation of the UPS.

c) For an autotransformer, the conditions specified in (a) are to be used with the supply voltage connected to the outer input legs and the load resistor connected to the outer output legs. See Figure 52.1.

Exception No. 1: A transformer supplied from either an inverter circuit or other means limiting the current to the transformer to less than three times rated current is to be loaded to a condition resulting in maximum obtainable input current without operation of overcurrent protection devices, if any are present.

Exception No. 2: A transformer employed in a switch-mode inverter or converter circuit may be subjected to the transformer overload test described in 52.3.5 in lieu of the transformer burnout test.

Exception No. 3: Any transformer, including a control circuit transformer or a power transformer used for the transfer of either the input or output power of the UPS, having overcurrent protection described in 28.2.6 need not comply with this requirement.

Exception No. 4: A transformer that will be protected by the intended branch circuit protection device that is sized in accordance with the requirements in 28.2.6 and is provided in a unit marked in accordance with 74.1.2(ab) need not comply with this requirement.

Exception No. 5: In lieu of the transformer burnout test, an isolating power transformer may be used for the transfer of either the input or output power of the UPS and shall comply with the Standard for Specialty Transformers, UL 506 or the Standard for Dry-Type General Purpose and Power Transformers, UL 1561, or shall be subjected to the transformer overload and induced potential tests described in 47.5.1 – 47.5.5 and 52.3.1 – 52.3.4.

Exception No. 6: In lieu of the transformer burnout test, a transformer may be subjected to the transformer overload and induced potential tests described in 47.5.1 – 47.5.5 and 52.3.1 – 52.3.4.

Exception No. 7: In lieu of the transformer burnout test, an isolating power transformer may be used for the transfer of either the input or output power of the UPS complying with the requirements in either of the following standards:

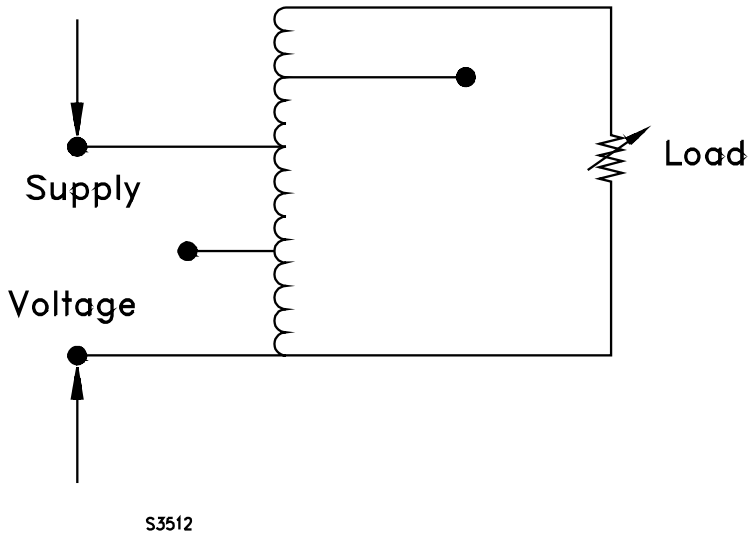
a) Class 2 and Class 3 Transformers, UL 1585;

b) Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411.

Exception No. 8: A signal or gate-drive transformer that is rated 10 watts or less and having a secondary circuit that does not extend out of the unit need not comply with this requirement.

Figure 52.1
Autotransformer burnout test[a]

Figure 52.1 revised November 17, 1997



[a] See 52.2.1(c) for description of test.

52.2.2 A ferro-resonant transformer is to be tested in accordance with 52.2.1 with the secondary winding loaded to maximum input current. The transformer is to be operated continuously until ultimate conditions are observed.

52.2.3 During the tests described in 52.2.1 and 52.2.2, secondary circuit protective devices that are external to the transformer are to be bypassed. Primary circuit protective devices are to be left in the circuit.

52.3 Transformer overload test

52.3.1 If an isolating power transformer is to be tested in accordance with Exception No. 6 to 52.2.1, then the tests described in 52.3.2 – 52.3.4 are to be conducted. If a transformer employed in a switch-mode inverter or converter circuit is to be tested in accordance with Exception No. 2 to 52.2.1, then the test described in 52.3.5 is to be conducted.

52.3.2 A resistive load is to be connected directly to each transformer secondary winding and adjusted to a value allowing each secondary winding to carry 50 percent of rated load until temperatures of the transformer core become stabilized. The load is then to be increased to 200 percent of the rated value; no further adjustment of the overload current is to be made. The duration of the overload is to be as specified in Table 52.2. The short circuit method as described in the Test Code for Dry-Type Distribution and Power Transformers, IEEE C57.12.91-1979 may be used to obtain the 200 percent of rated load current. If the short-circuit test method is used, all secondary windings are to be shorted and the voltage applied to the primary windings is to be adjusted to result in rated current to flow in the secondary windings.

52.3.3 With reference to the requirement in 52.3.2, testing of a transformer rated more than 500 kilovolt-amperes may be waived if:

a) The test has been performed with acceptable results on a smaller transformer rated not less than 500 kilovolt-amperes;

b) The smaller transformer has the same insulation system and same general construction as the larger transformer; and

c) The temperatures recorded during the temperature test are no greater for the larger transformer than those recorded during the temperature test for the smaller transformer.

52.3.4 Within 1 hour following the overload test, the transformer shall perform acceptably in:

a) A repeated dielectric voltage-withstand test except that the test value is to be at 65 percent of value specified in Section 47, Dielectric Voltage-Withstand Test; and

b) The induced potential test described in 47.5.1 – 47.5.5.

52.3.5 For a UPS tested in accordance with Exception No. 2 to 52.2.1, the power circuit supplied by the transformer is to be connected to a resistive load that will draw maximum obtainable output power without:

a) Causing operation of internal overcurrent protection devices or a protection circuit; or

b) Resulting in opening of a circuit component such as a diode, resistor, solid state device, or the like.

No Text on This Page

Table 52.2
Overload test times

Insulation class	Overload time, minutes
105	30
130	30
155	30
180	26
200	23
220	20

52.4 Output overload test

52.4.1 This test is to be conducted after thermal stabilization is reached during the mode of operation (see 44.1) that allows the output power to be delivered through the power conversion portion of the UPS. While delivering maximum rated output power to an adjustable resistive load connected to the output ac circuit, the UPS is to be subjected to the overload test described in 52.4.2.

52.4.2 The ac load is to be increased in increments of 10 percent of the maximum output rating of the UPS and held for 1/2 hour at each increment until:

a) Further change as a result of the test condition is not likely; or

b) The UPS transfers to the bypass mode.

Exception No. 1: Thermal stabilization may be obtained with a load adjusted to result in maximum obtainable output power without causing operation of overcurrent protective devices, followed by increased incremental loading as described above.

Exception No. 2: If the output power of a unit is not delivered through the power conversion portion of the unit during the normal mode of operation, the incremental loading is to be conducted in the reserve mode, following temperature stabilization in the normal mode.

52.5 Short circuit test

52.5.1 The direct current battery circuit and the alternating current output circuit of the UPS are to be shorted separately. For the alternating current output circuit, this test is to be conducted in the mode of operation (see 44.1) that allows output power to be delivered through the power conversion portion of the UPS. Shorting is to include from line to neutral (if provided) and from line to line.

Exception: A battery supply is considered to comply with the requirement if it complies with the following:

a) An overcurrent protection device is employed having a short-circuit interrupting rating not less than the maximum fault current available from the battery supply; and

b) The maximum current from the battery supply during the reserve mode (see 44.1) does not exceed the ampacity rating of the conductors connected to the batteries. Table 310-16 of the National Electrical Code, ANSI/NFPA 70-1993 is to be used for determining conductor ampacity.

52.5.2 With reference to the direct current battery circuit mentioned in 52.5.1, the test is to be conducted on the:

a) Battery circuit of a UPS having an integral battery supply;

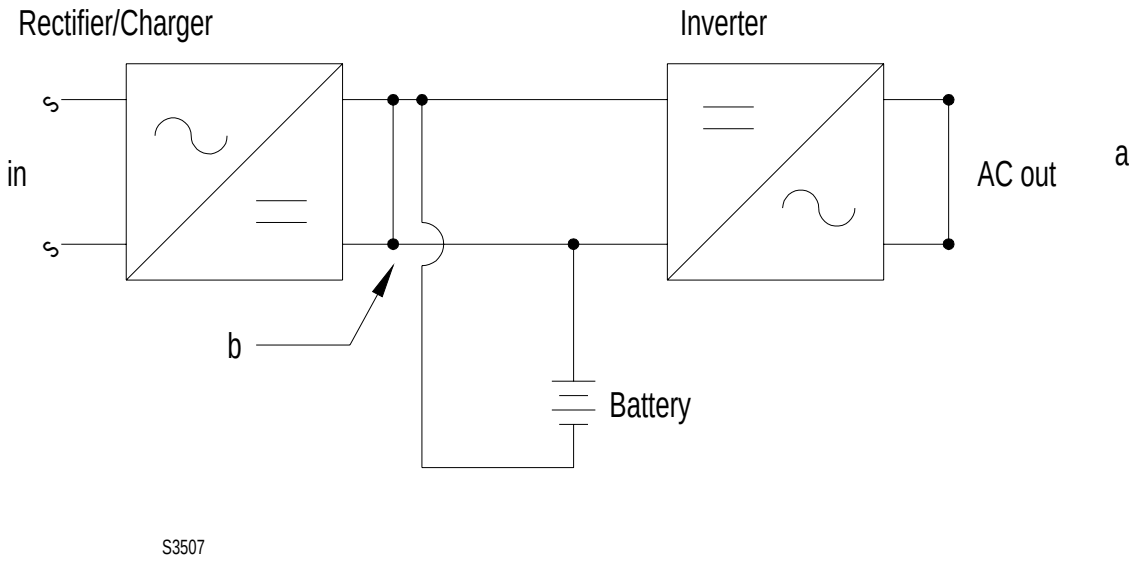
b) Direct current output of a UPS intended to be used with a remote battery supply; and

c) Direct current power circuit of a remote battery supply/cabinet assembly for use with a UPS and investigated under the requirements of this standard.

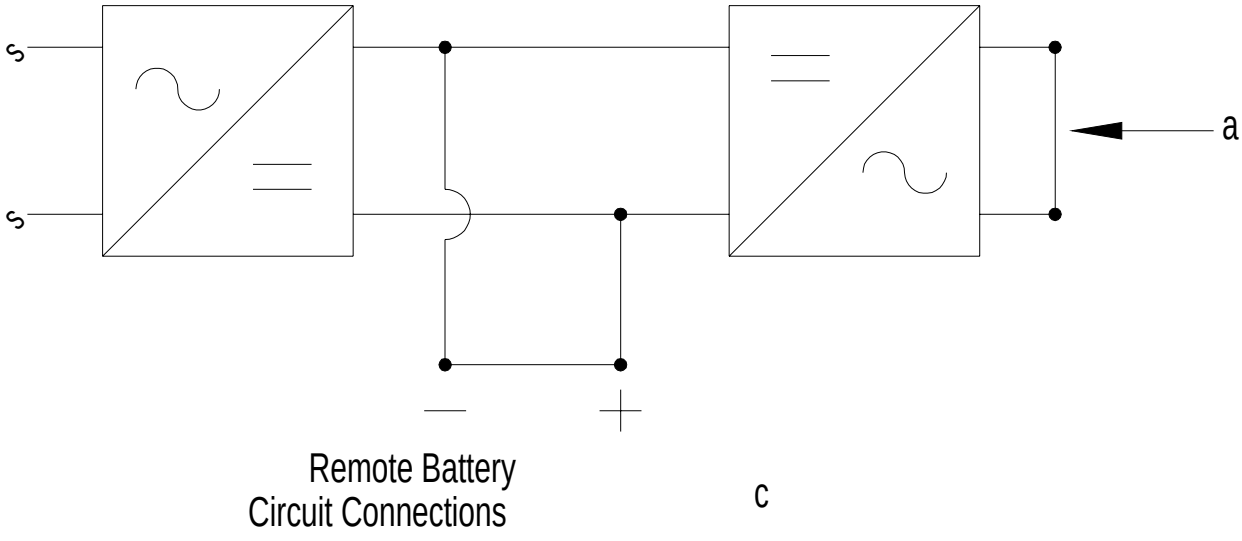
During the tests described by (a) and (c), batteries intended to be used with the UPS shall be used and are to be fully charged. During the test described by (b), batteries are not to be connected. The tests mentioned in (b) and (c) may be combined into one test with the batteries connected. See Figure 52.2.

Figure 52.2
Output short circuit tests

Figure 52.2 revised November 17, 1997

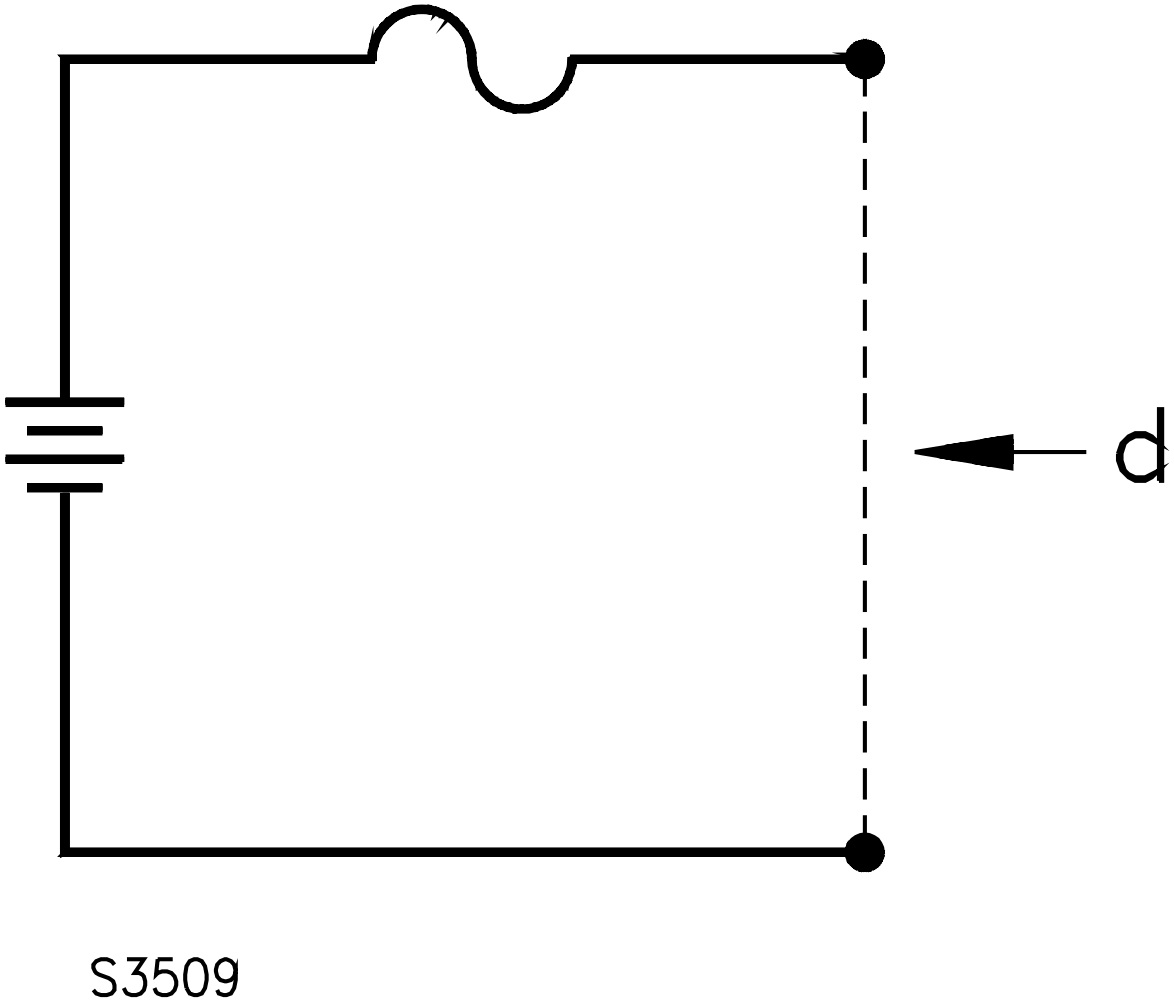


A unit having an integral battery supply per 52.5.2(b).



A unit intended to be used with a remote battery supply per 52.5.2(b).

Figure 52.2 (Cont'd)



A remote battery/supply cabinet per 52.5.2(c).

Notes – Short to be placed across:

a) ac output terminals

b) dc battery supply

c) Terminals of a UPS for connection to remote battery supply

d) Terminals of remote battery supply

52.6 Overcharge test

52.6.1 When connected to a supply circuit adjusted to 106 percent of the test voltage specified in 41.1, a battery supply of a UPS is to be subjected to 7 hours of overcharging using a fully charged battery. Any user adjustable controls associated with the charger or charging circuit are to be adjusted for the most severe charging rate.

Exception No. 1: This requirement does not apply to a UPS to be used with a battery supply that is not investigated with the UPS.

Exception No. 2: This requirement does not apply to a UPS provided with a regulating circuit preventing an increase in battery charging current when the ac input voltage is increased from rated value to 106 percent of rated value.

52.6.2 The most severe charging rate referred to in 52.6.1 is the maximum charging rate that does not cause a thermal or overcurrent protective device to open.

52.7 Capacitor surge current test

52.7.1 This test is conducted to determine compliance with the surge current protection requirement for the inverter storage capacitors mentioned in 28.5.1. With the input ac power to the UPS disconnected, the battery supply fully charged (see 52.7.2) and the inverter storage capacitors discharged, the battery supply voltage is to be applied to the inverter input circuit by closing the battery supply disconnect switch intended to be used with the UPS. This test is not required for a UPS:

a) Not having a manually operated battery supply disconnect switch; or

b) Having a battery supply disconnect switch that will not close onto the discharged capacitors without ac input power applied to the UPS.

52.7.2 With reference to 52.7.1, a dc power source other than batteries may be used provided that the source is capable of delivering an inrush current not less than that available from a fully charged battery supply.

52.8 Capacitor fault test

52.8.1 If required by Exception No. 2 to 31.6, a unit having a bottom-ventilated enclosure containing oil-filled capacitors shall be subjected to the performance tests specified for protected, oil-filled capacitors in the Standard for Capacitors, UL 810. These tests are to be conducted with the capacitors mounted in the unit enclosure as intended, and oil leakage from the capacitors passing through the enclosure, if any, shall be extinguished [see 52.1.3(a)].

52.9 Forced ventilation test

52.9.1 A UPS having forced ventilation is to be operated in the normal mode [see 44.1(d)] with the rotor of a blower motor locked. For a UPS having more than one blower motor, the test is to be conducted with the rotor of each blower motor locked, one at a time.

Exception: If agreeable to all concerned, all fan motors in a unit having more than one fan motor may be locked simultaneously.

52.9.2 A UPS having filters over ventilation openings is to be operated with the openings blocked to represent clogged filters. The test is to be conducted initially with the ventilation openings blocked approximately 50 percent, then to be repeated under fully blocked condition.

Exception: A single-fan unit with a filter need not be tested under the fully blocked condition.

52.9.3 The ventilating means for an enclosure or a compartment housing a battery shall comply with the requirements in 38.4.2, 38.4.4, and 38.4.5 under blocked fan and clogged filter conditions described in 52.9.1 and 52.9.2.

52.10 Component short- and open-circuit test

52.10.1 A component, such as a capacitor, diode, solid state device, or the like, connected in the input and output alternating current and direct current power circuits are to be short- or open-circuited, any two terminals one at a time, during any condition of operation including startup. This test is not required:

a) Where circuit analysis indicates that no other component or portion of the circuit will be overloaded; and

b) For electromagnetic radio frequency interference capacitors subjected to the dielectric voltage-withstand test described in Test No. 5 in Table 47.1, resistors, transformers, inductors, and optical isolators.

52.11 Electrolytic capacitor fault test

52.11.1 For a UPS having dc electrolytic inverter storage capacitors, the fault test described in 52.11.2 shall be conducted.

Exception: A capacitor complying with the requirements in the Standard for Capacitors, UL 810 need not comply. The capacitor shall have an available fault current rating of:

a) 10,000 amperes; or

b) A lower value where a circuit analysis indicates that because of a series impedance, the lower value is appropriate.

52.11.2 With reference to the requirement in 52.11.1, a fault in one of the capacitors in the inverter storage capacitor bank is to be simulated. This is to be accomplished by connecting the capacitor under test in reverse while the input ac supply to the UPS is not energized. The UPS is then to be energized followed by application of rated output load through the power conversion portion of the UPS.

52.12 Load transfer

52.12.1 For a bypass switch to be tested in accordance with the Exception to 12.9, the bypass alternating current source is to be displaced 120 electrical degrees from the alternating current output of the UPS for a 3-phase supply or 180 electrical degrees for a single phase supply. The transfer switch is to be subjected to one operation of switching the load from the alternating current output of the UPS to a bypass alternating current source. The load is to be adjusted to draw maximum rated alternating current power.

52.12.2 For a UPS employing a bypass switch having a control preventing switching between two ac sources out of synchronization, the test mentioned in 52.12.1 is to be conducted under the condition of a component failure (see 52.10.1) if such a condition can result in an out-of-phase transfer between the two ac sources of supply.

52.12.3 A solid state bypass switch shall continue to operate normally after completion of the test described in 52.12.1.

52.13 Mismatch voltage test

52.13.1 In accordance with the Exception to 15.4.7, a UPS equipped with an operator adjustable voltage selector shall be subjected to this test. The selector is adjusted to the lowest voltage within the selector range. The UPS is then connected and operated at the highest voltage within the selector range.

52.13.2 In accordance with 15.4.9, a portable or stationary UPS having an input rating of 208 volts, single phase and provided with an attachment plug rated 250 volts shall be connected to a 240 volt source of supply.

53 Flanged Bobbin Transformer Abnormal Test

53.1 A flanged bobbin transformer required to be tested as provided in (c) of Exception No. 1 to 26.2.3 (also see 26.2.4) shall operate for 15 days with the secondary winding or windings loaded to the conditions described below in (a) – (c). A risk of fire or electric shock shall not result from:

a) Short-circuiting the secondary winding;

b) Loading the secondary winding to a current equal to maximum normal current plus X percent of the difference between the short-circuit current and the rated current – where X equals 75, 50, 25, 20, 15, 10, and 5, respectively; and

c) Loading the secondary winding to maximum normal current.

Exception No. 1: A flanged bobbin transformer used in a circuit where isolation is not required or where the secondary circuit does not extend out of the unit (see 26.1.3) need not be subjected to this test.

Exception No. 2: A transformer is considered to comply with this requirement if it complies with the requirements in either of the following:

a) The Standard for Class 2 and Class 3 Transformers, UL 1585.

b) The Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411.

53.2 The results of the test are not acceptable when the cheesecloth glows or flames, or a breakdown occurs when the test is conducted.

53.2 revised January 11, 1999

53.3 Samples for the 15-day abnormal operation tests are to be prepared as follows:

a) The transformer is to be mounted either:

1) In the UPS enclosure as intended under the conditions described in 52.1.4; or

2) On a test bench with the cheesecloth mentioned in 52.1.4 draped over the transformer.

b) All secondary windings are to be loaded to rated current before the abnormal condition is introduced; and the loads, other than that connected to the winding to be overloaded, are not to be readjusted thereafter.

53.4 While still in a heated condition from the tests described in 53.1, a transformer shall withstand the dielectric voltage-withstand test described in Test No. 4 of Table 47.1. The dielectric voltage-withstand-test potential is to be applied to the transformer approximately 1 minute after completion of the abnormal-operation test.

53.5 The abnormal tests may be conducted with a protective device built into the transformer or with an external protective device used with the transformer in the UPS connected in either the primary or secondary circuit, or in both. A protective device that is relied upon to open the circuit as a result of an abnormal test is to be one that has been investigated and found to be acceptable for the purpose.

53.6 For the purpose of these requirements, each secondary winding tap and each primary winding tap that is used to supply power to a load in the UPS are considered to be the equivalent of a secondary winding.

53.7 For the sequence of tests described in 53.1, if an abnormal-operation test continues for 15 days without a winding or a protective device opening, the remaining tests need not be conducted. For example, if the test described in 53.1(a) continues for 15 days, the tests described in (b) and (c) need not be conducted.

53.8 To determine whether a transformer complies with the requirement in 53.1, three separate samples are to be subjected to each condition described in (a) – (c) of 53.1. For a transformer that employs more than one secondary winding, each of the secondary windings is to be loaded for each condition specified in 53.1 with the other windings loaded to rated current. The test conditions are to be as described in 53.9 – 53.13.

53.9 To determine the short-circuit current value for conducting the tests described in 53.1(b), the transformer is to be at room temperature at the beginning of the measurement, and the short-circuit current is to be measured approximately 1 minute after the voltage is applied to the primary winding. A protective device outside the transformer, if provided by the manufacturer, is to be short-circuited during the measurement of the short-circuit current. If the line fuse or transformer winding opens within 1 minute after the application of the primary voltage, the short-circuit current is considered to be that value recorded just before the line fuse or winding opens. The short-circuit current of any one winding is to be measured with the other secondary windings open-circuited.

53.10 For the loading conditions, a variable resistor is to be connected across the secondary winding. Each test described in 53.1(a) – (c) is to be continued until a risk of fire develops, the 3-ampere fuse opens, a winding of the transformer or a protective device opens or 15 days have passed. In conducting the tests described in 53.1(b) and (c), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, if necessary, 1 minute after voltage is applied to the primary winding.

Exception: For a switch-mode transformer, the load is to be connected to the output of the power supply connected to the transformer.

53.11 If short-circuiting the secondary winding causes one of the windings to open before 15 days, then the next test in the sequence described in 53.1(b) and (c) that continues for 15 days is to have the variable load resistor reduced to zero impedance at the end of the 15 days to cause the transformer to burn out.

53.12 For a transformer that is provided with a protective device built into the transformer or that is being tested in conjunction with an external protective device, a test described in 53.1(a) – (c) is to be discontinued if the protective device opens the circuit and the next test in the sequence is to be started. The protective device mentioned above includes automatic recycling type, manual reset type, or a replaceable type.

53.13 If a protective device opens the circuit or a winding on any sample opens during the 15-day abnormal- operation tests while the samples are unattended, the variable resistor load on the other samples is to be increased, by reducing the resistance, until the protective device opens the circuit or the winding opens, so that the samples may be subjected to the dielectric voltage-withstand test described in 53.4 while in a heated condition. The next test in the sequence in 53.1(b) and (c) that continues for 15 days is to be conducted.

54 Strain Relief and Flexing Tests

54.1 Strain relief

54.1.1 The strain relief means provided on a flexible cord or welding cable shall withstand for 1 minute without displacement a direct pull of 35 pounds (156 N) applied to the cord, with the connections within the UPS disconnected. The strain relief is not acceptable if, at the point of disconnection of the conductors, there is such movement of the cord as to indicate that stress on the connections may result.

Exception: A Class 2 transformer having an output cord for output connections is to be subjected to the strain relief test described in 54.1.2.

54.1.2 The strain-relief means provided for the output cord of a Class 2 transformer (as described in 2.10) shall withstand for 1 minute a direct pull of 20 pounds (89 N). The results are considered acceptable if, with the output cord connected internally, movement of the cord does not result in a reduction of spacings to primary or dead metal parts, damage to internal parts or enclosure, or interruption of the output-circuit wiring.

54.1.3 The weight is to be suspended from the cord and supported by the UPS so that the strain relief means will be stressed from any angle the construction of the UPS permits.

54.1.4 A wiring lead intended for field-wiring connection (see 15.1.14 and 15.1.16) shall withstand without damage or displacement a direct pull of:

a) 20 pounds (89 N) for 1 minute applied to a lead extending from the enclosure (such as through a knockout); and

b) 10 pounds (44.5 N) for 1 minute applied to a lead within a wiring compartment.

54.2 Flexing

54.2.1 With reference Exception No. 3 to 20.1.5, after the wiring has been subjected to flexing as described in 54.2.2, the unit shall be:

a) Subjected to the dielectric voltage-withstand test in Section 47; and

b) The wiring is to be examined for damage to determine if any conductors are broken or if individual strands have penetrated the insulation.

54.2.2 Wiring that is subjected to movement at times other than installation and servicing is to be tested by cycling the moving part through the maximum travel permitted by the construction. The duration of the test is to be 500 cycles.

54.3 Push-back relief

54.3.1 With reference to 15.5.3, a cord-connected UPS shall be tested in accordance with 54.3.2 without occurrence of any of the conditions specified in 15.5.3.

54.3.1 added January 11, 1999

54.3.2 The supply cord or lead is to be held 25 mm (1 inch) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing which extends further than 25 mm (1 inch) is present, it is to be removed prior to the test. When the bushing is an integral part of the cord, the test is to be carried out by holding the bushing. The cord or lead is to be pushed back into the product in 25-mm (1-inch) increments until the cord buckles or the force to push the cord into the product exceeds 27 N (6 pounds-force). The supply cord or lead within the product is to be manipulated to determine compliance with 54.3.1.

54.3.2 added January 11, 1999

55 Grounding Impedance Test

55.1 In accordance with 19.8, if penetration of nonconductive coatings cannot be determined by examination, a measurement of the grounding path resistance is to be made. The impedance at 60 hertz between the point of connection of the equipment-grounding means and the metal part that is required to be bonded to ground shall not be more than 0.1 ohm when measured in accordance with 55.2. The resistance of the equipment grounding conductor of a power supply cord shall not be included in the resistance measurement.

55.2 Compliance with 55.1 is to be determined by passing a current of 25 amperes derived from a 60 hertz source with a no-load voltage not exceeding 6 volts between the following points and measuring the voltage across these points:

a) The equipment grounding connection; and

b) The metal part in question.

56 Overcurrent Protection Calibration Test

56.1 A fuse, or circuit protective device, provided in the primary of a transformer for protection of the secondary circuit in accordance with 24.9 shall operate to open the circuit in not more than the time indicated in Table 56.1 when the transformer is delivering the specified secondary current.

56.2 To determine if a fuse or circuit protective device complies with the requirement in 56.1, the transformer is to deliver the test current to a resistance load with the primary connected to a circuit as described in 41.1. During the 2-minute test, the load is to be adjusted continuously to maintain the required test current. During the 60-minute test, the load is to be adjusted once after 15 minutes of operation and the test is to be continued without further adjustment.

56.3 If the fuse or circuit protective device is used to protect more than one secondary winding or taps, each winding or partial winding is to be tested as indicated in 56.1 or 56.2 with the remaining windings delivering rated load.

Table 56.1
Maximum acceptable time to open

Rated secondary potential, volts	Secondary test current, amperes	Maximum time for overcurrent protective device to open, minutes
20 or less	10	2
20 or less	6.75	60[a]
Over 20	$200/V_{max}$	2
Over 20	$135/V_{max}$	60[a]

[a] After 15 minutes of operation, the current is to be readjusted to the value shown.

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57 Battery Compartment Ventilation Test

57.1 If a measurement is needed to determine if a battery compartment complies with 38.4.5, the battery supply is to be subjected to the overcharge test in 52.6.1. During and at the conclusion of the test, the maximum hydrogen gas concentration shall not be more than 2 percent by volume. Measurements are to be made by sampling the atmosphere inside the battery compartment at periods of approximately 2, 4, 6, and 7 hours during the test. Samples of the atmosphere within the battery compartment are to be taken at the location where the greatest concentration of hydrogen gas is likely, using an aspirator bulb provided with the concentration measurement equipment, or other equivalent means.

58 Strength of Terminal Insulating Base and Support Test

58.1 In accordance with the requirement in 15.1.8, an insulating base or support and the bus or strap upon which pressure wire connectors for field wiring are mounted shall be subjected to the force created when the connectors, securing short lengths of conductors sized as described in 15.1.3, are torqued to 110 percent of the value marked on the unit. The results are acceptable if the base is not damaged as defined in 58.2.

Exception: The test is not required for wire connectors that are part of a component such as a terminal block, circuit breaker, switch, or the like.

58.2 With reference to 58.1, damage is considered to have occurred if the base insulating material cracks or rotates; bosses, recesses, or deforms in some way so as to prevent turning; does not perform its intended function; straps or bus bars bend or twist; or members other than the wire connector move at electrical joints. Minor chipping or flaking of brittle insulating material is acceptable if the performance is not otherwise impaired. Momentary flexing of metallic members without permanent deformation is acceptable.

59 Strength of Handles Test

59.1 A handle used to support or carry a unit is to withstand a load of four times the weight of the unit without damage to the handle, its securing means, or that portion of the enclosure to which the handle is attached.

59.2 To determine whether a unit complies with in 59.1, the load is to be uniformly applied over a 3-inch (76-mm) width at the center of the handle, without clamping. The load is to be started at zero and gradually increased so that the test value is attained in 5 to 10 seconds; the test value is to be maintained for 1 minute. If a unit has more than one handle and cannot be carried by one handle, the load is to be distributed between the handles. The distribution of the load is to be determined by measuring the percentage of the unit weight sustained by each handle with the unit in the normal carrying position. If a unit is furnished with more than one handle and can be carried by only one handle, each handle is to withstand the total load.

60 Mechanical Strength Tests for Metal Enclosures

60.1 In accordance with 23.1.4, an external metal enclosure of a unit intended for use in a controlled environment having reduced spacings between uninsulated live metal parts and the enclosure shall be subjected to the two tests described in 60.2 and 60.3. The tests shall not result in:

a) Permanent distortion to the extent that spacings are reduced below the values specified in 23.1.4;

b) Transient distortion that produces contact of the enclosure with uninsulated live parts other than those connected in a low-voltage circuit; and

c) Development of openings that expose uninsulated live parts that involve a risk of electric shock or electrical energy – high current levels. Any openings resulting from the tests are to be judged under the requirements in Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts – and User Servicing, Section 7.

60.2 For the first test specified in 60.1, the enclosure is to be subjected to a 25-pound force (111-N) for 1 minute. The force is to be applied to the outside of the enclosure at various locations likely to result in the greatest distortion or unacceptable results by means of a steel hemisphere 1/2 inch (12.7 mm) in diameter.

60.3 For the second test specified in 60.1, the enclosure is to be subjected to an impact of 5 foot-pounds (6.8 J). The impact is to be applied at various locations likely to result in the greatest distortion or unacceptable results by means of a smooth, solid, steel sphere 2 inches (50.8 mm) in diameter and having 1.18 pounds (535 g) mass. The sphere is to fall freely from rest through a vertical distance of 51 inches (1.29 m) at various locations on the outside of the enclosure. The method of test is to be as described in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

61 Evaluation of Reduced Spacings on Printed-Wiring Boards

61.1 General

61.1.1 In accordance with (a) in Exception No. 3 to 23.1.1, printed-wiring board traces of different potential having reduced spacings may be judged by conducting:

a) A dielectric voltage-withstand test described in 61.2.1 and 61.2.2 for a UPS investigated for use in a controlled environment; or

b) A shorted trace test described in 61.3.1 for a UPS investigated for use in either a controlled or general environment.

61.2 Dielectric voltage-withstand test

61.2.1 A printed-wiring board as mentioned in 61.1.1 shall withstand for 1 minute without breakdown the application of a dielectric withstand potential between the traces having reduced spacings in accordance with 47.1.1 and 47.1.2 or Table 47.2, as appropriate.

61.2.2 Power-dissipating component parts, electronic devices, and capacitors connected between traces having reduced spacings are to be removed or disconnected in such a manner that the spacings and insulations, rather than these component parts, are subjected to the full dielectric voltage-withstand test potential.

61.3 Shorted trace test

61.3.1 Printed-wiring board traces mentioned in 61.1.1 are to be short-circuited, one location at a time, and the test is to be conducted as described in 52.1.1 – 52.1.3, 52.1.5, 52.1.7, and 52.1.8. As a result of this test:

a) The overcurrent protection associated with the branch circuit to the UPS shall not open; and

b) A wire or a printed-wiring board trace shall not open.

If the circuit is interrupted by opening of a component, the test is to be repeated twice using new components, as necessary.

Exception: Opening of an internal overcurrent protective device is an acceptable result, and therefore the test need not be repeated.

62 Bonding Conductor Test

62.1 A bonding conductor that does not comply with 19.10(a) or (b) is acceptable if, using separate samples for each test, neither the bonding conductor nor the connection opens when:

a) Carrying currents equal to 135 and 200 percent of the rating or setting of the intended branch-circuit overcurrent-protective device for the times specified in Table 62.1; and

b) Three samples are subjected to a limited-short-circuit test using a test current as specified in Table 62.2 while connected in series with a nonrenewable fuse having a rating equal to the intended branch-circuit overcurrent-protective device.

Exception: If a fuse that is smaller than that indicated in (a) and (b) is employed in the unit for protection of the circuit to which the bonding conductor is connected, then the magnitude of the test current and size of fuse used during the test may be based on the rating of the smaller fuse.

62.2 The test circuit described in 62.1(b) is to have a power factor of 0.9 – 1.0 and a closed-circuit test voltage as specified in 41.1. The open-circuit voltage is to be 100 – 105 percent of the closed-circuit voltage. Each test is to be performed on each of the three samples.

Table 62.1
Duration of overcurrent test

Rating or setting of branch-circuit overcurrent protective device, amperes	Test time, minutes	
	135 percent of current	200 percent of current
0 – 30	60	2
31 – 60	60	4
61 – 100	120	6
101 – 200	120	8

Table 62.2
Circuit capacity for bonding conductor short-circuit test

Rating of unit, volt-ampere		Volts	Capacity of test circuit, amperes
Single phase	3-phase		
0 – 1176	0 – 832	0 – 250	200
0 – 1176	0 – 832	251 – 600	1000
1177 – 1920	833 – 1496	0 – 600	1000
1921 – 4080	1497 – 3990	0 – 250	2000
4081 – 9600	3991 – 9145	0 – 250	3500
9601 or more	9146 or more	0 – 250	5000
1921 or more	1497 or more	251 – 600	5000

63 Stability Test

63.1 Under all conditions of servicing and intended use after installation, a fully assembled portable or stationary unit shall not become physically unstable to the degree that an injury to operators or service personnel may result. A stationary unit intended to be fastened in place is considered to comply with this requirement.

63.2 A unit is not to be energized during the stability test. The test is to be conducted under conditions most likely to cause the product to overturn. The following conditions are to be such as to result in the least stability:

a) Position of all doors, drawers, casters, moveable battery supporting trays with batteries installed, and other movable or adjustable parts, including that of the supply cord resting on the surface supporting the unit;

b) Connection of or omission of any attachment made available by or recommended by the manufacturer;

c) Provision of or omission of any normal load if the product is intended to contain a mechanical load;

d) Direction in which the unit is tipped or the supporting surface is inclined; and

e) With or without batteries installed, whichever represents the most severe condition.

63.3 With reference to 63.2(a), if casters are used only to transport the unit and jacks are lowered after installation, then the jacks – not the casters – are to be used in the most unfavorable position for the test, consistent with reasonable leveling of the unit.

63.4 In conducting the stability test, the UPS is to be:

a) Placed on a plane inclined at an angle of 10 degrees from the horizontal; or

b) Tipped through an angle of 10 degrees from an at rest position on a horizontal plane.

63.5 With reference to the requirement in 63.4(b), for a unit that is constructed so that while being tipped through an angle of 10 degrees a part or surface of the UPS not normally in contact with the horizontal supporting surface touches the supporting surface before the UPS has been tipped through an angle of 10 degrees, the tipping is to be continued until the surface or plane of the surface of the UPS originally in contact with the horizontal supporting surface is at an angle of 10 degrees from the horizontal supporting surface.

64 Impact on Glass Covered Openings

64.1 With reference to 5.7.1(c), a glass covered opening shall withstand a 2-1/2 foot-pound (3.38 J) impact without cracking or breaking to the extent that a piece is released or dropped from its normal position.

64.2 The impact specified in 64.1 is to be applied by means of a smooth, solid steel sphere 2 inches (50.8 mm) in diameter and having 1.18 pounds (535 g) mass. The sphere is to fall freely from rest through a vertical distance of 25 inches (63.5 cm).

65 Impact Test – Guards Over Moving Parts

65.1 In accordance with 5.1.5, a part of a unit as described in 5.1.1 and 5.1.4 is to be subjected to an impact of 5 foot-pounds (6.8 J) on any surface that may be exposed to a blow during normal use. This impact is to be produced by dropping a steel sphere, 2 inches (50.8 mm) in diameter and weighing 1.18 pounds (535 g), from a height of 51 inches (1.29 m) to produce the 5-foot-pound impact. For surfaces other than the top, the steel sphere is to be suspended by a cord and allowed to swing as a pendulum, dropping through a vertical distance of 51 inches to strike the surface.

65.2 A unit is to be subjected to the impact test described in 65.1 with or without any attachment recommended by the manufacturer so as to result in the most severe test.

65.3 If a part as mentioned in 5.1.1 is made of a polymeric material, the impact test is to be first conducted on a sample or samples in the as-received condition. The test is then to be repeated on a different sample or samples that have been cooled to room temperature after being conditioned for 7 hours in an air oven operating at 10°C (18°F) higher than the maximum operating temperature of the material, but not less than 70°C (158°F). While being conditioned, a part is to be supported in the same manner in which it is supported on the UPS.

65.4 Upon being removed from the oven mentioned in 65.3 and before being subjected to the impact test, no sample shall show signs of checking, cracking, or other deleterious effects from the oven conditioning, and no sample shall be distorted so as to result in a risk of injury to persons.

65.5 After the impact test required by 65.1, any openings resulting from the test shall comply with the accessibility requirements described in Section 7.

66 Heat Sink Temperature Cycling Test

66.1 If required by Exception No. 2 to 21.3.1, a current-carrying, aluminum heat sink shall be subjected to the test described in 66.2 and 66.3.

66.2 Three samples of the heat sink/solid state component assemblies are to be subjected to this test. After completion of the 500th cycle described in 66.3, a temperature of the solid state component for each sample shall not be more than 15°C (27°F) higher than the temperature during the 24th cycle and neither temperature shall be more than the rating of the solid state component.

66.3 The samples are to be subjected to 500 cycles of current-on and current-off operations. During the current-on time, the samples are to be carrying maximum rated current. The duration of the current-on and current-off times shall be the length of time required to reach stable temperatures. Stable temperatures are considered to be obtained when three successive readings taken at not less than 10 minute intervals indicates no more than 2°C (3.6°F) variation between any two readings. Forced-air cooling may be employed to reduce the current-off time with the concurrence of those concerned.

67 Tests for Permanence of Cord Tag

67.1 General

67.1.1 In accordance with 72.1.3 or 72.2.22, the tests described in 67.3.1 shall be conducted on a power-supply-cord tag containing markings. Representative samples that have been subjected to these tests shall meet the following requirements:

a) The tag shall resist tearing for longer than 1/16 inch (1.6 mm) at any point;

b) The tag shall not separate from the power supply cord;

c) The tag shall not slip or move along the length of the power supply cord more than 1/2 inch (12.7 mm);

d) There shall be no permanent shrinkage, deformation, cracking, or any other condition that will render the marking on the tag illegible; and

e) Overlamination shall remain in place and not be torn or otherwise damaged. The printing shall remain legible.

67.2 Test conditions

67.2.1 Nine samples of the tag applied to the power-supply cord in the intended manner are to be tested. If tags are applied by an adhesive, tests are to be conducted no sooner than 24 hours after application of the tag. The samples are to be conditioned as follows:

a) Three of the samples are to be tested as received.

b) Three samples are to be tested at the end of 30 minutes of conditioning at a room temperature of 23 ±2°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity, following conditioning in an air-circulating oven at 60 ±1°C (140 ±1.8°F) for 240 hours.

c) The remaining three samples are to be tested within 1 minute after exposure for 72 hours to a humidity of 85 ±5 percent at 32 ±2°C (89.6 ±3.6°F).

67.3 Test method

67.3.1 Each sample is to consist of a length of power supply cord to which the tag has been applied. The power supply cord, with the attachment plug or connector pointing up, is to be held tautly in a vertical plane. A force of 5 pounds (22.2 N) is to be applied for 1 minute to the uppermost corner of the tag farthest from the power supply cord, within 1/4 inch (6.4 mm) of the vertical edge of the tag. The force is to be applied vertically downward in a direction parallel to the major axis of the cord. In determining compliance with 67.1.1(d), manipulation is permissible, such as straightening of the tag by hand. To determine compliance with 67.1.1(e), each sample is to be scraped 10 times across printed areas and edges, with a force of approximately 2 pounds (8.9 N), using the edge of a 5/64 inch (2.0 mm) thick steel blade held at a right angle to the test surface.

68 Ignition Test Through Bottom-Panel Openings

68.1 General

68.1.1 In accordance with Exception No. 3 to 5.10.1, a ventilated, bottom-panel construction may be judged by conducting the tests described in 68.2.1 – 68.2.4.

68.2 Hot, flaming oil test

68.2.1 Openings in a bottom panel shall be so arranged and sufficiently small in size and few in number that hot, flaming No. 2 fuel oil (see 68.2.3) poured three times onto the openings from a position above the panel is extinguished as it passes through the openings.

68.2.2 A sample of the complete, finished bottom panel is to be supported in a horizontal position a short distance above a horizontal surface under a hood or in another area that is ventilated but free from drafts. Bleached cheesecloth running 14 – 15 square yards to the pound (28 – 30 m^2/kg mass) and having, for any square inch (6.4 cm^2), 32 threads in one direction and 28 in the other, is to be draped in one layer over a shallow, flat-bottomed pan that is of a size and shape to cover completely the pattern of openings in the panel but is not sufficiently large to catch any of the oil that runs over the edge of the panel or otherwise does not pass through the openings. The pan is to be positioned with its center under the center of the pattern of openings in the panel. The center of the cheesecloth is to be 2 inches (50.8 mm) below the openings. Use of a metal screen or wired-glass enclosure surrounding the test area is recommended to reduce the likelihood of splattering oil, causing injury to persons.

68.2.3 A small metal ladle no more than 2-1/2 inches (63.5 mm) in diameter, with a pouring lip and a long handle whose longitudinal axis remains horizontal during pouring, is to be partially filled with 10 cubic centimeters of No. 2 fuel oil, which is a medium-volatile distillate having a minimum API gravity of 30 degrees, a flash point of 110 – 190°F (43.3 – 87.7°C), and an average calorific value of 136,900 Btu per gallon (38.2 MJ/L) (see the American Society for Testing and Materials Specification for Fuel Oils, ASTM D396-1992). The ladle containing the oil is to be heated and the oil is to be ignited. The oil is to flame for 1 minute and then is to be poured at the approximate rate of, but no less than, 1 cubic centimeter per second in a steady stream onto the center of the pattern of openings from a position 4 inches (102 mm) above the openings. It is to be observed whether the oil ignites the cheesecloth.

68.2.4 Five minutes after completion of the pouring of the oil, the cheesecloth is to be replaced with a clean piece and a second 10 cubic centimeter of hot, flaming oil is to be poured from the ladle onto the openings, and it is again to be observed whether the cheesecloth is ignited. Five minutes later, a third identical pouring is to be made. The openings are not acceptable if the cheesecloth is ignited in any of the three pourings.

69 Tests on Transformer Insulating Materials

69.1 If required by Table 26.1(c) or (g), the transformer insulating material shall be subjected to the test described in 69.2.

69.2 The insulating material is to be placed between two opposing electrodes. The electrodes are to be cylindrical brass or stainless steel rods 1/4 inch (6.4 mm) in diameter with edges rounded to a 1/32-inch (0.8-mm) radius. The upper movable electrode is to weigh 50 ±2 grams to exert sufficient pressure on the specimen to provide good electrical contact. The test potential is to be increased to the test value and the maximum test potential is to be maintained for 1 second. The result is acceptable if there is no dielectric breakdown.

70 Bus Bar Tests

70.1 An aluminum bus bar employing a coating mentioned in Exception No. 3 of 21.2.1 or a bus bar that has a clamped joint construction permitted by Exception Nos. 2 and 3 of 21.2.3 and 21.2.4, respectively, is to be subjected to the tests described in 70.2 – 70.4.

70.2 The temperature of the bus bar joint is to be measured during the temperature test described in Section 45, Temperature Test, and shall comply with the maximum temperature specified in Table 45.2.

70.3 The temperature rise at the joint during the five hundredth cycle shall not be more than 15°C (27°F) higher than the temperature rise at the end of the twenty-fifth cycle.

70.4 The test sample is to consist of an assembly of bus bars connected together to form a series circuit. The bus bars are to be clamped together with the joint construction used in actual production. The number and size of the bus bar are to represent the maximum ampere rating and the maximum current density in which the joint construction is employed. This may necessitate more than one test. The length of each bus bar is to be 2 feet (609 mm). The bus bar is to be connected to a power supply by any convenient means that will not affect the joint temperature. The power supply is to be adjusted to deliver a value of current that will result in a temperature of 75°C (135°F) above room temperature at the joint. The assembly is then to be subjected to a 500-cycle test. At the end of the 24th cycle, the current is to be readjusted to bring the temperature of the joint to 75°C above room temperature; and this current value is to be maintained for the remainder of the cycling test. At the end of the 25th and 500th cycles, the temperatures are to be recorded. The temperatures are to be measured on both sides of the joint as close as possible to the bolt or rivet. The cycling rate is to be 3 hours on and 1 hour off. The on period during which temperatures are recorded may be extended to more than 3 hours if necessary for the joint to attain thermal equilibrium.

Exception: The length of the bus bar may be less than 2 feet with the concurrence of those concerned.

70A Maximum Output VA Measurement Test

70A.1 If required by (b) in Exception No. 1 to 13.5, a unit is to be subjected to this test. While simulating a utility power outage, the inverter portion of the UPS is to receive power from the fully charged, intended battery bank. The battery supply is to be loaded at rated load, but not more than 750 VA. The battery current and voltage are to be monitored during this test. The maximum available VA measured at five minutes shall not exceed 750 VA.

Added 70A.1 effective February 1, 1999

70B Emergency DC Power Off Test

70B.1 If connection to a remote emergency power off circuit is required (see 13.5), then the unit is to be subjected to this test. While simulating the operation of a remote emergency power off switch, the inverter portion of the UPS is to receive power from either a fully charged battery bank or an external dc source of supply. The unit is to be operated at rated output ac load. The output battery current is to be monitored. Within five minutes of operating the remote emergency power switch, the output battery current shall be zero.

Added 70B.1 effective February 1, 1999

RATING

71 Details

71.1 A unit shall have the following ratings:

a) Input voltage;

b) Number of phases for input and output, except for a unit obviously intended for single-phase use only;

c) Input and output frequency;

d) Input in amperes (see 71.3), volt-amperes, or kilovolt-amperes;

e) Output voltage; and

f) Output in amperes, volt-amperes, or watts.

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71.2 The a-c output rating of a unit shall include a power factor, if less than unity unless the rating is expressed in:

a) Watts and volt-amperes; or

b) Watts and amperes.

71.3 With reference to 71.1(d), the rms value of the input current is to be used. For a UPS intended to be connected to a 3-phase, 4-wire source of supply, the phase currents and also the neutral current shall be included.

71.4 The dc circuit of a unit intended to be used with a remote battery supply and a remote battery supply/cabinet assembly shall have the following ratings:

a) Nominal dc voltage; and

b) Nominal dc current. The value used shall be determined by either of the following:

1) Measured value of battery current during reserve mode of operation, as described in 44.1(b), when the output voltage of the battery supply equals the nominal voltage rating of the battery supply, or

2) Calculated from the following expression:

$$I = \frac{W}{NV}$$

in which:

I = Nominal dc battery current in amperes;

W = Battery power output in watts, measured when the UPS is delivering rated output power during the reserve mode of operation – see 44.1*(b);*

N = Total number of battery cells in a series string; and

V = Nominal voltage rating of battery cells. For lead-acid and alkali type batteries, V = 2.0 and 1.2, respectively.

71.5 The electrical rating of a unit shall include the following:

a) The electrical rating for a 3-phase UPS that is limited to either a delta or wye connection for the supply or load circuit shall indicate the phase configuration; and

b) The electrical rating for a UPS having a 3-phase output or a single-phase output with a neutral conductor shall indicate the unbalanced load capability of the UPS.

Exception: Units which are tested at 100 percent of the output current rating of the UPS and are found to comply with Section 45, Temperature Test, and Section 46, Load Temperature Test (if applicable) need not indicate the unbalanced load capability of the UPS.

MARKING

72 Details

72.1 General

72.1.1 Unless otherwise stated, all markings are required to be permanent, that is, either by being molded, die-stamped, paint-stenciled; stamped or etched metal that is permanently secured; or indelibly stamped on a pressure-sensitive label secured by adhesive that, upon investigation, is found to comply with the requirements in the Standard for Marking and Labeling Systems, UL 969.

72.1.2 A unit shall be plainly and permanently marked where it will be readily visible, after installation, with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the UPS may be identified;

b) A distinctive catalog number or the equivalent;

c) The electrical ratings specified in Section 71; and

d) The date or other dating period of manufacture not exceeding any three consecutive months.

Exception No. 1: The manufacturer's identification may be in a traceable code if the unit is identified by the brand or trademark owned by a private labeler.

Exception No. 2: The date of manufacture may be abbreviated, or be in a nationally accepted conventional code, or in a code affirmed by the manufacturer, provided that the code:

a) Does not repeat in less than 20 years; and

b) Does not require reference to the production records of the manufacturer to determine when the unit was manufactured.

72.1.3 Markings may be located on a tag that is attached to the power supply cord and complies with the requirements in Section 67, Tests for Permanence of Cord Tag.

72.1.4 With reference to the requirement in 72.1.2(c), the symbols described in (a) – (c) may be used for markings:

a) A circuit intended to be connected to a direct-current supply shall be identified by markings indicating that the supply shall be direct current. The symbol illustrated in Figure 72.1 may be used for this marking. See 72.1.5.

b) A circuit intended to be connected to an alternating-current supply shall be identified by markings indicating that the supply shall be alternating current. The markings shall include the supply-circuit frequency or supply-circuit frequency-range rating (cycles per second, cycles/second, hertz, c/s, cps, or Hz). The symbol illustrated in Figure 72.2 may be used for this marking. See 72.1.5.

c) The number of phases shall be indicated if the unit is designed for use on a polyphase circuit. The symbol illustrated in Figure 72.3 may be used in place of the word ″phase.″ See 72.1.5.

Figure 72.1
Direct current supply symbol

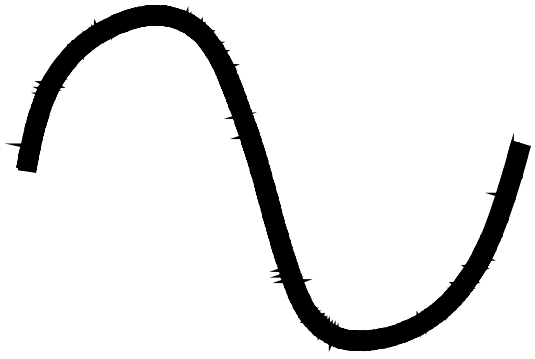
Figure 72.1 revised November 17, 1997

IEC5031

IEC Publication 417, Symbol 5031

Figure 72.2
Alternating current supply symbol

Figure 72.2 revised November 17, 1997

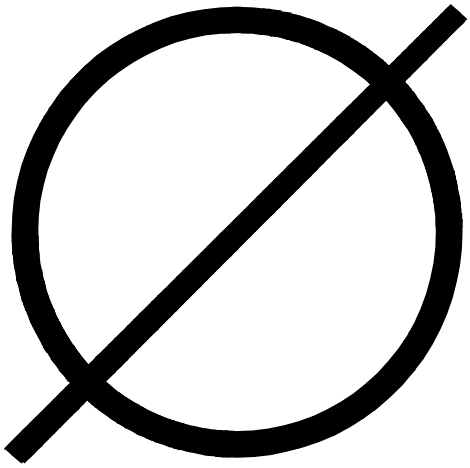


IEC5032

IEC Publication 417, Symbol 5032

Figure 72.3
Phase symbol

Figure 72.3 revised November 17, 1997



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72.1.5 If the symbol referenced in 72.1.4(a), (b), or (c) is used, the information described in 74.1.2(h) shall be provided.

72.1.6 If a unit is produced or assembled at more than one factory, each unit shall have a distinctive marking – which may be in code – by which it may be identified as the product of a particular factory.

72.1.7 The operating positions of a handle, knob, or other means intended for manual operation by the user shall be marked.

72.1.8 Wiring terminals shall be marked to indicate the proper connections for the unit, or a wiring diagram coded to the terminal marking shall be securely attached to the equipment.

72.1.9 Equipment field-wiring terminals shall be marked:

a) ″Use Copper Conductors Only″ if the terminal is acceptable only for connections to copper wire.

b) ″Use Aluminum Conductors Only″ or ″Use Aluminum or Copper-Clad Aluminum Conductors Only″ if the terminal is acceptable only for connection to aluminum wire.

c) ″Use Copper or Aluminum Conductors″ or ″Use Copper, Copper-Clad Aluminum, or Aluminum Conductors″ if the terminal is acceptable for connection to either copper or aluminum wire.

72.1.10 In accordance with 18.16, a pressure wire connector intended for connection of an equipment-grounding conductor shall be identified by:

a) Being marked ″G,″ ″GR,″ ″GND,″ ″Ground,″ ″Grounding,″ or the like;

b) A marking on a wiring diagram attached to the unit; or

c) The symbol illustrated in Figure 72.4 on or adjacent to the connector or on a wiring diagram provided on the unit. See 72.1.11.

72.1.11 With reference to 72.1.10(c), the following requirements apply when the symbol illustrated in Figure 72.4 is used:

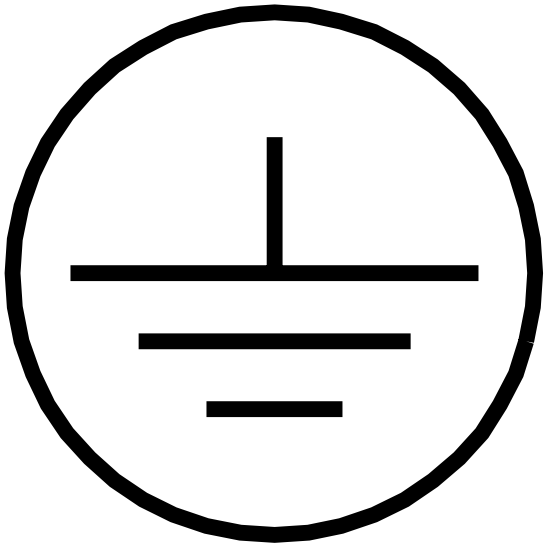
a) The information described in 74.1.2(h) shall be provided in the instruction manual.

b) The symbol may be used for identifying only the field wiring equipment grounding terminal. However, a symbol as shown in Figure 72.4 except with the circle omitted, may be used for identifying various points within the unit that are bonded to ground.

Exception: If the symbol illustrated in Figure 72.4 is used with one of the other means of identification specified in 72.1.10(a) and (b), the information need not be provided.

Figure 72.4
Symbol for equipment grounding conductor

Figure 72.4 revised November 17, 1997



IEC Publication 417, Symbol 5019

72.1.12 A terminal for the connection of a grounded conductor shall be identified by means of a metallic plated coating substantially white in color, and shall be readily distinguishable from the other terminals; or proper identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as:

a) A marking on the unit;

b) An indication on a wiring diagram attached to the unit; or

c) Information provided in the instruction manual.

If field wiring leads are provided, the lead intended to be grounded shall have a white or natural gray color and shall be readily distinguishable from other leads.

72.1.13 A terminal in a fixed unit, as described in 17.7, that is intended for connection to the grounding electrode conductor shall be marked ″Grounding Electrode Terminal.″

72.1.14 A UPS intended for use with a remote battery supply and a remote battery supply/cabinet assembly investigated and found suitable for use with reduced wire size for the battery supply circuit in accordance with Exception No. 1 to 15.1.3 shall be marked indicating the minimum wire size to be used for connections to the battery supply circuit.

72.1.15 A unit employing pressure terminal connectors for field wiring connections shall be provided with a marking making reference to the instruction manual for the tightening torque to be applied to the wiring terminals. See 74.1.2(f).

72.1.16 A UPS intended to be used with a remote battery supply shall be plainly marked indicating the polarity of the connections between the battery supply and the UPS with:

a) The words ″positive″ and ″negative;″

b) The signs ″+″ for positive and ″–″ for negative;

c) The color coding red for a positive lead and black for a negative lead; or

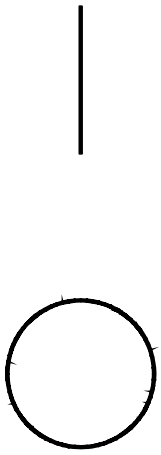
d) A pictorial representation illustrating the proper polarity, orientation, and the like of the battery supply, as applicable for the type of battery supply involved. See 72.1.4(a).

72.1.17 A multiple-voltage unit for permanent connection to the branch circuit supply shall be marked to indicate the particular voltage for which it is set when shipped from the factory. The marking may be in the form of a paper tag or any other nonpermanent material. Stationary and portable unit shall be provided with instructions in accordance with 74.1.2(g).

72.1.18 Both the on and off positions of the disconnect control devices mentioned in Section 13, Disconnection Device, or the main disconnect switch on portable equipment, if provided, shall be identified. The symbols illustrated in Figure 72.5 may be used for this purpose. Identification only by illumination is not acceptable. See 72.1.19.

Figure 72.5
On and off symbols

Figure 72.5 revised November 17, 1997



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IEC Publication 417, Symbols 5007 and 5008

72.1.19 If the symbol illustrated in Figure 72.5 is used in accordance with 72.1.18, the information described in 74.1.2(h) shall be provided.

72.1.20 With reference to the Exception to 15.4.7, a unit with an operator adjustable voltage selector switch shall be marked to instruct the operator to set the voltage selector to the voltage to which the unit will be connected.

72.1.21 A clock, timing device, or alarm circuit on or remote from a unit that remains energized with a voltage exceeding the values specified in Table 8.1 during servicing functions shall be marked to indicate that the circuit remains energized while the unit is off.

72.1.21 revised February 1, 1996

72.1.22 In accordance with 13.2(d), a marking shall be provided identifying the disconnect switch or breaker for the output ac and dc power circuits.

72.1.23 A unit not furnished with a detachable power supply cord as described in the Exception to 15.4.8 shall be marked adjacent to the appliance coupler or at an equivalent location to inform the user to see the instruction manual [see 74.1.2(n)] for proper selection of the power-supply cord.

Exception: The marking may be in the form of a tag, nonpermanent label, or product insert that is provided on or packaged with the unit so that the marking is visible at the time of installation.

72.1.24 In accordance with 5.2.1, individual modules of a modular UPS shall be marked with:

a) Information identifying the module such as ″rectifier/charger section of Model XYZ UPS″ or ″inverter section of Model XYZ UPS″ or the equivalent; and

b) A reference to the installation instructions.

The marking may be in the form of a paper tag or any other nonpermanent material. See 74.1.2(q).

72.1.25 If required by 15.1.17, a unit containing a field-wiring lead that is connected to a wire binding screw located in the field-wiring compartment shall be marked with information clearly indicating the intended use of the lead.

72.1.26 Low-voltage Class 2 field-wiring leads, color coded in accordance with the exception in 18.9, shall be identified. The marking shall not require the use of a separate wiring diagram to make proper connections.

72.1.27 A unit may be marked ″Suitable for computer-room applications″ or the equivalent provided that internal combustible materials comply with the flammability requirements in Section 36, Flammability Classification of Internal Materials, and if applicable, 5.6.4, and 5.6.5.

72.1.28 A UPS having an output ac circuit that is intended to be grounded in the field shall be marked with the following or equivalent words: ″The output ac circuit is considered as a separately-derived source. If local codes require grounding of this circuit, use terminal (identify terminal) for bonding this circuit to the enclosure. Ground the enclosure to a suitable grounding electrode in accordance with local code requirements.″

72.1.29 A unit investigated for use in a controlled environment specified in 23.1.3 and in accordance with the exception to 43.1 shall be marked with the following or equivalent words: ″Intended for installation in a controlled environment.″ See 74.1.2(z). The marking shall be located outside the unit.

Exception: For a fixed unit, the marking may be located internally in a location visible where field wiring connections are made.

72.1.30 Units in accordance with Exception No. 2 of 40.1 shall have the following or equivalent marking on the unit: ″For use with (manufacturer's name and model) ____* only,″ where the space shall indicate the specific product used.

72.1.30 revised and separated into 72.1.30 and 72.1.31 February 1, 1996

72.1.31 Units in accordance with Exception No. 3 of 40.1 shall have the following or equivalent marking on this unit: ″For use with ____* loads only,″ where the space shall indicate the generic type of device used (such as computer loads, electronic data processing load, and the like).

72.1.30 revised and separated into 72.1.30 and 72.1.31 February 1, 1996

72.1.32 If required by Exception No. 5 to 40.1, then a unit shall be marked to indicate that it is for use with Cable TV equipment.

72.1.32 added February 1, 1996

72.1.33 If required by 29.3, a marking shall reference the instruction manual [see 74.1.2(ae)] and shall indicate that the breaker is to be provided by the installer.

72.1.33 added February 1, 1996

72.1.34 When required by 3.1.5, telecommunication type connectors and terminals not intended for connection to the telecommunication network shall be:

a) Provided with a marking identifying the specific function or circuit characteristics intended;

b) Marked ″Not for telecommunication (telephone) network″ or equivalent wording; or

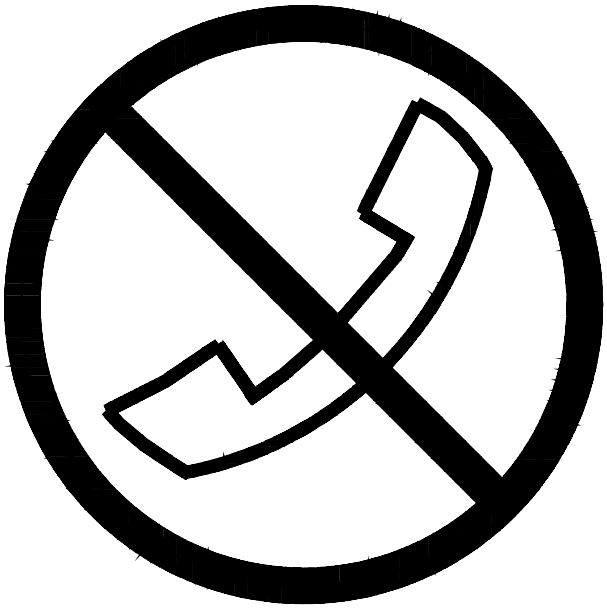
c) Marked with the symbol in Figure 72.5A. (See 74.1.2(ac).)

The marking shall be located in a readily visible location adjacent to the connector.

Added 72.1.34 effective January 11, 2001

Figure 72.5A
Symbol for ″no telecommunication connection″

Added Figure 72.5A effective January 11, 2001



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72.2 Cautionary markings

72.2.1 The words ″CAUTION,″ ″WARNING,″ OR ″DANGER″ in a cautionary marking shall be in letters not less than 1/8 inch (3.2 mm) high. The remaining letters in a cautionary marking shall not be less than 1/16 inch (1.6 mm) high.

72.2.2 A cautionary marking shall be:

a) Located on a part that cannot be removed without impairing the operation of the UPS; and

b) Visible and legible to the operator during normal operation of the unit.

72.2.3 A cautionary marking pertaining to internal parts that is applicable only to service personnel are to be located internally in an appropriate location with respect to the parts of concern.

72.2.4 A cautionary marking for a stationary unit that is not intended to be fastened in place and has an input rating of 20 amperes or less, 125 volts maximum, may be marked as specified in 72.2.5 with one marking on the bottom of the unit and the second referral marking visible to the operator during normal operation of the unit.

72.2.5 If required by 72.2.4, a unit shall be marked ″CAUTION – Risk of electric shock″ and the following words or the equivalent ″Refer to bottom of unit for cautionary markings.″ This marking shall be visible to the operator during normal operation of the unit.

72.2.6 A live heat sink or other part that is likely to be mistaken for dead metal, is considered to render a risk of electric shock or electrical energy – high current levels, and is not guarded as specified in 39.7 shall be marked with the word ″CAUTION″ and the following or the equivalent: ″Risk of electric shock (or fire as appropriate) – Plates (or other word describing the type of part) are live. Disconnect UPS before servicing.″ The marking shall be located on or near the live part so as to make the risk of fire or electric shock known before the part is likely to be touched. A single marking for multiple number of parts may be used.

72.2.7 A fixed unit that exceeds the temperature limits specified in the third item in Table 45.1 (see the Exception to 45.2) shall be legibly marked externally where readily visible after installation with the word ″CAUTION″ and the following or the equivalent ″Hot surfaces – To reduce the risk of burns – Do not touch.″

72.2.8 A UPS intended to be connected to more than one input ac source of supply or to an external battery supply shall be marked ″CAUTION – Risk of electric shock″ and the following or the equivalent: ″This UPS receives power from more than one source – disconnection of (the) (all) ac sources(s) (and the dc source) is required to de-energize this unit before servicing.″ The marking shall be either located on the outside of the unit or shall be prominently visible with any cover or panel opened or removed.

72.2.9 A UPS having an internal battery supply shall be marked ″CAUTION – Risk of electric shock″ and the following words or the equivalent: ″Hazardous live parts inside this UPS are energized from the battery supply even when the input ac power is disconnected.″ The marking shall be located either on the outside of the UPS or inside the UPS if it is prominently visible with any cover or panel opened.

72.2.10 A UPS provided with single-pole circuit breakers in the input circuit in accordance with the Exception to 28.1.6 shall be marked internally with the word ″CAUTION″ and the following or the equivalent: ″To reduce the risk of electric shock and fire – Do not connect to a circuit operating at more than 150 volts to ground.″

72.2.11 A unit indicated in (a) or (b) shall be externally marked with the word ″CAUTION″ and the following warning or equivalent: ″Risk of electric shock, do not remove cover. No user serviceable parts inside. Refer servicing to qualified service personnel.″ This marking applies to the following units:

a) A unit having an access cover that is not hinged and complies with Exception No. 2 in 5.3.1; and

b) A stationary unit having an input rating of 20 amperes or less, 125 volts maximum.

72.2.12 There shall be a marking for each fuse that is used to comply with the requirements in this standard, indicating the ampere, voltage, and ac or dc rating of the fuse to be used for replacement. The marking shall be located so that it is obvious as to which fuse or fuseholder the marking applies. This marking may consist of a pictorial identifying the rating of one or more fuses. In addition, the following prominent marking shall be provided – a single marking is acceptable for a group of fuses – with the word ″WARNING″ and the following or the equivalent: ″To reduce the risk of fire, replace only with same type and ratings of fuse.″

Exception: Fuses that are secured by solder need not comply with this requirement.

72.2.13 A removable panel covering a capacitor in accordance with Exception No. 1 to 31.7 shall be marked ″CAUTION – Risk of electric shock″ and the following or equivalent wording: ″Capacitor stores hazardous energy. Do not remove cover until ___ minutes after disconnecting all sources of supply.″ The time indicated in the marking is to be whatever time needed to discharge the capacitor to within the limitations specified in 31.7, but not greater than 5 minutes.

72.2.14 If required by Exception No. 2 in 31.7, a UPS shall be marked ″CAUTION – Risk of electric shock and/or electric energy-high current levels″ and the following or equivalent wording: ″Disconnect and discharge (identify capacitor) before removing panel as follows.″ Appropriate instructions shall follow indicating how to disconnect and discharge the capacitor. The procedure indicated shall be limited to functions such as operating a switch, unplugging a connector, or the equivalent.

72.2.15 Ungrounded dead metal parts mentioned in (f) of the Exception to 19.2 shall be plainly marked with the word ″CAUTION″ and the following or the equivalent: ″(Identify part or parts not earth grounded) (is) (are) not grounded – (it) (they) may present risk of electric shock. Test before touching.″ The marking shall be provided on or adjacent to the ungrounded dead metal parts and shall be visible so that each part or group of parts is positively identified.

72.2.16 A UPS or a battery supply cabinet assembly containing batteries having an output voltage exceeding 60 volts shall be marked with the word ″DANGER″ and the following or the equivalent: ″Risk of electric shock. Do not touch uninsulated battery terminal.″ The marking shall be provided in the compartment containing the batteries.

72.2.17 For a remote battery supply/cabinet assembly having a grounded battery circuit, the enclosure door for the battery supply shall be marked ″CAUTION – Risk of Electric Shock″ and the following or equivalent wording ″Battery supply circuit is grounded. Refer to instruction manual before working on batteries.″

72.2.18 A UPS having internal batteries or a battery supply/cabinet assembly shall be marked with the word ″WARNING″ and with the following or equivalent: ″To reduce risk of injury to persons, do not smoke, strike a match, or cause a spark in the vicinity of this battery compartment.″ The marking shall be located on the outside of the battery compartment enclosure.

Exception: A UPS or battery supply/cabinet assembly employing valve-regulated or sealed batteries need not be so marked.

72.2.19 A unit incorporating an overcurrent protective device in the grounded circuit conductor as specified in (d) of Exception No. 2 in 28.1.8 shall be plainly marked with the word ″CAUTION″ and the following or the equivalent: ″Risk of electric shock. Grounded circuit conductor (neutral) provided with overcurrent protection. Test components before touching.″ The marking shall be readily visible to service personnel servicing the unit.

72.2.20 A UPS having a low-voltage battery supply without transformer isolation in accordance with the Exception in 38.7.1 shall be marked ″CAUTION″ and the following or the equivalent: ″Risk of Electric Shock – Battery Circuit is not isolated from ac input, hazardous voltage may exist between battery terminals and ground. Test before touching.″ The marking shall be provided internally adjacent to the batteries.

72.2.21 In accordance with 15.4.9(b), a cord connected UPS having a rating of 208 volts and provided with an attachment plug for an input cord or cord connector for an output cord rated 250 volts shall be marked as specified in 72.2.22 and 72.2.23.

72.2.21 revised February 1, 1996

72.2.22 With reference to 72.2.21, the input power supply cord shall be provided with a tag that is permanently attached to the cord. The marking shall indicate: ″CAUTION″ and the following or the equivalent: ″To reduce the risk of fire and electric shock, connect this unit to a receptacle wired for 208 volts ac.″ The tag material and means of attachment to the power supply cord shall be judged under the requirements in Section 67, Tests for Permanence of Cord Tag.

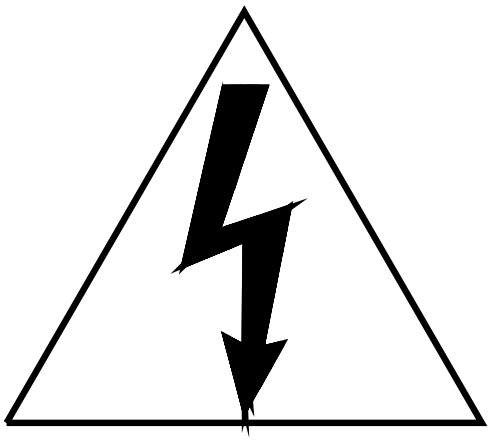
72.2.23 With reference to 72.2.21, a UPS having an output rating of 208 volts, single phase and provided with an output receptacle rated 250 volts shall be marked: ″CAUTION″ and the following or the equivalent: ″Output of this UPS is rated 208 volts.″ The marking shall be located adjacent to the receptacle.

72.2.24 If required by Exception No. 3 in 31.7, a marking shall be provided indicating ″CAUTION – Risk of electric shock or electric energy-high current levels″ and the following or the equivalent: ″Dangerous electric charge may be stored in (identify capacitor) and associated circuitry. Test before touching.″ The marking shall be located internally adjacent to the capacitor.

72.2.25 With reference to the requirements in 72.2.6, 72.2.8, 72.2.9, 72.2.11, 72.2.13, 72.2.15 – 72.2.17, 72.2.19, and 72.2.20, the symbol illustrated in Figure 72.6 may be used in place of the cautionary statement ″Risk of electric shock.″ The other markings required by the referenced paragraphs shall be provided in addition to the symbol. If the symbol is used, the information described in 74.1.2(ac) shall be provided in the instruction manual.

Figure 72.6
Symbol for ″risk of electric shock″ statement

Figure 72.6 revised November 17, 1997



SA1965

IEC Publication 417, Symbol 5036

INSTRUCTIONS

73 Instruction Manual

73.1 A UPS and, if investigated separately under the requirements in this standard, a remote battery supply/cabinet assembly or maintenance bypass cabinet assembly shall be provided with an instruction manual as described in 73.2 – 73.6. The instructions shall be legible and shall contrast with the background.

73.2 The instruction manual shall describe the practices to be followed during battery installation and maintenance of the UPS and batteries as described in Section 74, Important Safety Instructions.

73.3 The instruction manual for a UPS intended to provide power to cable TV equipment shall contain the installation instructions described in Section 75, Installation Instructions for Cable TV Uninterruptible Power Supplies.

73.4 The important safety instructions shall appear before the preliminary guidelines for battery installations, the battery installation procedures and maintenance.

73.5 The headings for the instruction manual, and the opening statements of the instructions specified in Section 74, Important Safety Instructions, ″IMPORTANT SAFETY INSTRUCTIONS″ and ″SAVE THESE INSTRUCTIONS″ – shall be entirely in upper case letters not less than 3/16 inch (4.8 mm) high or emphasized to distinguish them from the rest of the text. Upper case letters in the instructions shall not be less than 5/64 inch (2.0 mm) high, and lower case letters shall not be less than 1/16 inch (1.6 mm) high.

73.6 There shall be no substitute for the words ″CAUTION,″ ″WARNING,″ or ″DANGER″ in the text of the instructions.

Exception: The words ″WARNING″ or ″DANGER″ may be used in lieu of the word ″CAUTION.″

74 Important Safety Instructions

74.1 General

74.1.1 The instruction manual shall include important safety instructions as detailed in 74.1.2. The statement ″IMPORTANT SAFETY INSTRUCTIONS,″ and the statement ″SAVE THESE INSTRUCTIONS″ shall precede the list. The word ″CAUTION″ shall be entirely in upper case letters.

74.1.2 The information described in (a) – (ae), as appropriate, shall be provided for a UPS, a remote battery supply/cabinet assembly, and a maintenance bypass cabinet assembly. A single installation manual may be used for a UPS investigated in combination with a remote battery supply/cabinet or maintenance bypass cabinet assembly. The information contained in (c) – (ae) may be marked on the unit in lieu of providing it in the instruction manual.

IMPORTANT SAFETY INSTRUCTIONS

a) SAVE THESE INSTRUCTIONS – This manual contains important instructions for Models _____ (blank space is to be filled in with appropriate model numbers) that should be followed during installation and maintenance of the UPS and batteries.

Exception: If the instructions are exactly the same for all models, specific model numbers need not be specified.

No Text on This Page

b) In accordance with 15.1.7, if pressure terminal connectors or the fastening hardware are not provided on the UPS as shipped, the instruction manual shall indicate which pressure terminal connector or component terminal assemblies are for use with the UPS.

c) With reference to (b), the terminal assembly packages and the instruction manual shall include information identifying wire size and manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified.

d) If a pressure terminal connector provided in the unit [or in a terminal assembly covered in 15.1.7(d)] for a field installed conductor requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any necessary instructions for using the tool shall be included in the instruction manual.

e) A unit provided with a wire connector for field installed wiring as covered in Exception No. 2 to 15.1.14 shall be provided with instructions specifying that the connector provided is to be used in making the field connection.

f) A unit employing pressure terminal connectors for field wiring connections shall be provided with instructions specifying a range of values or a nominal value of tightening torque to be applied to the clamping screws of the terminal connectors. The minimum specified tightening torque shall not be less than 90 percent of the value specified in Table 74.1 or Table 74.2 as applicable for the wire size determined by the requirement described in 15.1.3.

Exception: The torque value may be less than 90 percent if the connector is investigated in accordance with the lesser assigned torque value in either:

a) The Standard for Wire Connectors and Soldering Lugs for Use With Copper Conductors, UL 486A;

b) The Standard for Wire Connectors for Use With Aluminum Conductors, UL 486B; or

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

g) In accordance with 72.1.17, the instruction manual for stationary and portable units having multiple input voltage ratings shall include information indicating the type of attachment plug that is to be used for connection to a voltage supply other than what the UPS is set for when it is shipped from the factory. The attachment plug referenced in the instructions shall comply with 15.4.4.

h) If a symbol is used for compliance with marking requirements mentioned in 72.1.5, 72.1.11, or 72.1.19, the instruction manual shall identify the symbol.

i) The instruction manual for a unit that exceeds the temperature limits in the third item of Table 45.1 (see the Exception to 45.2) shall specify that the unit is to be installed so that it is not likely to be contacted by people.

j) For a UPS having primary circuit filtering to meet EMC regulations and is required to comply with (b)(4) in the Exception to 42.1, the instruction manual shall include mention of all the following conditions of installation:

1) An insulated grounding conductor that is identical in size, insulation material, and thickness to the grounded and ungrounded branch-circuit supply conductors except that it is green with or without one or more yellow stripes is to be installed as part of the branch circuit that supplies the unit or system.

2) The grounding conductor described in (1) is to be grounded to earth at the service equipment or, if supplied by a separately derived system, at the supply transformer or motor-generator set.

3) The attachment-plug receptacles in the vicinity of the unit or system are all to be of a grounding type, and the grounding conductors serving these receptacles are to be connected to earth ground at the service equipment.

k) The instruction manual for a UPS having an internal battery supply or a battery supply/cabinet assembly shall indicate the nominal voltage rating of the battery supply.

Exception: A unit marked as specified in 72.2.11 need not comply with this requirement.

l) In accordance with 74.2.3 and 74.3.1, the instruction manual for a UPS intended to be used with a remote battery supply that is not provided with the UPS shall make reference to the battery manufacturer's installation manual for battery installation and maintenance instructions.

m) In accordance with note 4 in Table 28.2, the instruction manual for a UPS having an input ac rating of 5 kilovolt-amperes or larger and intended to be used with a battery supply contained in a remote room shall indicate the maximum available fault current from the battery supply and the dc voltage rating of the battery supply overcurrent protective device that is to be installed near the battery supply.

n) In accordance with the Exception in 15.4.8 and 72.1.23, the instruction manual for a UPS intended for use with a detachable power supply cord but is not provided with the unit shall contain complete instructions concerning proper selection of the power supply cord. The instructions shall comply with the requirements in 15.4.2 – 15.4.7.

o) In accordance with 45.13, the instruction manual for a UPS having an ambient temperature rating higher than 25°C (77°F) shall indicate the maximum ambient temperature rating.

p) In accordance with the Exception in 38.1.1, the instruction manual for a unit having an integral battery compartment that is not provided with the batteries, or battery cabinet that is not provided with the batteries shall specify the manufacturer's name and catalog number of batteries that may be used with the product. The specified batteries shall comply with the requirements in 38.5.1.

q) In accordance with 5.2.1 and 72.1.24, instructions for field assembly of modules of a modular unit, including an interconnection wiring diagram, shall be either:

1) Packaged with the modules; or

2) Contained in the instruction manual provided that the marking on the module makes reference to the instruction manual.

r) If required by Exception No. 2 in 13.1, the instruction manual shall include a statement indicating that a disconnect switch shall be provided by others for the circuit – ac output or dc output – not having a disconnect switch.

s) If required by note 5 of Table 28.2, the instruction manual shall include a statement indicating that overcurrent protection for the battery circuit is to be provided by others.

t) If required by Exception No. 1 to 28.3.1, the instruction manual shall include a statement indicating that overcurrent protection for the output ac circuit is to be provided by others.

u) For a unit having a single equipment field-wiring terminal that is intended for connection of more than one conductor, the instruction manual shall include information identifying the number of conductors and range of conductor sizes.

v) For a unit provided with field-wiring terminals or leads, the instruction manual shall include the information indicated in Row 1, 2, 3, or 4 of Table 74.3 or with equivalent wording, if it is:

1) Intended for use on a supply circuit rated 110 amperes or less; or

2) Intended for field connection with No. 1 AWG (42.4 mm^2) or smaller conductors.

w) For a unit provided with field-wiring terminals or leads, the instruction manual shall include the information indicated in Row 3 or 4 of Table 74.3, or with equivalent wording, if it is:

1) Intended for use on a supply circuit rated more than 110 amperes; or

2) Intended for field connection with conductors larger than No. 1 AWG (42.4 mm^2).

x) If required by the Exception to 15.3.1, the instruction manual shall include a statement indicating that Class 1 wiring methods are to be used for field wiring connections to terminals of a Class 2 circuit.

y) If required by 7.16, the instruction manual shall include instructions for battery installation and replacement.

z) The instruction manual for a unit investigated for use in a controlled environment specified in 23.1.3 and in accordance with the Exception in 43.1 shall indicate that the unit is intended for installation in a temperature-controlled, indoor area free of conductive contaminants.

aa) The instruction manual for a 3-phase UPS shall include the following electrical ratings:

1) Delta or wye phase configuration if the UPS is limited to only one configuration; and

2) Unbalanced load capability if the output has a neutral conductor.

ab) The instruction manual for a unit described by (1) or (2) below shall include the word ″CAUTION″ and the following or equivalent: ″To reduce the risk of fire, connect only to a circuit provided with _____ amperes maximum branch circuit overcurrent protection in accordance with the National Electrical Code, ANSI/NFPA 70.″ The blank space is to be filled in with the appropriate ampere rating of branch circuit overcurrent protection described in 52.1.6.

1) In accordance with 52.1.9, if an abnormal test is terminated by operation of the intended branch circuit overcurrent protective device; or

2) In accordance with Exception No. 3 to 28.3.5, if the a-c input overcurrent protection is relied upon for protection of an a-c output receptacle.

ac) If a symbol is used for compliance with marking requirements mentioned in 72.2.6, 72.2.8, 72.2.9, 72.2.11, 72.2.13, 72.2.15 – 72.2.17, 72.2.19, and 72.2.20, the instruction manual shall illustrate and explain the meaning of the symbol; for example, the lightning flash with arrowhead within a triangle is intended to tell the user that parts inside the product are a risk of shock to persons. See Figure 72.6

ad) In accordance with Exception No. 2 to 40.1, the instruction manual for a UPS tested with a specific product (see 72.1.30) to determine the effects of harmonic voltage distortion shall identify the load equipment intended to be used with the UPS by the manufacturer's name and model designation.

ae) In accordance with 72.1.33, instructions shall be provided which explain how to install a remote shunt-trip circuit breaker for a unit which is intended to be used with this type of breaker.

74.1.2 revised November 17, 1997

Table 74.1
Tightening torque for pressure wire connectors having screws[a]

Table 74.1 revised November 17, 1997

Size of wire that is to be used for connection of the unit		Tightening torque, pound-inches (N·m)			
		Slotted head No. 10 (4.7 mm) and Larger[b]		Hexagonal head - external drive socket wrench	
AWG /kcmil	mm^2	Slot width – 0.047 inch (1.2 mm) or less, and slot length – 1/4 inch (6.4 mm) or less	Slot width – over 0.047 Inch (1.2 mm), and slot length – over 1/4 inch (6.4 mm)	Split-bolt connectors	Other connections
18 – 10	0.82 – 5.3	20 (2.3)	35 (4.0)	80 (9.0)	75 (8.5)
8	8.4	25 (2.8)	40 (4.5)	80 (9.0)	75 (8.5)
6 – 4	13.3 – 21.2	35 (4.0)	45 (5.1)	165 (18.6)	110 (12.4)
3	26.7	35 (4.0)	50 (5.6)	275 (31.1)	150 (16.9)
2	33.6	40 (4.5)	50 (5.6)	275 (31.1)	150 (16.9)
1	42.4	–	50 (5.6)	275 (31.1)	150 (16.9)
1/0 – 2/0	53.5 – 67.4	–	50 (5.6)	385 (43.5)	180 (20.3)
3/0 – 4/0	85.0 – 107.2	–	50 (5.6)	500 (56.5)	250 (28.2)
250 – 350	127 – 177	–	50 (5.6)	650 (73.4)	325 (36.7)
400	203	–	50 (5.6)	825 (93.2)	325 (36.7)
500	253	–	50 (5.6)	825 (93.2)	375 (42.4)
600 – 750	304 – 380	–	50 (5.6)	1000 (113.0)	375 (42.4)
800 – 1000	406 – 508	–	50 (5.6)	1100 (124.3)	500 (56.5)
1250 – 2000	635 – 1016	–	–	1100 (124.3)	600 (67.8)

[a] Connectors having a clamping screw with multiple tightening means (for example, a slotted, hexagonal head screw) are to be tested using both values of torque.

[b] For values of slot width or length not corresponding to those specified, select the largest torque value associated with the conductor size. Slot width is the nominal design value. Slot length is to be measured at the bottom of the slot.

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Table 74.2
Tightening torque for pressure wire connectors having internal drive socket head screws

Socket size across flats,		Tightening torque,	
inch	(mm)[a]	pound-inches	(N·m)
1/8	(3.2)	45	(5.1)
5/32	(4.0)	100	(11.4)
3/16	(4.8)	120	(13.8)
7/32	(5.6)	150	(17.0)
1/4	(6.4)	200	(22.6)
5/16	(7.9)	275	(31.1)
3/8	(9.5)	375	(42.4)
1/2	(12.7)	500	(56.5)
9/16	(14.3)	600	(67.8)

[a] See note a in Table 74.1 for screws with multiple tightening means.

74.2 Batteries

74.2.1 The information described in 74.2.4 and 74.3.1 shall be provided for a:

a) UPS having internal batteries;

b) Remote battery supply investigated under the requirements in this standard; and

c) UPS intended for use with batteries to be located in a remote battery room where the batteries are furnished with the UPS.

This information may be in a manual separate from that required in 74.1.2 provided that the information in 74.1.2(a) is repeated for the separate manual.

Exception: The instruction manual for a unit marked as specified in 72.2.11 need not be provided with the information specified in 74.2.4 and 74.3.1.

74.2.2 The text of these instructions shall be verbatim, or in equally definitive terminology. The parenthetical statements describing the applicability of the requirement is not to be included in the instruction manual.

74.2.3 For a UPS not having internal batteries or intended for use with a remote battery supply that is not provided with the UPS, the information mentioned in 74.1.2(l) shall be included in the instruction manual.

Table 74.3
Termination markings

Temperature rating of wire that is intended to be used for connection of the unit	Copper conductors only	Aluminum conductors or copper-clad conductors[a]
60 or 75°C	″Use either No. ____[b] AWG, 60°C or No. ___[c] AWG, 75°C copper wire″	Row 1 ″Use 60°C wire, either No. ___[b] AWG copper or No. ___[b] AWG aluminum; or 75°C wire, either No. ___[c] AWG copper or No. ___[c] AWG aluminum″
60°C	″Use No. ___[b] AWG, 60°C copper wire″	Row 2 ″Use 60°C wire, either No. ___[b] AWG copper or No. ___[b] AWG aluminum″
75°C	″Use No. ___[c] AWG, 75°C copper wire″	Row 3 ″Use 75°C wire, either No. ___[c] AWG copper or No. ___[c] AWG aluminum″
90°C	″Use No. ___[c] AWG, 90°C copper wire″	Row 4 ″Use 90°C wire, either No. ___[c] AWG copper or No. ___[c] AWG aluminum″

[a] Reference to copper wire is not to be included if wiring terminals are suitable for only the conductors specified in 72.1.9(b).

[b] The wire size for 60°C wire need not be included in the marking; however, if it is included, it shall be based on the ampacities given in Table 310-16 of the National Electrical Code, ANSI/NFPA 70-1993, for 60°C wire and the derating factor described in 15.1.3.

[c] The conductor size shall be no smaller than the larger of the following:

1) The conductor size used for the temperature test (see 45.5); or

2) The 75°C wire size based on the ampacities given in Table 310-16 of the National Electrical Code, ANSI/NFPA 70-1993, and the derating factor described in 15.1.3.

74.2.4 In accordance with 74.2.1, the information described in (a) – (e) shall be included in the instruction manual:

a) Servicing of batteries should be performed or supervised by personnel knowledgeable of batteries and the required precautions. Keep unauthorized personnel away from batteries.

Exception: The instruction manual need not contain instructions for user replacement of batteries in accordance with 74.1.2(y).

b) When replacing batteries, replace with the same number of the: _____ (blank space is to be filled in with information identifying the manufacturer's name and cat. no. designation of the batteries used with the UPS or remote battery supply).

c) CAUTION – Do not dispose of battery or batteries in a fire. The battery may explode.

d) CAUTION – Do not open or mutilate the battery or batteries. Released electrolyte is harmful to the skin and eyes. It may be toxic.

e) CAUTION – A battery can present a risk of electrical shock and high short circuit current. The following precautions should be observed when working on batteries:

1) Remove watches, rings, or other metal objects.

2) Use tools with insulated handles.

3) Wear rubber gloves and boots.

4) Do not lay tools or metal parts on top of batteries.

5) Disconnect charging source prior to connecting or disconnecting battery terminals.

6) Determine if the battery is inadvertently grounded. If inadvertently grounded, remove source of ground. Contact with any part of a grounded battery can result in electrical shock. The likelihood of such shock will be reduced if such grounds are removed during installation and maintenance (applicable to a UPS and a remote battery supply not having a grounded supply circuit).

Exception: The words "electrical shock" and the precautions stated in (3) – (6) may be omitted for battery supplies rated 60 volts or less.

74.2.4 effective December 6, 1994

74.3 Vented batteries

74.3.1 The information described in (a) and (b) shall be provided for a UPS and a remote battery supply having vented batteries. The text of these instructions shall be verbatim, or in equally definitive terminology. The parenthetical statements describing the applicability of the requirement is not to be included in the instruction manual. For a UPS not having internal batteries or intended for use with a remote battery supply that is not provided with the UPS, the information mentioned in 74.1.2(l) shall be included in the instruction manual.

a) CAUTION – The electrolyte is a dilute sulfuric acid that is harmful to the skin and eyes. It is electrically conductive and corrosive. The following procedures should be observed:

1) Wear full eye protection and protective clothing.

2) If electrolyte contacts the skin, wash it off immediately with water.

3) If electrolyte contacts the eyes, flush thoroughly and immediately with water. Seek medical attention.

4) Spilled electrolyte should be washed down with a suitable acid neutralizing agent. A common practice is to use a solution of approximately one pound (500 grams) bicarbonate of soda to approximately one gallon (4 liters) of water. The bicarbonate of soda solution should be added until the evidence of reaction (foaming) has ceased. The resulting liquid should be flushed with water and the area dried.

b) CAUTION – Lead-acid batteries can present a risk of fire because they generate hydrogen gas. The following procedures should be followed:

1) DO NOT SMOKE when near batteries.

2) DO NOT cause flame or spark in battery area.

3) Discharge static electricity from body before touching batteries by first touching a grounded metal surface.

75 Installation Instructions for Cable TV Uninterruptible Power Supplies

75.1 In accordance with 73.3, the Instruction Manual for a UPS intended to supply power to cable TV equipment shall include the instructions for proper installation. The text of these instructions shall be verbatim as described in the following (a) – (d) or in equally definitive terminology and shall appear under the heading of Installation Instructions:

a) A service disconnect switch having overcurrent protection is to be connected between the UPS and the utility transformer.

b) A bucket truck and other suitable equipment, including climbing spikes and safety harness are to be used during installation or servicing of the UPS on the utility pole.

c) The utility power conductors are to be connected to this UPS through an appropriate service entrance weather head.

d) Permission to mount the UPS on the utility pole shall be in accordance with agreements between the cable company and the utility company.

MANUFACTURING AND PRODUCTION TESTS

76 Production-Line Dielectric Voltage-Withstand Test

76.1 As a routine production-line test, each unit shall withstand without electrical breakdown the application of an alternating-current potential at a frequency within the range of 40 – 70 hertz or a direct-current potential:

a) Between the primary wiring, including connected components, and accessible dead metal parts that are likely to become energized; and

b) Between primary wiring and accessible low-voltage – 42.4 volts peak, 60 volts, dc or less – metal parts, including terminals and connector contacts.

76.2 The test duration and potential shall be as described in either condition A or B of Table 76.1.

76.3 The test potential can be gradually increased to the required value but the full value is to be applied for 1 second or 1 minute, as required.

76.4 The unit can be at intended operating temperature, at room temperature, or at any intermediate temperature for the test.

Table 76.1
Production test condition

Unit voltage rating, volts	Condition A			Condition B		
	Test potential, volts ac	Test potential, volts dc	Time, seconds	Test potential, volts ac	Test potential, volts dc	Time, seconds
Rated 250 or less	1000	1400	60	1200	1700	1
Rated more than 250	1000+2V[a]	1400+2.8V[a]	60	1200+2.4V[a]	1700+3.4V[a]	1

[a] Maximum marked voltage.

76.5 The test shall be conducted when the unit is fully assembled. It is not intended that the UPS be unwired, modified, or disassembled for the test.

Exception No. 1: Parts such as snap covers or friction-fit knobs that interfere with performance of the test need not be in place.

Exception No. 2: The test can be performed before final assembly if the test is equivalently representative of the completed unit. Any component not included shall not affect the results with respect to determination of possible electric shock from miswiring, defective components, unacceptable spacings, and the like.

Exception No. 3: Solid state components that might be damaged by a secondary effect (induced voltage surge, excessive heating, and the like) of the test may be short-circuited by means of a temporary electrical jumper, or the test may be conducted without the component electrically connected, providing the wiring and terminal spacings are maintained. Additionally, transient voltage suppression devices other than capacitors connected from primary wiring to dead metal may be disconnected during the test.

76.6 The test equipment shall have a means of indicating the test potential, an audible or visual indicator of electrical breakdown and, for automated or station type operations, either a manual-reset device to restore the equipment after electrical breakdown or an automatic-reject feature for any unacceptable unit. When an alternating-current test potential is applied, the test equipment shall include a transformer having an essentially sinusoidal output.

76.7 When the rated output of the test equipment is less than 500 volt-amperes, the equipment shall include a voltmeter in the output circuit to indicate directly the applied test potential.

76.8 When the rated output of the test equipment is 500 volt-amperes or more, the test potential can be indicated:

a) By a voltmeter in the primary circuit or in a tertiary-winding circuit;

b) By a selector switch marked to indicate the test potential; or

c) By a marking in a readily visible location to indicate the test potential in the case of equipment having a single test-potential output.

If an indicating voltmeter is not used, the test equipment shall include a visual means (such as an indicator lamp) to indicate that the test voltage is present at the test-equipment output.

76.9 Test equipment other than that described in 76.6 – 76.8 may be used if found to accomplish the intended factory control.

76.10 For the test, either a sufficient number of control devices are to be closed or separate applications of the test potential are to be made so that all parts of the primary circuit are tested.

77 Production-Line Grounding-Continuity Test

77.1 Each unit that has a power-supply cord with a grounding conductor and each unit shipped without a power supply cord shall be tested, as a routine production-line test, to determine that grounding continuity is provided between the grounding blade or pin of the attachment plug and the accessible dead metal parts of the unit that are likely to become energized. For a unit shipped without a power supply cord, the test is to be made between the grounding terminal of the cord connector and accessible dead metal parts.

77.2 Only a single test need be made if the accessible metal selected is conductively connected to all other accessible metal.

77.3 Any indicating device (an ohmmeter, a battery and buzzer combination, or the like) can be used to determine compliance with the grounding continuity requirement.

PART 2 – OUTDOOR-USE UNITS

INTRODUCTION

78 General

78.1 The requirements in Sections 79 – 83 supplement, and in some cases modify, the general requirements in Sections 3 – 77.

CONSTRUCTION

79 Enclosure and Corrosion Protection

79.1 The enclosure of an outdoor unit shall be protected against outdoor exposure in accordance with the requirements in 79.2 – 79.14.

79.2 Metal shall not be used in combination such as to cause galvanic action that will adversely affect an enclosure.

79.3 Hinges and other attachments shall be resistant to corrosion.

79.4 These requirements do not include consideration of corrosion that might be caused by exposure to the earth or other corrosive agents.

79.5 The requirements in 79.6 – 79.14 do not apply to a part such as a decorative grill that is not required to form a part of the enclosure.

79.6 A nonmetallic enclosure is to be judged on the basis of the effect of exposure to water and ultraviolet light.

79.7 A metallic enclosure shall be protected against corrosion as specified in 79.8 – 79.14.

79.8 Aluminum, stainless steel, polymeric materials, copper, bronze, or brass containing at least 80 percent copper may be used without additional protection against corrosion.

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

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

b) One coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. The acceptability of the paint may be determined by consideration of its composition or, if necessary, by corrosion tests.

79.10 An enclosure of sheet steel having a thickness less than 0.126 inch (3.2 mm) when zinc-coated, or 0.123 inch (3.12 mm) thick when uncoated, shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in 79.12:

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G90 in the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM Designation A653/A653M (1996), with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM designation. The weight of zinc coating shall be determined by any suitable method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M (1995).

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00061 inch (0.0155 mm) on each surface with a minimum thickness of 0.00054 inch (0.0137 mm). The thickness of the coating shall be established by the metallic-coating thickness test described in 82.1 – 82.10. An annealed coating shall also comply with 79.14.

c) A zinc coating conforming with 79.11(a) or (b) with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. The suitability of the paint shall be determined by its composition or, when required, by corrosion tests.

d) A cadmium coating not less than 0.001 inch (0.03 mm) thick on both surfaces. The thickness of coating shall be established in accordance with the metallic-coating thickness test described in 82.1 – 82.10.

e) A cadmium coating not less than 0.00075 inch (0.0191 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.0005 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established in accordance with the metallic-coating thickness test described in 82.1 – 82.10 and the paint shall be as specified in (c).

79.10 revised November 17, 1997

79.11 An enclosure of sheet steel 0.126 inch (3.20 mm) thick or more when zinc-coated, or 0.123 inch (3.12 mm) thick or more when uncoated, shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been shown to provide equivalent protection as described in 79.12:

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M (1996) with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM designation. The weight of zinc coating shall be determined by any suitable method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M (1995). An A60 (alloyed) coating shall also comply with 79.14.

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00041 inch (0.0104 mm) on each surface with a minimum thickness of 0.00034 inch (0.0086 mm). The thickness of the coating shall be established by the metallic- coating thickness test described in 82.1 – 82.10. An annealed coating shall also comply with 79.14.

c) Two coats of an organic finish of epoxy or alkyd resin or other outdoor paint on each surface. The suitability of the paint shall be determined by its composition or, when required, by corrosion tests.

d) Any one of the means specified in 79.10.

79.11 revised November 17, 1997

79.12 With reference to 79.10 and 79.11, other finishes, including paints, special metallic finishes, and combinations of the two may be accepted when comparative tests with galvanized sheet steel – without annealing, wiping, or other surface treatment – conforming with 79.10(a) or 79.11, as applicable, indicate they provide equivalent protection. Among the factors that are taken into consideration when judging the suitability of such coating systems are exposure to salt spray, moist carbon dioxide-sulfur dioxide-air mixtures, moist hydrogen sulfide-air mixtures, ultraviolet light, and water. See Supplement B to the Standard for Industrial Control Equipment, UL 508, for Investigation of Component Coatings.

79.13 Test specimens of a finish as described in 79.9 or 79.12, 79.10(c), or 79.11(c), if the paint is tested, are to be consistent with the finish that is to be used in production with respect to the base metal, cleaning or pretreatment method, application method, number of coats, curing method, thickness, and the like.

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

PERFORMANCE

80 Rain Test

80.1 An outdoor-use UPS is to be subjected to a rain test as described in 80.2 – 80.4. At the conclusion of the test:

a) For a UPS having a rainproof enclosure, there shall be no wetting of a live part nor entrance of water above the lowest live part; and

b) For a UPS having a raintight enclosure, there shall be no entrance of water into the enclosure.

80.2 After being subjected to the rain test, an outdoor-use UPS shall:

a) Have an insulation resistance of not less than 50,000 ohms between live parts and interconnected dead metal; and

b) Comply with the requirements in Section 47 in a repeated dielectric voltage-withstand test.

80.3 The complete enclosure with conduit connected – without pipe thread compound – is to be mounted as intended. The tightening torque for rigid conduit threaded into an opening in the enclosure is to be 800 pound-inches (90 N·m) for 3/4-inch and smaller trade sizes, 1000 pound-inches (113 N·m) for 1-, 1-1/4-, and 1-1/2-inch trade sizes, and 1600 pound-inches (180 N·m) for 2-inch and larger trade sizes.

80.4 The water spray apparatus is to consist of three spray heads mounted in a pipe rack as illustrated in Figure 82.1. Spray heads are to be constructed in accordance with the details shown in Figure 82.2. The water pressure for all tests is to be maintained at 5 psi (34 kPa) at each spray head. The distance between the center nozzle and the equipment is to be approximately 5 feet (1.5 m). The spray is to be directed at an angle of 45 degrees from vertical toward the louvers or other openings nearest current-carrying parts. A water spray is then to be applied to the enclosure from the top and sides for 1 hour.

81 Accelerated Aging Test

81.1 Gaskets depended upon for protection from rain and mounting feet depended upon for support (see 45.8) made of neoprene or rubber compounds and solid polyvinyl-chloride materials, except foamed materials, shall have physical properties as indicated in Table 82.1 before and after the conditioning indicated in Table 82.2.

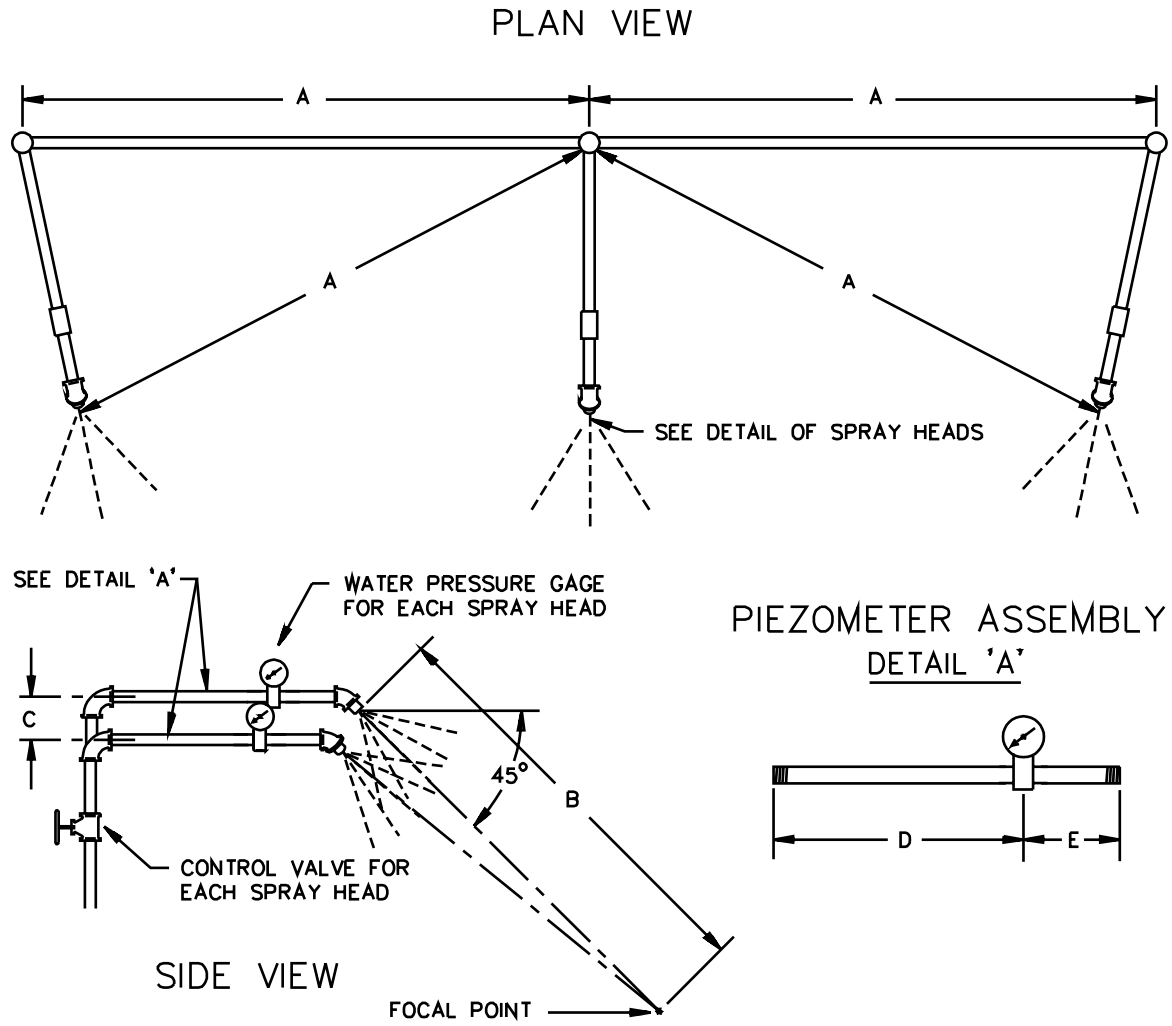
82 Metallic Coating Thickness

82.1 With reference to 79.10(b), (d), and (e) and 79.11(b), the method of determining the thickness of a zinc or cadmium coating is described in 82.3 – 82.10.

82.3 The solution to be used for this test is to be made from distilled water and is to contain 200 grams per liter of reagent grade chromic acid (CrO_3); and 50 grams per liter of reagent grade concentrated sulfuric acid (H_2SO_4). The latter is equivalent to 27 milliliters per liter of reagent grade concentrated sulfuric acid, specific gravity 1.84, containing 96 percent of H_2SO_4.

Figure 82.1
Rain-test spray-head piping

Figure 82.1 revised November 17, 1997



Item	inch	mm
A	28	710
B	55	1400
C	2–1/4	55
D	9	230
E	3	75

RT101E

82.4 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube having an inside bore of approximately 0.025 inch (0.64 mm) and a length of 5.5 inches (140 mm). The lower end of the capillary tube is to be tapered to form a tip, the drops from which are about 0.025 milliliters each. To preserve an effectively constant level, a small glass tube is to be inserted in the top of the funnel through a rubber stopper and its position is to be adjusted so that, when the stopcock is open, the rate of dropping is 100 ±5 drops per minute. If desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

82.5 The sample and the test solution are to be kept in the test room long enough to stabilize at room temperature. The room temperature is to be recorded. The test is to be conducted at an ambient temperature of 21.1 – 32.2°C (70 – 90°F).

82.6 Each sample is to be thoroughly cleaned before testing. All grease, lacquer, paint, and other nonmetallic coatings are to be removed completely by means of solvents. Samples are then to be thoroughly rinsed in water and dried. Care is to be exercised to avoid contact of the cleaned surface with the hands or any foreign material.

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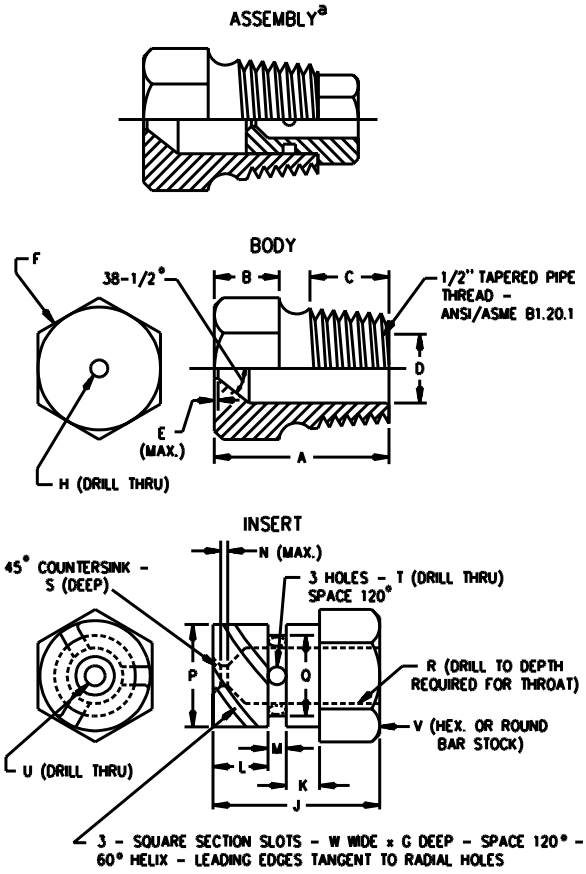
Figure 82.2
Rain-test spray head



Item	inch	mm	Item	inch	mm
A	1-7/32	31.0	N	1/32	0.80
B	7/16	11.0	P	.575	14.61
C	9/16	14.0		.576	14.63
D	.578	14.68	Q	.453	11.51
	.580	14.73		.454	11.53
E	1/64	0.40	R	1/4	6.35
F	c	c	S	1/32	0.80
G	.06	1.52	T	(No. 35)[b]	2.80
H	(No.9)[b]	5.0	U	(No. 40)[b]	2.50
J	23/32	18.3	V	5/8	16.0
K	5/32	3.97	W	0.06	1.52
L	1/4	6.35			
M	3/32	2.38			

[a] Nylon Rain-Test Spray Heads are available from Underwriters Laboratories

[b] ANSI B94.11M Drill Size

[c] Optional - To serve as a wrench grip.

RT100E

Table 82.1
Physical properties for gaskets

Physical property[a]	Neoprene or rubber compound		Polyvinyl-chloride materials	
	Before conditioning	After conditioning	Before conditioning	After conditioning
Tensile Minimum set when 1 inch (25.4 mm) gage marks are stretched to 2-1/2 inches (63.5 mm), held for 2 minutes and measured 2 minutes after release.	1/4 inch (6.4 mm)	–	Not Specified	Not Specified
Elongation Minimum increase in distance between 1 inch gage marks at break.	250 percent [to 3-1/2 inches (88.9 mm)]	65 percent of original	250 percent [to 3-1/2 inches (88.9 mm)]	75 percent of original
Tensile Strength Minimum force at breaking point.	850 psi (5.86 MPa)	75 percent of original	1200 psi (8.27 MPa)	90 percent of original

[a] To be determined using the test methods and apparatus described in Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension, ASTM D412-1992, except the method for tensile set is to be as specified in this table.

Table 82.2
Conditioning parameters

Table 82.2 revised March 15, 1996

Minimum material temperature rise[a] degrees C (F)	Conditioning	
	Rubber or neoprene	Thermoplastic
35 (63)	70 hours in an air-circulated oven at 100 ±2°C (212 ±3.6°F)	7 days in an air-circulated oven at 87°C (189°F)
50 (90)	7 days in an air-circulated oven at 100 ±2°C (212 ±3.6°F)	10 days in an air-circulated oven at 100°C (212°F)
55 (99)	7 days in an air-circulated oven at 113°C (235.4°F)	7 days in an air-circulated oven at 113°C (235.4°F)
65 (117)	10 days in an air-circulated oven at 121°C (249.8°F)	7 days at 121°C (249.8°F or 60 days at 97°C (206°F) in an air-circulated oven
80 (144)	7 days in an air-circulated oven at 136°C (276.8°F)	7 days in an air-circulated oven at 136°C (276.8°F)

[a] Measured during the Temperature Test, Section 45.

82.7 The sample to be tested is to be supported 0.7 – 1 inch (18 – 25 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested is to be inclined about 45 degrees from horizontal.

82.8 The stopcock is to be opened and the time in seconds is to be measured until the dropping solution dissolves the protective metallic coating, exposing the base metal. The end point is the first appearance of the base metal recognizable by the change in color at that point.

82.9 Each sample of a test lot is to be subjected to the test at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface and at an equal number of points on the outside surface at places where the metallic coating may be expected to be the thinnest. On enclosures made from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.

82.10 To calculate the thickness of the coating being tested, the thickness factor from Table 82.3 applicable for the temperature at which the test was conducted is to be multiplied by the time in seconds required to expose base metal as noted in 82.8.

Table 82.3
Thickness factors

Temperature, degrees F (C)	Thickness factors, 0.00001 inches (0.00025 mm) per second	
	Cadmium platings	Zinc platings
70 (21.1)	1.331	0.980
71 (21.7)	1.340	0.990
72 (22.2)	1.352	1.000
73 (22.8)	1.362	1.010
74 (23.3)	1.372	1.015
75 (23.9)	1.383	1.025
76 (24.4)	1.395	1.033
77 (25.0)	1.405	1.042
78 (25.6)	1.416	1.050
79 (26.1)	1.427	1.060
80 (26.7)	1.438	1.070
81 (27.2)	1.450	1.080
82 (27.8)	1.460	1.085
83 (28.3)	1.470	1.095
84 (28.9)	1.480	1.100
85 (29.4)	1.490	1.110
86 (30.0)	1.501	1.120
87 (30.6)	1.513	1.130
88 (31.1)	1.524	1.141
89 (31.7)	1.534	1.150
90 (32.2)	1.546	1.160

MARKING

83 Details

83.1 An outdoor-use UPS shall be marked ″Rainproof″ or ″Raintight.″ See 80.1.

PART 3 – ACCESSORY EQUIPMENT AND CONVERSION UNITS

INTRODUCTION

84 Scope

84.1 Sections 1 – 83 cover requirements that, in addition to the provisions in this supplement, apply to accessory equipment and conversion units intended to modify the unit construction.

Exception: Operator-installed accessories and conversion units intended to be supplied from circuits complying with 24.4 – 24.7 need not be investigated.

84.2 For the purposes of these requirements, accessory equipment is defined as pieces of equipment that:

a) Are designed to be attached or added to a unit of a system; and

b) Are of a size that they can be marked for identification by a catalog number or its equivalent.

84.3 Conversion units are intended to cover individual items of circuitry or components that, for reasons of improving, modifying, or repairing the functions of a unit, are added to the unit subsequent to the time of initial assembly and that lose their identity in the process.

CONSTRUCTION

85 Details

85.1 Accessory equipment and conversion units shall be constructed so that they can be added to a unit without presenting a risk of fire, electric shock, injury to persons, or electrical energy – high current levels.

85.2 The installation of accessory equipment or conversion units by an operator shall be restricted to an arrangement that can be accomplished mechanically by means of simple tools and electrically by means of plug-in connections to receptacles available on the basic unit or as a part of the building wiring.

85.3 The installation of accessory equipment or conversion units by qualified service personnel shall be such that:

a) The mechanical positioning can be accomplished by means of regular tools normally available at installation or by means of special tools provided as a part of the installation kit by the organization responsible for the product; and

b) The electrical connections can be readily accomplished by making use of existing terminals and connections in the unit wherever possible.

85.3 revised November 17, 1997

85.4 The requirement in 85.3 does not preclude the addition or removal of components or insulated conductors or rerouting of insulated conductors to accomplish the desired change as long as the alterations in the unit wiring:

a) Can be accomplished by the use of materials and reference to instructions, both of which are furnished as part of the accessory-equipment kit and conversion-unit kit; and

b) Do not require the use of makeshift or substitute parts not used in the basic construction of the system.

85.5 All wiring provided as a part of an item of accessory equipment or a conversion unit or related to their installation shall be acceptable for use at the highest voltage and temperature that can be encountered in the area in which the wire is to be installed.

PERFORMANCE

86 Installation Test

86.1 Each piece of accessory equipment and each conversion unit shall be installed in its intended manner on the unit for which it is intended by following the instructions provided (see 87.3 and 87.4).

86.2 The mechanical mounting arrangements and types of plugs provided with operator-installed accessory equipment and conversion units shall be such that the equipment can be properly positioned and the plug-in connections cannot be interchanged in a manner that presents a risk of fire, electric shock, injury to persons, or electrical energy – high current levels.

86.3 With the accessory equipment or conversion unit installed and operating, the basic unit shall be subjected to each of the tests set forth in Section 41 – 68 that are necessary for determining that the performance of the unit is not altered in any unacceptable manner.

MARKING

87 Details

87.1 Each piece of accessory equipment and each conversion unit shall be marked with the manufacturer's name, trademark, or other descriptive marking by means of which the organization responsible for the product can readily be identified and with a distinctive catalog number or equivalent identification.

Exception: The marking for a conversion unit may be on the package.

87.2 Accessory equipment and conversion units shall comply with the appropriate marking requirements described in 72.1.1 – 72.2.24.

87.3 Accessory equipment intended to be installed by an operator shall be marked to indicate the unit for which it is intended or shall be marked with a reference to an instruction manual that tabulates the units for which it is intended. Additionally, accessory equipment shall include instructions on or packed with the equipment such that the accessory equipment can be properly mounted on and interconnected with the basic unit.

87.4 Accessory equipment intended to be installed by qualified personnel and conversion units shall include instructions either on or packed with each piece of accessory equipment or each conversion unit. The instructions shall provide a detailed sequence of the mechanical and electrical steps that are necessary for proper installation and operation.

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APPENDIX A

Standards for Components

Standards under which components of the products covered by this standard are evaluated include the following:

Title of Standard − UL Standard Designation

Air Filter Units – UL 900
Analog Instruments – Panelboard Types, Electrical– UL 1437
Attachment Plugs and Receptacles – UL 498
Building Materials, Tests for Surface Burning Characteristics of – UL 723
Capacitors – UL 810
Controls, Limit – UL 353
Cord Sets and Power-Supply Cords – UL 817
DC Fuses for Industrial Use – UL 198L
Enclosures for Electrical Equipment – UL 50
Electromagnetic Interference Filters – UL 1283
Emergency Lighting and Power Equipment – UL 924
Engine-Generator Assemblies for Use in Recreational Vehicles– UL 1248
Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors – UL 486E
Fittings for Conduit and Outlet Boxes – UL 514B
Flexible Cord and Fixture Wire – UL 62
Fuseholders – UL 512
Fuses, Class H – UL 198B
Fuses, Class R – UL 198E
Fuses, Class T – UL 198H
Fuses for Supplementary Overcurrent Protection – UL 198G
Fuses, Class K – UL 198D
Fuses, Plug – UL 198F
Industrial Control Equipment – UL 508
Insulating Materials – General, Systems of – UL 1446
Information Technology Equipment – UL 1950 (Third Edition)
Lampholders, Edison-Base – UL 496
Marking and Labeling Systems – UL 969
Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures –UL 489
Motors, Electric – UL 1004
Motors, Overheating Protection for – UL 2111
Optical Isolators – UL 1577
Outlet Boxes, Flush-Device Boxes and Covers, Nonmetallic– UL 514C
Outlet Boxes, Metallic – UL 514A
Panelboards – UL 67
Plastic Materials for Parts and Devices and Appliances, Tests for Flammability of – UL 94
Polymeric Materials – Fabricated Parts – UL 746D
Polymeric Materials – Long Term Property Evaluations– UL 746B
Polymeric Materials – Short Term Property Evaluations– UL 746A
Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C

Printed-Wiring Boards – UL 796
Secondary Protectors for Communications Circuits – UL 497A
Supplementary Protectors for Use in Electrical Equipment – UL 1077
Snap Switches, General-Use – UL 20
Switches, Automatic Transfer – UL 1008
Switches, Special-Use – UL 1054
Tape, Polyvinyl Chloride Polyethylene and Rubber Insulating – UL 510
Telephone Equipment – UL 1459
Temperature-Indicating and -Regulating Equipment – UL 873
Terminal Blocks – UL 1059
Terminals, Electrical Quick-Connect – UL 310
Tests for Sharpness of Edges on Equipment – UL 1439
Thermal Cutoffs for Use in Electrical Appliances and Components – UL 1020
Transformers, Class 2 and 3 – UL 1585
Transformers, Specialty – UL 506
Transient Voltage Surge Suppressors – UL 1449
Wire Connectors and Soldering Lugs for Use With Copper Conductors – UL 486A
Wire Connectors for Use With Aluminum Conductors – UL 486B
Wires and Cables, Thermoplastic-Insulated – UL 83