UL 1012

STANDARD FOR SAFETY

Power Units Other Than Class 2

UL Standard for Safety for Power Units Other Than Class 2, UL 1012

Eighth Edition, Dated November 9, 2010

Summary of Topics

This revision of ANSI/UL 1012 dated March 30, 2021 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

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

The requirements are substantially in accordance with Proposal(s) on this subject dated January 22, 2021.

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UL 1012

Standard for Power Units Other Than Class 2

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This ANSI/UL Standard for Safety consists of the Eighth Edition including revisions through March 30, 2021.

The most recent designation of ANSI/UL 1012 as a Reaffirmed American National Standard (ANS) occurred on March 30, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover portable, stationary, and fixed power units having an input rating of 600 volts or less, direct- and alternating- current, with at least one output not marked Class 2, and that are intended to be employed in ordinary locations in accordance with the National Electrical Code, ANSI/NFPA 70.

1.2 These requirements cover general purpose power supplies and power supplies for uses such as to supply some household appliances, school laboratories, cathodic protection equipment; power supply-battery charger combinations; and industrial equipment, including inverters, divided into two classes – those rated 10 kilovolt-amperes or less and those rated more than 10 kilovolt-amperes.

1.3 Power units with all outputs identified as Class 2 are covered under the Standard for Class 2 Power Units, UL 1310.

1.4 These requirements do not cover the following types of battery chargers:

a) Battery chargers intended to charge motor-starting batteries as covered by Standard for Battery Chargers for Charging Engine-Starter Batteries, UL 1236;

b) Battery chargers for charging industrial batteries which power material handling trucks, tractors, personnel carriers, and similar motive equipment, as covered by the Standard for Industrial Battery Chargers, UL 1564;

c) Chargers or charging functions incorporated into converter or inverters for use in recreational vehicles and boats, as covered by the Standard for Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts, UL 458; and

d) Charge controllers or charging functions incorporated into equipment for use in independent power systems, as covered by the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741.

1.5 A battery charger not wholly within the scope of one of the standards specified in 1.4 shall be investigated to the requirements of this Standard supplemented by the applicable requirements of whichever of the standards in 1.4 is most applicable.

1.6 These requirements do not cover a power supply for a fire-protective or burglary-protective signaling system, electrostatic-air cleaning equipment, recreational vehicles, electric discharge or neon tubing, test equipment for commercial or industrial laboratories; or an appliance or system in which the power supply is used.

1.7 These requirements cover power supplies for centralized ac or dc power systems, including dc power supplies, rectifiers, and the like, that form part of these systems.

1.8 A power supply that is intended for use with a specific type of product other than as referenced in 1.2 is investigated under the standard for that end product.

1.9 These requirements do not cover the effect that a power supply may have on an equipment or a system to which it is connected.

1.10 A power system, the primary function of which is maintaining continuity of an alternating power source in case of input power failure, is covered under the Standard for Uninterruptible Power Systems, UL 1778.

2 Components

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

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

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

b) Is superseded by a requirement in this standard.

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

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

3 Units of Measurement

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

4 Terminology

4.1 Unless otherwise stated, values of current and voltage are root-mean-square (rms).

4.2 The term "product" as used in these requirements refers to all power units or any part thereof covered by these requirements unless specifically noted otherwise.

4.3 The term "power unit" as used in these requirements refers to all power supplies, battery chargers, and transformers covered by these requirements.

5 Undated References

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

6 Glossary

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

6.2 BATTERY, SEALED – A battery that has no provision for the addition of water or electrolyte or for external measurement of electrolyte specific gravity.

6.3 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."

6.4 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."

6.5 CLASS 2 OUTPUT – An output complying with the requirements for Class 2 Output Circuits. See 38.1.

6.6 CLASS 3 OUTPUT – An output having limited voltage and energy capacity and complying with the requirements for Class 3 Output Circuits. See 38.2. See also the Maximum Output Voltage Test, Section 83, and the Output Current and Power Test, Section 84.

6.7 CONDUCTIVELY CONNECTED – A part connected to another part such that the current through a 1500 ohm resistor connected between the parts exceeds 5 mA rms or 7.07 mA peak.

6.8 CONTROLLED ENVIRONMENT – An environment that is relatively free of conductive contaminants, such as carbon dust and the like that may result from the end-use equipment that the power unit will be installed with or that may be due to the location of the end-use equipment, and that is provided with protection against humidity and the formation of condensation. A temperature and humidity controlled indoor area free of conductive contaminants, is considered to be a controlled environment. An equivalent environment may be provided within the enclosure of an appliance by means of:

a) A hermetically sealed enclosure;

b) Encapsulation;

c) A conformal coating;

d) A gasketed, tight-fitting enclosure; or

e) A filter system reducing the level of contamination in conjunction with a system reducing the level of condensation (for example, maintaining the surrounding air at constant temperature and low relative humidity).

6.9 DIRECT CURRENT (DC) – A voltage or current waveform where voltage across two points does not change polarity, and the current through a conductor does not change direction.

6.10 ELECTRICAL ENERGY – HIGH CURRENT LEVELS – The capability for damage 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 can cause a burn or a fire if enough energy is available at the component to vaporize, melt, or more than warm the metal.

6.11 ENERGY LIMITING CIRCUIT/IMPEDANCE – A circuit or component depended on to limit an output to Class 3 levels. Reliability of circuit components shall be determined unless the unit is tested as specified in 87.1.

6.12 INTENDED FOR USE BY TRAVELERS – A multiple voltage rated direct plug-in power unit with a 125 V 15 A (parallel) input blade configuration, or a multiple voltage rated cord-connected power unit with a non-detachable power supply cord terminating in a 125 V 15 A (parallel) blade plug.

6.13 ISOLATED LIMITED-ENERGY CIRCUIT – A circuit derived from an isolated secondary winding of a transformer having a maximum capacity in accordance with Section 51 and an open-circuit secondary voltage rating not exceeding 1000 volts. A circuit derived from a line-voltage source of supply by

connecting resistance in series with the supply circuit as a means of limiting the voltage and current is not considered to be an isolated limited-energy circuit.

6.14 LINE-VOLTAGE CIRCUIT – Wiring and components that are conductively connected to a branch circuit.

6.15 LOW VOLTAGE LIMITED ENERGY (LVLE) CIRCUIT – A circuit involving a potential of not more than 42.4 volts peak or 60 V dc with limited energy as described in 36.5 – 36.13.

6.16 MULTIPLE VOLTAGE RATED POWER UNIT – A power unit with a rated voltage range (such as 100 – 240 volts) or a power unit with more than one discrete voltage rating (such as 120/240 volts).

6.17 POWER UNIT, COMMERCIAL – A power unit other than the household type as defined in 6.18.

6.18 POWER UNIT, FIXED – A power unit that is intended to be permanently connected electrically.

6.19 POWER UNIT, HOUSEHOLD – A power unit intended for use with equipment found in the home.

6.20 POWER UNIT, PORTABLE – A cord and plug connected power unit that:

a) Has no provision for permanent mounting; and

b) Can be moved easily from one place to another for use.

6.21 POWER UNIT, STATIONARY – A cord and plug connected power unit that is intended to be fastened in place or located in a dedicated space.

6.22 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered likely to occur at any part if the potential between the part and earth ground or any other accessible part is more than 30 volts rms, 42.4 volts peak, or 60 V dc, and the continuous current flow through a 1500-ohm resistor exceeds 5 milliamperes.

6.23 RISK OF INJURY – A risk of injury to persons is considered likely to occur if one or more of the following conditions exist:

a) If power-operated moving parts such as gears and linkages are accessible during intended operation and are capable or causing a cut or laceration.

b) If sharp edges, burrs, or projections are present that can cause injury during use or servicing.

c) If the stability of a product is such that it can cause injury to persons. See Stability Test, Section 50.

d) If there is likelihood that a part of the body could be endangered or that clothing would be entangled by the moving part resulting in an injury.

The words "injury to persons" are in reference to physical harm to persons other than the physiological effects of electric shock.

6.24 SPECIAL APPLICATION BATTERY CHARGER – A battery charger intended to charge batteries employed in wheel chairs or other similar types of mobility aids.

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

ALL POWER UNITS

CONSTRUCTION

7 Frame and Enclosure

7.1 General

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

7.1.2 A power unit shall be provided with an enclosure to house all parts other than the power supply cord or primary connector and the output leads or output connector that present a risk of fire, electric shock, or injury to persons under any condition of use.

7.1.3 A cast- or sheet-metal section of the enclosure shall have a thickness not less than that specified in Table 7.1.

Exception: A part of an enclosure that complies with the Mechanical Strength Tests for Metal Enclosures, Section 45, need not comply with the thickness specified in Table 7.1.

Table 7.1
Minimum acceptable thickness of enclosure metal

Metal	At small, flat, unreinforced surfaces and at surfaces of a shape or size to provide adequate mechanical strength		At surfaces to which a wiring system is to be connected in the field		At relatively large unreinforced flat surfaces	
	Inches	(mm)	Inches	(mm)	Inches	(mm)
Die-cast	3/64	(1.2)	–	–	5/64	(2.0)
Cast malleable iron	1/16	(1.6)	–	–	3/32	(2.4)
Other cast metal	3/32	(2.4)	–	–	1/8	(3.2)
Uncoated sheet steel	0.026	(0.66)	0.032	(0.81)	0.026	(0.66)
Galvanized sheet steel	0.029	(0.74)	0.034	(0.86)	0.029	(0.74)
Nonferrous sheet metal other than copper	0.036	(0.91)	0.045	(1.14)	0.036	(0.91)
Copper	0.033	(0.84)	0.043	(1.09)	0.033	(0.84)

7.1.4 An enclosure or part of an enclosure that also serves as a compartment for a rechargeable vented battery shall be ventilated to permit dispersion of gases from the battery.

7.1.5 In addition to the criteria specified in this Standard, the following factors are to be considered when judging the suitability of a polymeric enclosure:

a) Moisture absorptive properties;

b) Material flammability properties; and

c) Resistance to arcing properties.

These properties shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. See also 39.4.

7.1.6 A conductive coating applied to a nonmetallic surface such as the inside surface of a cover, enclosure, and the like shall comply with the appropriate requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, unless it can be determined that flaking or peeling of the coating does not result in a reduction of spacings or the bridging of live parts that may result in a risk of fire, electric shock, or injury to persons.

7.1.7 The enclosure of a power unit shall prevent molten metal, burning insulation, flaming particles, or the like from falling on combustible materials, including the surface upon which the power unit is supported. A barrier as mentioned in 7.1.10 shall:

a) Be horizontal;

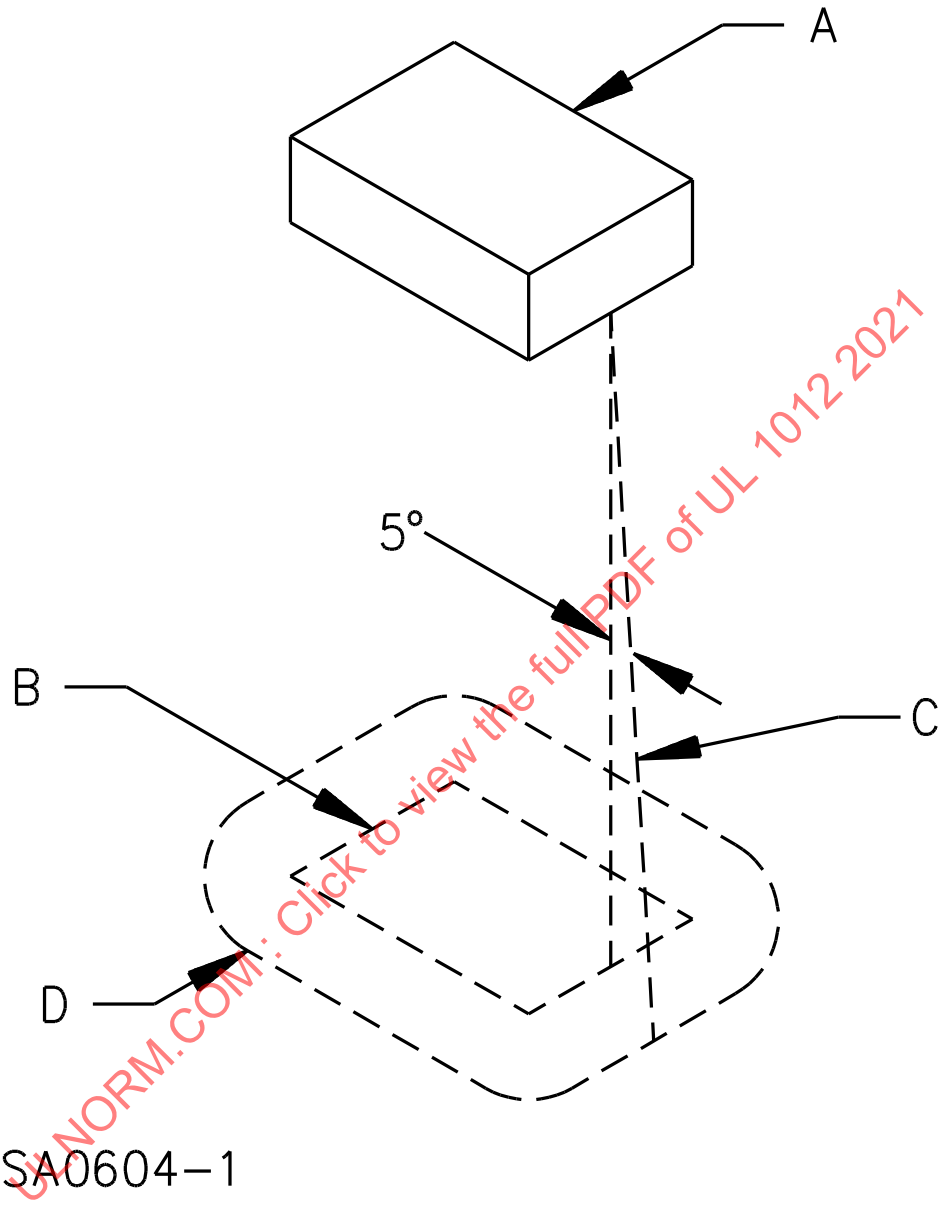
b) Comply with Figure 7.1; and

c) Comply with 7.1.8 if it is made of a polymeric material.

Openings for drainage, ventilation, and the like may be employed in the barrier provided such openings do not permit molten metal, burning insulation, or the like, to fall on combustible material.

Figure 7.1

Location and extent of barrier



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 that is partially shielded by the component enclosure or equivalent.

B – Projection of outline of component on horizontal plane.

C – Inclined line that traces out minimum area of barrier. The line is always:

1) Tangent to the component,

2) 5 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.

7.1.8 With reference to 7.1.7, a barrier made of a polymeric material shall:

a) Have a flammability classification of V-1 or better in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94; and

b) Comply with the requirements for physical barriers specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

7.1.9 The requirement in 7.1.7 necessitates that a switch, a relay, a solenoid, or the like, be completely and individually enclosed, unless it can be shown that:

a) Malfunction of the component does not result in a risk of fire; or

b) There are no openings in the enclosure through which molten metal, burning insulation, flaming particles or the like could fall.

Exception No. 1: This requirement does not apply to terminals.

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 7.2; 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; or other construction complying with the Hot, Flaming Oil Test, Section 57.

Table 7.2
Perforated metal plates for enclosure bottom

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)

NOTE – In accordance with Exception No. 2 to 7.1.9.

7.1.10 With regard to 7.1.7, if openings in the enclosure are provided, it will also necessitate the use of a barrier:

a) Under wire, unless it is of the flame-retardant type, such as neoprene- or thermoplastic-insulated wire; and

b) Under a fuse, unless a complete, unventilated enclosure is provided for each fuse.

Exception: A barrier is not needed under:

a) A supplementary fuse;

b) A fuse connected in a Class 2 circuit;

c) An individually enclosed fuse such as an extractor fuse; or

d) A fuse within a complete unventilated enclosure.

Consideration will be given to a fuse enclosed within a transformer winding.

7.1.11 A compartment or part of an enclosure that contains field-wiring splices in other than a Class 2 circuit shall not be provided with ventilating openings.

7.1.12 Glass or thermoplastic covering an opening for user servicing, such as replacing a pilot lamp, and enclosing live parts that are guarded in accordance with 7.6.3, 7.6.4, or 9.1.4 shall be securely retained in place, and shall comply with:

a) Mechanical Strength Tests for Metal Enclosures, Section 45;

b) Abnormal Tests, Section 54; and

c) Flammability tests for thermoplastic enclosures as specified in 7.1.5.

7.1.13 The operating handle of a circuit breaker, the operating button of a manually-operable protector, the capped portion of an extractor-type fuseholder, or a similar part may project outside the enclosure.

7.2 Mounting means

7.2.1 A power unit intended to be fastened in place shall have a means for securely mounting it in position. Bolts, screws, and other parts used for mounting the power unit shall be independent of those used for securing components.

7.2.2 A portable power unit intended for wall mounting shall employ a keyhole slot or the equivalent as a mounting means.

7.2.3 A barrier or the equivalent may be used to prevent wall-mounting screws from projecting into a compartment containing electrical parts and reducing spacings to less than that specified in Spacings, Section 35.

7.2.4 Mounting instructions shall be furnished with each power unit designed for permanent mounting. If special hardware is required, it shall be provided by the manufacturer.

7.3 Integral meters

7.3.1 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 No. 1: An electrical instrument connected in a secondary circuit need not comply with the requirements for an enclosure if damage or deterioration of the materials comprising the housing does not result in a risk of fire or electric shock.

Exception No. 2: This requirement does not apply to a meter as described in 7.3.2.

7.3.2 A panel mounted analog meter shall comply with the Standard for Electrical Analog Instruments – Panelboard Types, UL 1437.

Exception: An analog meter connected to an isolated circuit of not more than 42.4 V peak or 60 V dc need not comply if the meter housing does not constitute part of the power unit enclosure.

7.4 Supporting material

7.4.1 Material supporting terminals or used as internal electrical insulation of an electrical instrument shall comply with Insulating Materials, Section 24.

Exception: This requirement does not apply to an electrical instrument connected in a secondary circuit if damage to or deterioration of the materials does not result in a risk of fire or electric shock.

7.4.2 Supporting feet of a power unit that form part of the enclosure or that are needed for ventilation shall be reliably secured in place and the aging, physical, and flammability properties of the material shall be investigated. A rubber or neoprene material shall comply with the physical properties test requirements in 65.2.1.

Exception: This requirement does not apply to a power unit subjected to the Temperature Test, Section 42, with the supporting means removed. See 42.9.

7.4.3 An adhesive used to attach a cover to a power unit shall be investigated with respect to exposure to environmental conditions, such as high and low temperatures, high and low humidity, and the like, to determine its ability to retain the cover in position.

Exception: Methods utilizing fusion techniques, such as solvent cementing, ultrasonic welding, electromagnetic induction, and thermal welding are not required to be investigated.

7.5 Doors and covers

7.5.1 A door or cover that provides access to a live part that can cause electric shock shall be securely held in place so that it can be opened or removed only by using a tool.

Exception: A door or cover that provides access to a live part that does not involve risk of electric shock shall be securely held in place, but need not be secured so that it is necessary to use a tool to open or remove it.

7.5.2 A door or cover of an enclosure shall be hinged or attached in an equivalent manner if:

a) It provides access to an overload-protective device the intended functioning of which requires renewal; or

b) It is necessary to open the cover in connection with intended operation of the protective device.

A door or cover providing access to a fuseholder shall be tight-fitting and shall be positively held closed. See 28.1.

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

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

b) Rated 2 amperes or less for loads not exceeding 100 volt-amperes;

c) Extractor fuses having an integral enclosure;

d) Fuses connected in a low-voltage limited energy circuit; or

e) In accordance with the Exception to 29.1.

7.6 Protection against injury to persons

7.6.1 If operation, maintenance, or reasonably foreseeable misuse of a power unit by the user involves a risk of injury to persons, protection shall be provided to reduce such risk to an acceptable degree.

7.6.2 Specific service functions of a power unit that are not intended to be performed shall be given appropriate consideration.

7.6.3 A part capable of causing injury to persons shall be enclosed or guarded.

7.6.4 A rotating member, such as a fan blade, the breakdown of which could result in a risk of injury to persons, shall be enclosed or guarded to reduce the likelihood of injury.

7.6.5 With reference to 7.6.3, a part that is within the enclosure or casing of the power unit and that cannot be contacted by the probe illustrated in Figure 8.1 is considered to be acceptably guarded. An opening in a guard shall not exceed 1 inch (25.4 mm) in diameter.

7.6.6 A cover or guard for a moving part that involves a risk of injury to persons – such as a fan blade – is to be arranged so that if it is removed, it must be replaced before intended operation of the power unit. Other features of a cover or guard 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 additional risks of injury such as pinch points during servicing, replacement of fuses, and maintenance.

Exception: A commercial or power unit may be provided with a marking – in lieu of other means – located adjacent to the part being guarded, to instruct the user that the cover or guard should be replaced before intended operation of the power unit. See 61.1.14.

7.6.7 A rotating or moving part that creates a risk of injury to persons if it should become disengaged shall be provided with a positive means to retain it in place under conditions of use.

7.6.8 An enclosure, a frame, a guard, a handle, or the like shall not be sharp enough to cause a risk of injury to persons in normal maintenance or use.

Exception: This requirement does not apply to a sharp edge that might be exposed to enable the power unit to perform its intended function.

7.7 Modular units

7.7.1 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 complies with the requirements of this Standard. Identification of the modules and instructions for assembling shall be provided in accordance with 61.2.22 and 62.1.11. The provisions for electrical connection between modules shall comply with Section 14, Interconnections Between Sections.

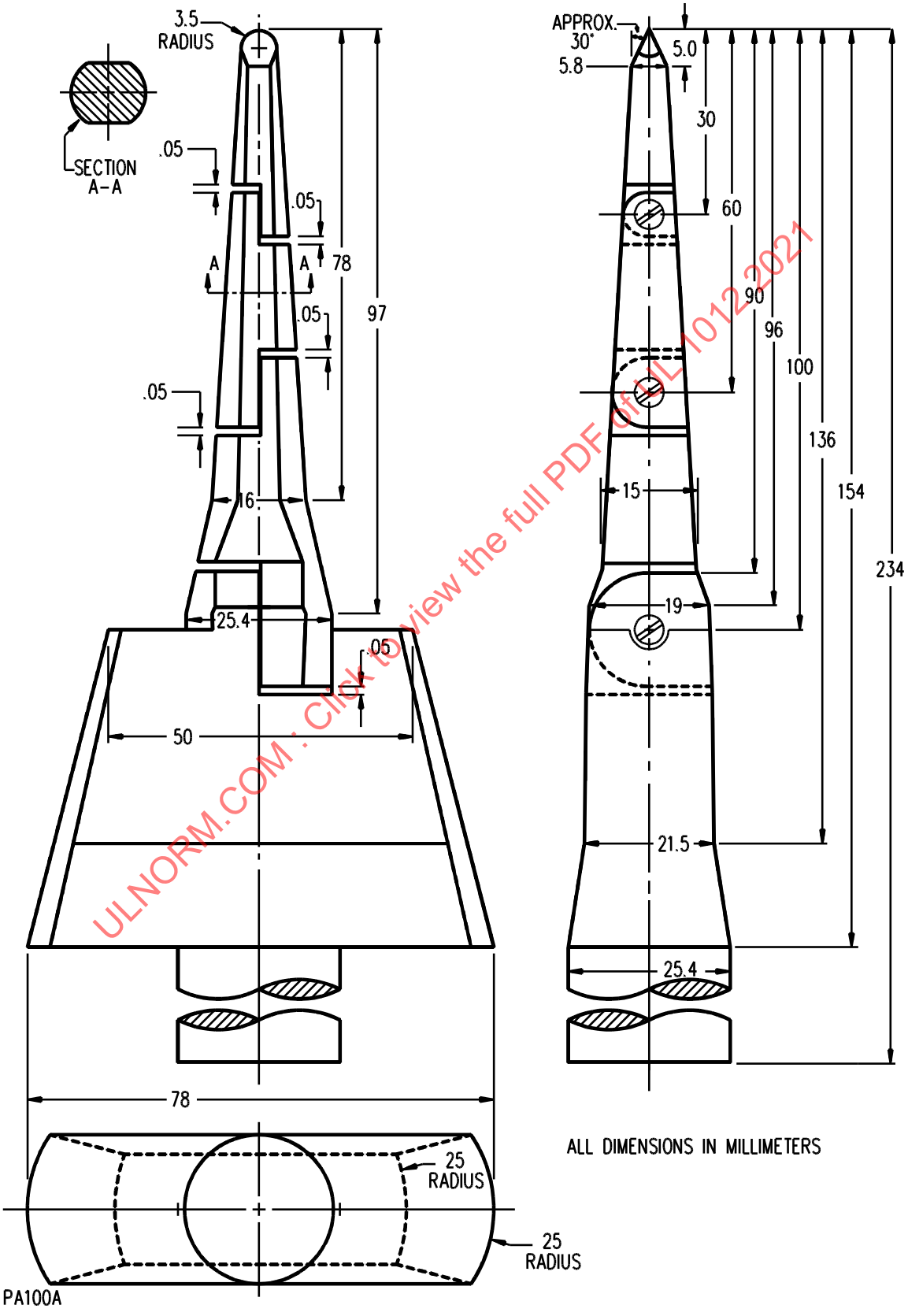
8 Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts

8.1 An opening in the enclosure of a power unit shall not permit entrance of a 1-inch (25.4-mm) diameter rod. A smaller opening is acceptable if a probe as illustrated in Figure 8.1, when inserted through the opening, cannot be made to touch any uninsulated live part that may involve a risk of electric shock, film-coated wire that may involve a risk of electric shock, or moving part that may involve a risk of injury to persons.

8.2 The probe illustrated in Figure 8.1 is to be applied to any depth that the opening permits and with a force not greater than 1 pound (4.4 N), and is to be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the power supply. The probe is to be applied in any possible configuration, and, if necessary, the configuration is to be changed after insertion through the opening.

Figure 8.1

Articulate probe with web stop



8.3 A guard, baffle, or cover that can be removed without using a tool is to be removed when determining if a part is accessible to the user. A part that can be contacted by the probe illustrated in Figure 8.1 when inserted through an opening in a permanently-attached guard or baffle is considered to be accessible.

8.4 A part on the back of a component mounting panel and a part located such that it requires major disassembly by using a tool are not considered to be accessible to the user; such parts are not considered accessible to the service personnel unless it is likely that servicing will be done while the parts are energized after disassembly.

8.5 An uninsulated live part that can cause electric shock shall be located or enclosed so that protection against unintentional contact is provided.

9 Protection of Service Personnel

9.1 General

9.1.1 These requirements apply to live parts used in circuits involving a risk of electric shock.

9.1.2 Live parts shall be so arranged and covers so located as to reduce the risk of electric shock when covers are being removed and replaced.

9.1.3 Consideration shall be given to a construction in which live parts are recessed at least 1/8 inch (3.2 mm) from the plane of the front of the fixed portion of the enclosure, and to an equivalent construction incorporating projections or guards.

9.1.4 An uninsulated live part involving a risk of electric shock and a moving part that involves a risk of injury to persons shall be located, guarded, or enclosed to reduce the likelihood of unintentional contact with such part by persons while changing a lamp or fuse, lubricating a motor, adjusting a control, or performing other like operations, including those performed only at the time of installation or during servicing procedures.

9.1.5 A live heat sink for a solid-state component, a live relay frame, a live part that can be mistaken for dead metal, and the like shall comply with the requirements in 9.2.2 and 9.3.1. Such a part shall also either be guarded to prevent contact by persons or be marked in accordance with 61.1.2.

Exception: This requirement does not apply to a heat sink mounted on a printed wiring board.

9.1.6 A means such as a bleeder resistor shall be provided to drain the charge stored in a capacitor to the extent that the potential, V, measured between the terminals of the capacitor 1 minute after the capacitor has been disconnected from its source of energy is less than 50 volts, and the energy stored, J, is less than 20 joules as determined by the following relation, in which C is in microfarads:

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

Exception: The requirement does not apply if a tool is necessary to remove a panel to reach the capacitor and the power unit is marked to warn service personnel as specified in 61.1.15.

9.2 Mechanical servicing

9.2.1 The requirements in 9.2.2 are intended to provide a reasonable degree of protection to the service personnel performing mechanical functions on energized equipment. Such functions do not in themselves require exposure to live parts involving a risk of electric shock or to moving parts that involve a risk of injury to persons, but it is usually necessary to perform them with the equipment energized.

9.2.2 An uninsulated live part involving a risk of electric shock and a moving part that involves a risk of injury to persons shall be located, guarded, or enclosed to prevent unintentional contact by service personnel adjusting or resetting controls, and 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.

9.2.3 An adjustable or resettable electrical control or manual switching device may be located or oriented with respect to uninsulated live parts so that manipulation of the mechanism for adjustment, resetting, or operation can be accomplished in the normal direction of access if uninsulated live parts:

a) Are not located in front – in the direction of access – of the mechanism; and

b) Are not located near any side or behind the mechanism, unless guarded.

Exception: This requirement does not apply to an uninsulated live part not involving a risk of electric shock.

9.3 Electrical servicing

9.3.1 An electrical component that may require examination, 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 service personnel to the likelihood of electric shock or risk of injury to persons. Access to components in a power unit is not to be impeded by other components or by wiring in the direction of access.

9.3.2 Protection against the risk of electric shock and injury to persons may be obtained by mounting control components so that unimpeded access to each component is provided by an access cover or panel in the outer cabinet.

9.3.3 The electrical components referred to in 9.3.1 and 9.3.2 include the following: fuses, adjustable or resettable overload relays, magnetically operated relays, manual-switching devices, clock timers, and incremental voltage taps. Such components in a limited-energy circuit of 30 volts rms or less as defined in 6.13 and 6.15 shall comply with the requirements in 9.3.1 with respect to uninsulated live parts in a circuit of greater energy level and to moving parts involving a risk of injury to persons.

9.3.4 The following are not considered to be uninsulated live parts: coils and windings of relays, solenoids, and transformers that are provided with acceptable insulating overwraps at least 1/32 inch (0.8 mm) thick, or the equivalent; enclosed motor windings; terminals and splices with acceptable insulation; and insulated wire.

10 Assembly

10.1 An uninsulated live part shall be secured to the base or surface so that it is prevented from rotating or shifting in position as the result of stresses if such movement results in a reduction of spacings below the minimum acceptable values.

10.2 A component such as a control switch, a lampholder, an attachment-plug receptacle, or a plug connector shall be mounted securely and shall be prevented from turning by means other than friction between surfaces.

Exception No. 1: A switch need not comply with this requirement if all of the following conditions are met:

a) The switch is a plunger or other type that does not tend to rotate when operated – a toggle switch is considered to be subject to forces that tend to turn the switch;

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

c) Spacings are not reduced below the minimum acceptable values if the switch rotates; and

d) Intended operation of the switch is by mechanical means rather than by direct contact by persons.

Exception No. 2: A lampholder of the type in which the lamp cannot be replaced, such as a sealed neon pilot or indicator light, need not comply with this requirement if rotation cannot reduce spacings below the minimum acceptable value.

10.3 A small stem-mounted device having a single-hole mounting may be prevented from rotating by a properly applied lock washer.

11 Protection Against Corrosion

11.1 Iron and steel parts shall be protected against corrosion by enameling, painting, galvanizing, plating, or an equivalent means.

Exception No. 1: This requirement does not apply to bearings, laminations, and other parts of iron or steel such as washers and screws.

Exception No. 2: A part need not be protected against corrosion if the corrosion of the part does not result in a risk of fire, electric shock, or injury to persons.

12 Supply Connections

12.1 Permanently-connected power units

12.1.1 A fixed power unit shall have provision for the connection of a wiring system.

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

12.1.3 A knockout shall be surrounded by a flat surface to accommodate for seating of a conduit bushing or locknut of the appropriate size.

12.1.4 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 full threads in the metal, and the construction of the device shall be such that a conduit bushing can be properly attached.

12.1.5 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 that shall afford protection to the conductors equivalent to that provided by a standard conduit bushing and that shall have an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

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

12.1.7 A field-wiring compartment in which power unit connections are to be made shall be located so that the connections may be readily inspected after the power unit is installed as intended.

12.1.8 A field-wiring compartment intended for connection of a wiring system shall be attached to the power unit so that it is prevented from turning.

12.1.9 An outlet box, terminal box, wiring compartment, or the like in which connections to the power unit circuit are made in the field shall be free from any sharp edge, including screw threads, a burr, a fin, a moving part, or the like, that may abrade the insulation on conductors or otherwise damage the wiring.

12.2 Wiring terminals and leads

12.2.1 The field-wiring terminals mentioned in 12.2.2 – 12.2.12 are terminals to which supply, control, output, or other permanent connections are made in the field when the power unit is installed.

12.2.2 Field-wiring terminals or leads shall be sized for the connection of conductors having an ampacity appropriate for the rating of the power unit.

12.2.3 A wiring terminal shall be provided with a pressure terminal connector securely fastened in place – for example, firmly bolted or held by a screw.

Exception No. 1: A wire-binding screw may be employed at a wiring terminal intended for connection of a 10 AWG (5.3 mm^2) or smaller conductor if upturned lugs or the equivalent are provided to hold the wire in position.

Exception No. 2: A wiring terminal need not be provided with a pressure terminal connector if the terminal is intended for connection of a 8 AWG (8.4 mm^2) or larger conductor, and the power unit complies with the requirements in 12.2.11.

12.2.4 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.

12.2.5 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 14 AWG (2.1 mm^2) conductor.

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

12.2.6 A wire-binding screw shall thread into metal.

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

Exception No. 1: A plate not less than 0.030 inch (0.76 mm) may be used if the tapped threads will not strip when subjected to the tightening torque specified in Table 12.1.

Exception No. 2: A plate less than 0.030 inch (0.76 mm) thick may be used in a Class 2 circuit, Class 3 circuit, or an isolated-limited-energy circuit if the tapped threads will not strip when subjected to the tightening torque specified in Table 12.1.

12.2.8 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 Class 2 circuit, Class 3 circuit, or an isolated limited-energy circuit 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 12.1.

Table 12.1
Tightening torque for wire-binding screws

Size of terminal screw, number	Wire sizes to be tested, AWG	Tightening torque	
		Pound-inches	Newton-meters (N·m) or kilogram-meters (kg·m)
6	16 – 22[a]	12	1.4 or 0.14
8	14[b] and 16 – 22[a]	16	1.8 or 0.18
10	10 – 14[b] and 16 – 22[a]	20	2.3 or 0.23

[a] Stranded wire.
[b] Solid wire.

12.2.9 Upturned lugs, a cupped washer, or the equivalent shall be capable of retaining a conductor of the size specified in 12.2.5 under the head of the screw or washer.

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

12.2.11 With reference to Exception No. 2 to 12.2.3, a pressure terminal connector is not required to be provided with a wiring terminal when the following conditions are met:

a) A terminal assembly shall be either:

1) Supplied by the manufacturer – installed or shipped separately; or

2) Specified in a marking on the power unit in accordance with 61.2.15 and 61.2.16.

b) A fastening device, such as a stud, nut, bolt, spring or flat washer, or similar device, as required for an effective installation, shall either be provided as part of the terminal assembly or be mounted on or separately packaged with the power unit.

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

d) When the pressure terminal connector provided in a terminal assembly requires the use of a special tool for securing the conductor, any required instructions shall be included in the assembly package or with the power unit. See 61.2.17.

e) After installation of the pressure terminal connector in the intended manner, the power unit shall comply with the requirements in this standard.

12.2.12 A terminal intended for connection of a grounded power supply conductor shall be made of or plated with metal substantially white in color and shall be readily distinguishable from other terminals.

Exception: This requirement does not apply if proper identification of that terminal is clearly shown in some other manner, such as on an attached wiring diagram.

12.2.13 The surface of a lead for the connection of a grounded power unit conductor shall be white or grey and shall be readily distinguishable from the other leads.

12.3 Cord-connected power units

12.3.1 A portable or stationary power unit shall be provided with a flexible cord in accordance with Table 12.2 and an attachment plug for connection to the power supply circuit. The supply cord shall be attached permanently to the unit or shall be in the form of a detachable power supply cord with a means for connection to male contacts affixed to the unit. The length of cord external to the power unit and including the attachment plug shall not be less than 6 feet (1.8 m) as measured from the face of the attachment plug to the point of attachment or entry.

Exception No. 1: A power unit weighing 1 pound (454 g) or less need not comply with the cord length requirements if the total length of the input and output cords is 6 feet (1.8 m) or more and the length of the input cord is at least 3 feet (0.91 m).

Exception No. 2: This requirement does not apply to rack mounted power units. See 12.3.2.

Exception No. 3: A power unit marked in accordance with 61.2.20 and provided with instructions in accordance with 62.1.10 need not be provided with the detachable power supply cord.

Exception No. 4: If a power unit is intended for use in a country other than the U.S.A., the detachable power supply cord shall comply with the requirements of the country of destination.

Table 12.2
Acceptable flexible cords for power units[a,b]

Intended use of power unit	Flexible cord type	Maximum length, feet (m)
A. Desk, countertop, rack mounted, or the like	SP-2, SPE-2, SPT-2, SV, SVE, SVT	10 (3)
B. Floor mounted, stationary, or the like	S, SE, SO, SP-3, SPT-3, ST, STO, SJ, SJE, SJO, SJT, SJTO	Not specified

[a] Refer to 12.3.1 and to sections pertaining to specific types of power units.

[b] See 12.3.3.

12.3.2 A rack mounted power unit shall be provided with the shortest length of flexible cord for the purpose.

12.3.3 A stationary power unit intended to be fastened in place may require a form of supply connection that facilitates the interchange of equipment to maintain continuous service or otherwise meet special conditions of use. For such service, a Type S, SE, or equivalent flexible cord may be employed and may be of a length appropriate for the purpose, but no longer than 10 feet (3 m). Normally, a 24 inch (610 mm) length of cord is sufficient for the plug and receptacle connection.

12.3.4 A supply cord shall be:

a) Of a type that is acceptable for the usage; and

b) Acceptable for use at a voltage and ampacity no less than the rated voltage and ampacity of the power unit.

12.3.5 The ampacity of the attachment plug for a power unit intended to be continuously loaded for 3 hours or more shall not be less than 125 percent of the input rating.

12.3.6 If a unit with a permanently attached power supply cord 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 shipped from the factory. The power unit shall be provided with instructions as described in 62.1.4.

12.3.7 If a multiple voltage rated power unit is intended for use with a detachable power supply cord, the cord shall be provided with the unit if either of the following apply:

a) The power unit is provided with an operator adjustable voltage selector and complies with 54.5.1; or

b) The power unit is capable of operating at different voltages without user adjustment.

Instructions shall be provided as described in 62.1.5. The power unit shall also be marked in accordance with 62.1.6.

Exception: A power unit marked in accordance with 61.2.20 and provided with instructions in accordance with 62.1.10 need not be provided with the detachable power supply cord.

12.3.8 A power unit intended for use by travelers shall comply with (a) – (e):

a) The power supply input shall be a 125 volt, 15 amp configuration;

b) The power unit shall employ a user adjustable voltage selector and comply with 54.5.1, or be capable of operating at different voltages without user adjustment;

c) The input voltage rating shall include nominal 120 volt;

d) The power unit shall be marked as indicated in 61.2.21; and

e) The power unit shall be provided with instructions per 62.1.7.

12.3.9 In a power unit rated 125 volts or less, 125/250 volts (three-wire) or less, or 277 volts, the screw shell of an Edison-screw-shell lampholder shall be electrically connected to the cord conductor intended to be grounded. A switch or overcurrent-protective device of the single-pole type, other than an automatic control without a marked off position, shall be connected in a circuit to the cord conductor not intended to be grounded.

12.3.10 A power unit shall employ a polarized or grounding-type attachment plug.

12.4 Strain relief

12.4.1 Strain relief shall be provided to prevent mechanical twisting or stress on the supply cord or output cord from being transmitted to terminals, splices, or interior wiring. The means for preventing twisting is to be evaluated by inspection. The suitability of the strain relief is to be evaluated in accordance with 45.1.

12.4.2 A metal strain-relief clamp or band is acceptable without supplementary protection on a Type SV, SVO, SJ, SJE, SJO, S, SO, SJT, SJTO, ST, or STO cord. A metal strain-relief clamp or band is acceptable on a Type SP-2, SPE-2, SPT-2, SVE, SVT, or SVTO cord only if supplementary nonconductive, mechanical protection is provided over the cord.

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

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

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

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

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

d) Damaging internal connections or components.

To determine compliance, the supply cord or lead shall be tested in accordance with Section 47, Push-Back Relief Test.

12.5 Bushings

12.5.1 A bushing or the equivalent shall be provided at a point where a flexible cord passes through an opening in a wall, barrier, or enclosing case. The bushing shall be substantial, mechanically secured in place, and shall have a smooth, rounded surface against which the cord may bear. If a Type SP-2, SPE-2, or SPT-2 cord is employed, the wall or barrier is of metal, and the construction is such that the cord may be subjected to stress or motion, the bushing shall be an insulating bushing.

Exception: For a cord hole in wood, porcelain, phenolic composition, or other nonconductive material, a smooth, rounded surface is considered to be the equivalent of an insulating bushing.

12.5.2 Ceramic materials and some molded compositions are acceptable for insulating bushings.

12.5.3 A bushing molded integrally with the supply cord is acceptable on Type SP-2, SPE-2, or heavier cord provided it is not less than 1/16 inch (1.6 mm) thick in the area where the cord passes through the enclosure.

12.5.4 An insulated metal grommet is acceptable as an insulating bushing if the insulating material is not less than 1/32 inch (0.8 mm) thick and completely fills the space between the grommet and the metal in which it is mounted.

13 Output Connections

13.1 Output terminals shall not be exposed unless they are used for Class 2 output circuits.

Exception: A power unit may employ exposed terminals if the terminals are located in an isolated secondary circuit and all of the following conditions are met:

a) The maximum output voltage (V_{max}) does not exceed 42.4 volts peak ac or 60 volts dc.

b) The output current rating does not exceed 8 amperes for ac or dc voltages up to 30 V rms, or 150/V_{max} amperes for dc voltages between 30 V and 60 V.

c) The exposed terminals comply with the requirements in 12.2.1 – 12.2.9.

d) A nonmetallic terminal cover is employed to reduce the likelihood of bridging between terminals. The cover shall be close-fitting over the top and all sides of the terminal block, with no opening other than those necessary for entry of conductors. The cover shall be attached so that it cannot be discarded. The nonmetallic material shall comply with the requirements in 7.1.5, and shall also

comply with the requirements for resistance to hot-wire ignition in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

e) The power unit is marked as required by 61.1.5.

13.2 A metal enclosure of a power unit shall not be used as an output-circuit current-carrying part.

13.3 A power unit having a flexible power supply cord shall be provided with an integral output cord terminating in a connector, or with a connector directly attached to the enclosure.

Exception No. 1: A stationary power unit intended to be fastened in place may be provided with output connections for permanent wiring if the connections are enclosed but readily accessible by means of a hinged cover, access opening, or the equivalent. A standard trade size conduit knockout shall be provided for connection of the output conduit system. See 12.3.3.

Exception No. 2: This requirement does not apply to a power unit output circuit complying with Exception No. 1 to 13.1.

13.4 The output flexible cord required by 13.3, whether permanently attached to the power unit or provided in the form of a separate cord set, is to be equivalent to the power supply cord specified in Table 12.2.

Exception: Output wiring for Class 2 circuits may be parallel cord insulated with rubber, neoprene, or thermoplastic having a wall thickness not less than 0.013 inch (0.33 mm).

13.5 A battery charger provided with output contacts in a recessed compartment to accommodate a battery or battery pack shall either:

a) Employ recessed contacts that are not accessible to the articulate probe (see Figure 8.1);

b) Employ an interlock to de-energize contacts that are accessible to the articulate probe (see Figure 8.1) with the battery fully removed; or

c) Have an output not exceeding 60 volts dc and employ contacts that do not provide electrical energy – high current levels (See 6.10).

13.6 A special application battery charger shall be provided with a special use polarized connector complying with the requirements in the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977.

13.7 A connector for an output circuit, other than one intended for use with a Class 2 circuit, shall comply with the requirements in the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977, or the Standard for Attachment Plugs and Receptacles, UL 498.

13.8 A connector intended for use with other than line voltage shall have a nonstandard pin configuration.

13.9 A connector for an output not exceeding 42.4 volts peak or 60 volts dc shall have no exposed current carrying pins that could be short-circuited when placed on a flat metal surface.

13.10 A strain-relief means and a bushing for the output cord shall comply with the requirements in 12.4 and 12.5.

13.11 A rubber or neoprene bushing intended for use with Class 2 or Class 3 field-installed output wiring shall not be less than:

a) 1/8 inch (3.2 mm) thick with the opening in which the bushing is mounted free from rough or sharp edges that may damage the bushing; or

b) 3/64 inch (1.2 mm) thick with an opening that is eyeletted or otherwise provided with smooth edges.

14 Interconnections Between Sections

14.1 The means provided for external connection between sections of a unit or between units of a system shall comply with the requirements described in 14.2 – 14.10.

14.2 A flexible-cord or -cable assembly used for interconnection shall be of a type as specified in Table 12.2 and shall be provided with bushings and strain relief in accordance with 12.4.1 – 12.5.4.

Exception No. 1: The strain relief for wires and cables that are part of the secondary circuits mentioned in 36.5 – 36.15 shall comply with the Exception to 46.1.

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 Table 12.2.

14.3 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 14.5.

14.4 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 14.5 and 14.6.

14.5 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 14.3 and 14.4.

14.6 Unless acceptable cable assemblies are provided, each section of a unit shall be provided with acceptable field-wiring terminals or leads to facilitate interconnection by means of permanently installed wiring.

14.7 Sections of a unit that are intended to be combined in field installations to form overall unified enclosures (modular units – see 7.7.1) 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.

14.8 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 14.6, 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.

14.9 A connector used for interconnection between modules or for connection to an external control circuit shall comply with 13.7.

14.10 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 Battery Charger Backfeed Protection

15.1 The requirements in this Section apply to battery chargers intended to charge portable equipment or batteries for use with portable equipment such as battery powered tools (drills, saws, screwdrivers, and similar tools), telephones, radios, and similar products where the charger output is by means of an output cord and connector, or a connector attached to or integral with the charger enclosure.

15.2 A battery charger shall be provided with a means to inhibit backfeed of current during a fault in the output circuit. The means of prevention shall protect each output and shall consist of an output cord (if provided) equivalent to that specified in Table 12.2. The battery charger shall comply with the test specified in 54.9.

Exception No. 1: A means of protection is not required when a specific battery or battery pack, to be used with the charger, does not exceed Class 2 parameters at any level of charge condition. See 61.1.11.

Exception No. 2: A battery charger employing integral batteries is not required to comply with 15.1.

16 Grounding Connections

16.1 Power units required to comply with applicable grounding requirements are:

a) A fixed or stationary power unit;

b) A portable outdoor or commercial power unit;

c) A portable power unit for use in a circuit involving a potential of more than 150 volts to ground; and

d) A power unit provided with a grounding means, whether required or not.

16.2 A fixed power unit shall be provided with a terminal or lead for grounding all dead metal parts that are exposed or are likely:

a) To be touched by a person during operation or adjustment of the power unit; and

b) To become energized through an electrical fault.

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

a) The proximity of wiring;

b) The results of a dielectric voltage-withstand test after a test such as the overload or the endurance test; and

c) The results of appropriate burnout tests.

16.4 The grounding connection shall be located so that it is unlikely to be removed during normal servicing. The grounding connection shall penetrate any nonconductive coating, such as paint or vitreous enamel, over the part to be grounded.

16.5 A wire-binding screw 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 plainly identified by:

a) A marking, such as "G," "GR," "GND," "Ground," "Grounding," or the like;

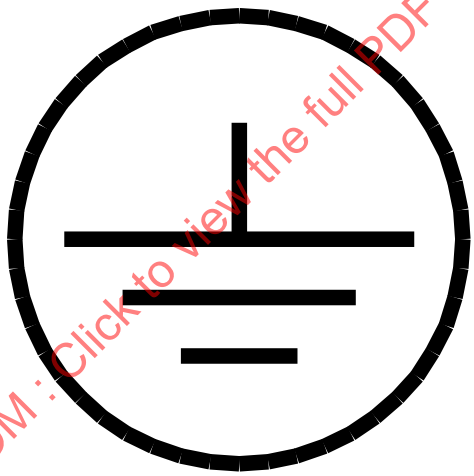
b) A wiring diagram attached to the power unit; or

c) The grounding symbol illustrated in Figure 16.1, on or adjacent to the terminal.

The wire-binding screw or pressure wire connector shall be located so that it does not require removal during intended servicing of the unit.

Figure 16.1

Grounding symbol



16.6 The grounding terminal shall be capable of securing a conductor of a size required for the application in accordance with Column 2 of Table 17.2.

Exception: A grounding terminal capable of securing a conductor of a size specified in 61.2.11 may be used.

16.7 A soldering lug, a screwless (push-in) connector, a quick-connect, or other friction-fit connector shall not be used. A sheet metal screw shall not be used to connect a grounding conductor or connection device to an enclosure.

Exception: A quick-connect terminal may be used in conjunction with solder for securing the grounding conductor.

16.8 A grounding conductor shall be a size specified in Column 2 of Table 17.2 or larger. A grounding 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 a Class 2 circuit when the low voltage leads or terminals are either:

a) Located remote from the line-voltage connections and the segregation complies with the requirements in 23.1 – 23.3; or

b) Specifically marked so that reference to a wiring diagram is not required.

16.9 The surface of any insulation on the grounding conductor of a flexible supply cord shall be green with or without one or more yellow stripes and no other conductor shall be so identified.

16.10 The grounding conductor 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 such as a screw or stud, nut, and lockwasher. An external force applied to the power supply cord shall not transmit stress to the grounding connection on the frame or enclosure before the line-voltage connections are broken.

16.11 A grounding connection, grounding conductor, enclosure, frame, component mounting panel, or any other part connected to earth ground shall not carry current except during an electrical fault.

Exception No. 1: A Class 2 or an isolated limited-energy circuit may be connected to a single-point reference ground. Current is not to be carried through the field-equipment-grounding connection, metallic raceway, or other grounding means.

Exception No. 2: A line by-pass capacitive impedance circuit for a radio frequency signal circuit need not comply with this requirement.

16.12 A grounded circuit conductor shall not be connected to any grounding or bonding circuit or device in a power unit.

17 Bonding of Internal Parts

17.1 General

17.1.1 If grounding is required – see 16.1 – an exposed dead metal part that is likely to become energized by an electrical fault shall be bonded to the point of connection of the field-equipment-grounding means. See 16.2 and 16.3. See also Bonding Conductor Test, Section 57.

17.1.2 Uninsulated dead metal parts such as a cabinet, component enclosure, and cover shall be electrically bonded together if they might be contacted by the user or service personnel.

Exception No. 1: A metal panel or cover need not be bonded if it is either:

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

b) Not likely to become energized because uninsulated live parts are enclosed and wiring is positively separated from the panel or cover; or

c) Separated from live parts and wiring by a grounded or bonded interposing metal barrier or part such that the metal barrier will be the first to be subjected to an electrical fault.

Exception No. 2: An internal dead metal part need not be bonded if it is marked as specified in 61.1.3.

17.1.3 A metal part, such as an adhesive-attached metal marking plate, a screw, or a handle, located on the outside of an enclosure or cabinet, need not be bonded if it is:

a) Isolated from electrical components and wiring by a grounded metal part so that it is not likely to become energized; or

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

17.1.4 In addition to the parts mentioned in 17.1.3, other parts not required to be bonded are small internal assembly screws, rivets, or other small fasteners, a handle for a disconnect switch, and a relay or contactor magnet and armature.

17.1.5 Uninsulated live parts and wiring shall be separated from a moving or movable part, such as a relay or contactor armature, a panel, or a cover by clamping, positioning, or an equivalent means that maintains permanent separation.

17.1.6 An internal connection for bonding an internal part to the enclosure may employ a quick-connect terminal of the dimensions specified in Table 17.1 if the connector is not likely to be displaced and the component is limited to use in a circuit having a branch-circuit protective device rated 20 amperes or less. A quick-connect terminal is not acceptable for a connection to be made in the field.

Table 17.1
Dimensions for quick-connect bonding terminal

Terminal dimensions, inch (mm)
0.020 (0.51) by 0.187 (4.75) by 0.250 (6.35)
0.032 (0.81) by 0.187 (4.75) by 0.250 (6.35)
0.032 (0.81) by 0.205 (5.21) by 0.250 (6.35)
0.032 (0.81) by 0.250 (6.35) by 0.313 (7.95)

17.2 Bonding conductor

17.2.1 Bonding shall be accomplished by a metal-to-metal contact of parts or by a separate bonding conductor as specified in 17.2.6.

17.2.2 A bonding conductor shall be copper, copper alloy, or other acceptable material.

17.2.3 Ferrous metal in the grounding path shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means.

Exception: Corrosion protection is not required at electrical connections.

17.2.4 A separate bonding conductor:

a) Shall be protected from mechanical damage or located within the outer enclosure; and

b) Shall not be secured by a removable fastener used for a purpose in addition to bonding unless the bonding conductor is not likely to be omitted if the fastener is removed and replaced as intended.

A bonding conductor shall be in metal-to-metal contact with the parts to be bonded.

17.2.5 A splice shall not be employed in a bonding conductor.

17.2.6 A separate component-bonding conductor shall either:

a) Be not smaller than the size specified in Column 2 of Table 17.2;

b) Be not smaller than the conductor supplying the component; or

c) Comply with the Bonding Conductor Test, Section 56.

Exception: This requirement does not apply to component bonding conductors complying with 17.2.7.

Table 17.2
Size of circuit bonding, equipment-grounding, and grounding electrode conductors

Column 1	Column 2						Column 3				Column 4			
	Mimimun size of equipment grounding or bonding conductor AWG or kcmil (mm^2)[b]						Minimum size of grounding electrode conductor AWG or kcmil (mm^2)				Minimum size of output circuit bonding jumper AWG or kcmil (mm^2)[e,f]			
Maximum current rating[a] (amperes)	Copper		Aluminum or copper-clad aluminum		Rigid conduit or pipe trade size, inch	Electrical metallic tubing, trade size, inch	Copper		Aluminum or copper-clad aluminum		Copper		Aluminum or copper-clad aluminum	
15	14	(2.1)	12	(3.3)	1/2	1/2	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
20	12	(3.3)	10	(5.3)	1/2	1/2	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
60	10	(5.3)	8	(8.4)	1/2	1/2	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
90	8	(8.4)	6	(13.3)	1/2	1/2	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
100	8	(8.4)	6	(13.3)	1/2	1/2	6	(13.3)	6	(13.3)	6	(13.3)	4	(21.2)
150	6	(13.3)	4	(21.2)	1/2	1	6	(13.3)	4	(21.2)	6	(13.3)	4	(21.2)
200	6	(13.3)	4	(21.2)	1/2	1	4	(21.2)	2	(33.6)	4	(21.2)	2	(33.6)
300	4	(21.2)	2	(33.6)	3/4	1-1/4	2	(33.6)	1/0	(53.5)	2	(33.6)	1/0	(53.5)
400	3	(26.7)	1	(42.4)	3/4	1-1/4	1/0[c]	(53.5)	3/0[c]	(85.0)	1/0[c]	(53.5)	3/0[c]	(85.0)
500	2	(33.6)	1/0	(53.5)	3/4	1-1/4	2/0	(67.4)	4/0	(107.2)	1/0	(53.5)	3/0	(85.0)
600	1	(42.4)	2/0	(67.4)	3/4	1-1/4	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)	1	2	3/0	(85.0)	250	(127)	2/0	(67.4)	4/0	(107.2)
1000	2/0	(67.4)	4/0	(107.2)	1	2	3/0	(85.0)	250	(127)	3/0	(85.0)	250	(127)
1200	3/0	(85.0)	250	(127)	1	2	3/0	(85.0)	250	(127)	250[d]	(127)	250	(127)

NOTE – See Table 17.3 for equivalent area of bus.

[a] Maximum ampere rating of the input circuit overcurrent protective device in 54.1.3 or the output circuit overcurrent protective device described in 31.1 – 31.5.

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

[c] When the wire terminal connectors for the input or output circuit conductors, as appropriate, are rated for two 3/0 AWG copper or two 250 kcmil aluminum conductors and do not accept a 600 kcmil (304 mm^2) conductor, these values may be reduced to 2 AWG copper or 1/0 AWG aluminum.

[d] The cross section is able to 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. This applies when the cross section of the circuit conductors is limited by the wire terminal connectors provided.

Table 17.2 Continued on Next Page

Table 17.2 Continued

Column 1	Column 2				Column 3		Column 4	
	Mimimun size of equipment grounding or bonding conductor AWG or kcmil (mm^2)[b]				Minimum size of grounding electrode conductor AWG or kcmil (mm^2)		Minimum size of output circuit bonding jumper AWG or kcmil (mm^2)[e,f]	
Maximum current rating[a] (amperes)	Copper	Aluminum or copper-clad aluminum	Rigid conduit or pipe trade size, inch	Electrical metallic tubing, trade size, inch	Copper	Aluminum or copper-clad aluminum	Copper	Aluminum or copper-clad aluminum

[e] The bonding jumper for a stationary or portable unit is able to be the same size as the current-carrying conductors of the output circuit.

[f] The bonding jumper for a permanently connected Class 2 or Class 3 output circuit is able to be the same size as the current carrying conductors. The jumper shall not be smaller then 14 AWG for copper or 12 AWG for aluminum.

Table 17.3
Equivalent cross-sectional areas of wires and buses

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)

17.2.7 If more than one size of branch-circuit overcurrent-protective device is used, the size of a component-bonding conductor is to be based on the rating of an overcurrent-protective device providing ground-fault protection for that component. For a component individually protected by a branch circuit overcurrent-protective device rated less than the overcurrent-protective device used in the power unit circuit, a bonding conductor is to be sized on the basis of the component overcurrent-protective device rating.

18 Identification for Connection of Grounded Conductors

18.1 A unit rated as follows shall have the grounded conductor connected to the components, when provided, and as specified in 18.2 (a) – (c):

a) 120 volts, 2-wire;

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

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.

18.2 The following components, when provided, shall be connected to the grounded conductor of a unit rated as shown in 18.1:

a) The identified terminal or lead of a receptacle as specified in 31.8 and 31.9, 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 or shall be connected to the field-wiring lead intended for the connection of a grounded conductor. 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 28.11.

Exception: The grounded conductor may be connected to a single-pole overcurrent protective device under the conditions described in Exception No. 2 of 29.5.

19 Wire Bending Space

19.1 A permanently connected unit employing pressure terminal connectors for field connection of circuits shall be provided with space within the enclosure as specified in 19.3 – 19.7 for the installation of conductors, including grounding conductors, required by the installation.

19.2 The conductor size used in evaluating the wiring space shall be based on the use of a conductor sized in accordance with 12.2.2.

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

a) Pressure wire connector as specified in 19.4 or 19.5; and

b) Opening or knockout for a conduit or wireway in a gutter as specified in 19.9.

19.4 When a conductor is intended to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 19.1. When there is an opening or knockout for a wireway or conduit in a top, back, bottom, or side surface, this wire bending requirement applies.

Table 19.1
Minimum wire-bending space for conductors through a wall

Wire size, AWG or kcmil (mm²)		Wires per terminal (pole)[a]											
		1			2			3			4 or more		
		inches	[inches]	(mm)	inches	[inches]	(mm)	inches	[inches]	(mm)	inches	[inches]	(mm)
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][a]	(165)	6-1/2	[1/2][a]	(165)	8		(203)		–	
4/0	(107)	7	[1][a]	(179)	7-1/2	[1-1/2][a]	(191)	8-1/2	[1/2][a]	(216)		–	
250 kcmil	(127)	8-1/2	[2][a]	(216)	8-1/2	[2][a]	(216)	9	[1][a]	(229)	10		(254)
300	(152)	10	[3][a]	(254)	10	[2][a]	(254)	11	[1][a]	(279)	12		(305)
350	(177)	12	[3][a]	(305)	12	[3][a]	(305)	13	[3][a]	(330)	14	[2][a]	(355)
400	(203)	13	[3][a]	(330)	13	[3][a]	(330)	14	[3][a]	(355)	15	[3][a]	(381)
500	(253)	14	[3][a]	(355)	14	[3][a]	(335)	15	[3][a]	(381)	16	[3][a]	(406)
600	(304)	15	[3][a]	(381)	16	[3][a]	(406)	18	[3][a]	(457)	19	[3][a]	(483)
700	(355)	16	[3][a]	(406)	18	[3][a]	(457)	20	[3][a]	(508)	22	[3][a]	(559)
750	(380)	17	[3][a]	(432)	19	[3][a]	(483)	22	[3][a]	(559)	24	[3][a]	(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)		–			–			–	

NOTE – The table includes only those multiple-conductor combinations that are most commonly used. Combinations not specified are able to be evaluated.

[a] Wire bending spaces are able 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 (more than one removable wire connector per terminal is able to be provided); and

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

19.5 When a conductor is not intended to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 19.2. The wire bending space complies with Table 19.2 when:

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 19.1.

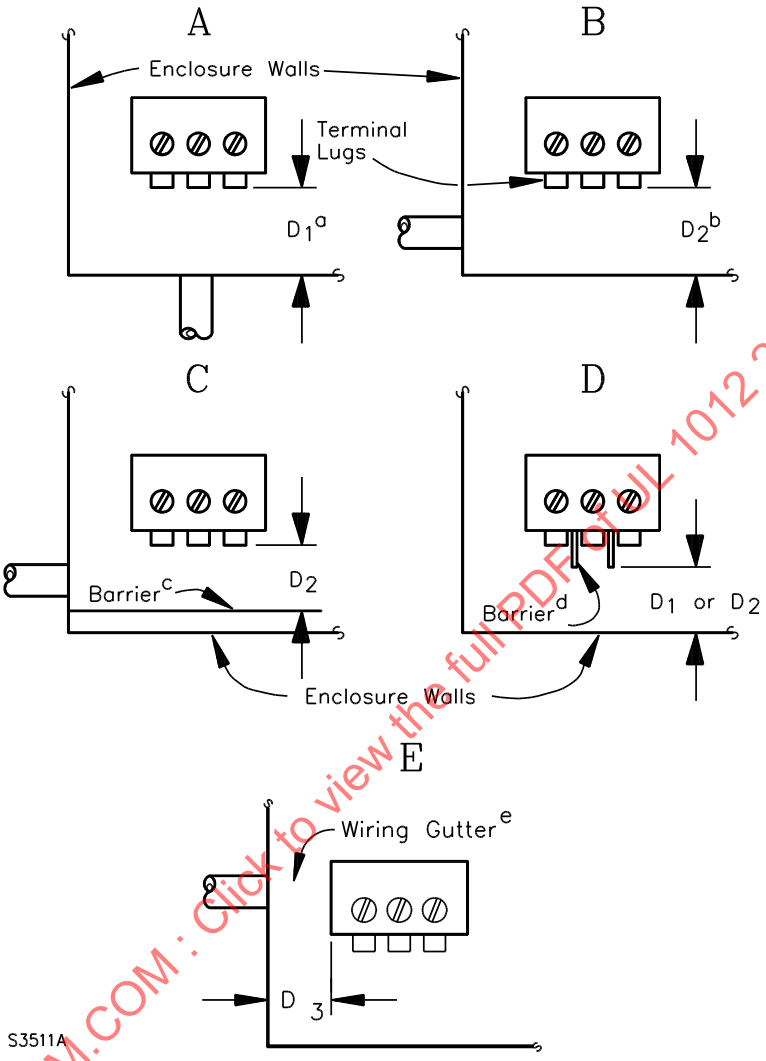
Table 19.2
Minimum width of gutter and wire-bending space for conductors through a wall not opposite terminals in inches (mm)

Size of wire, AWG or kcmil (mm^2)		Wires per terminal (pole)									
		1		2		3		4		5	
		inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)
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 – 67.4)	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)	–		–		–		–	

NOTE – The table includes only those multiple-conductor combinations that are most commonly used. Combinations not specified are able to be evaluated.

Figure 19.1

Wire bending space



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

D_3 is the width of a wiring gutter having a side through which conductors are intended 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 19.1.

[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 19.2.

[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 19.2.

[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 19.2.

19.6 When a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance shall be measured from the end of the barrier. See illustration D of Figure 19.1.

19.7 For a unit not provided with a conduit opening or knockout, the minimum wiring bending space specified in 19.4 – 19.6 shall be based on:

a) Any enclosure wall intended 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.

19.8 The distance specified in 19.3 – 19.5 shall 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 19.1. The wire terminal shall 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 is able to assume without defeating any means provided to prevent turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or similar means. A barrier, shoulder, or similar means shall be disregarded when the measurement is being made, when it does not reduce the radius to which the wire must be bent. When a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance shall be measured from the wire opening closest to the wall of the enclosure.

19.9 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 associated with that knockout. The values of the minimum required width of a wiring gutter, with respect to conductors entering a knockout, are the same as the values of minimum required bending space given in Table 19.2. See illustration E of Figure 19.1.

Exception: The wiring space may be of less 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 able to be conveniently used in the intended wiring of the unit.

20 Output Circuit Grounding

20.1 The requirements for circuit grounding specified in 20.2 – 20.12 apply to the output circuit of fixed units and of units having standard configuration grounding type receptacles for the output ac power connections.

20.2 An output ac 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;

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

c) The circuit is as described in (1) – (3). See requirements for Alternating-Current Circuits and Systems to Be Grounded in the National Electrical Code, ANSI/NFPA 70, 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 ac power circuit complying with (a) is able to be grounded when the construction complies with the requirements described in 20.3 and 20.11.

20.3 With reference to 20.2, the conductor to be grounded shall be as follows:

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

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

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

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

20.4 An output dc 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;

b) The circuit is intended to extend to premises wiring; and

c) The circuit is as described in (1) or (2):

1) Two wire rated from 50 to 300 volts.

2) Three wire.

20.5 With reference to 20.4, the conductor to be grounded shall be as follows:

a) Two wire dc system – one conductor.

b) Three wire dc system – the neutral conductor.

20.6 An output ac power circuit rated less than 50 volts 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;

b) The circuit is intended to extend to premises wiring; and

c) The circuit is supplied by a transformer where the transformer primary circuit:

1) Exceeds 150 volts to ground; or

2) Is ungrounded.

20.7 With reference to 20.6, the conductor to be grounded shall be one of the output circuit conductors.

20.8 With reference to 20.6, when the primary circuit to the transformer is derived from the secondary of another transformer, that circuit shall either be:

a) Grounded in accordance with 20.9 and 20.10;

b) Evaluated as being ungrounded; or

c) Ungrounded.

20.9 Grounding of the circuits specified in 20.2 – 20.8 shall be made by a bonding jumper connected between the conductor to be grounded and dead metal parts that are grounded via the equipment grounding conductor.

Exception: The following provisions may be made so that the circuit is able to be grounded in the field:

a) A field-wiring terminal intended for use with a conductor size specified in Column 4 of Table 17.2 and identified in accordance with 12.2.12 or 12.2.13 shall be connected to the circuit by a bonding jumper of a size not less than specified in Column 4 of Table 17.2; and

b) A marking identifying the circuit as a separately derived source and referencing the instruction manual in accordance with 61.2.13.

20.10 The size of the bonding jumper specified in 20.9 shall be, based on the current rating of the circuit, not less than the value specified in Column 4 of Table 17.2.

20.11 A fixed unit shall be provided with a terminal that complies with 12.2.3 – 12.2.9 for connection of the grounding electrode conductor to the metal enclosure or equipment grounding conductor described in 20.9 (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 17.2; and

b) Marked as described in 61.2.14.

20.12 For a unit having a polarized receptacle, lead, or terminal identified as a grounded circuit (see 12.2.12 and 12.2.13) that is not grounded at the unit itself because of an electrical connection to supply conductors originating in another wiring system [see 19.2(c)(1), 19.4(c), and 19.6(c)], a risk of electric shock shall not exist between ground and the grounded circuit contact, terminal, or lead. Compliance with this requirement shall be determined by the test specified in 53.1.

Exception: The test described in 53.1 is not required when the input neutral and output neutral conductors are solidly connected together, that is, no electronic components connected between the neutral conductors.

21 Live Parts

21.1 A current-carrying part shall be of silver, copper, a copper alloy, or other material acceptable for the application.

21.2 Aluminum may be used as a current-carrying part if determined to be acceptable with respect to heating, oxidation, and connection of dissimilar metals. A connection between aluminum and a dissimilar metal in which corrosion can occur shall be evaluated by the heat-cycling test specified in the Standard for Wire Connectors, UL 486A-486B.

21.3 Plated iron or steel may be used for a current-carrying part:

a) If acceptable in accordance with 2.1;

b) Within a motor, or associated governor; and

c) In a secondary circuit rated 42.4 volts peak (30 volts rms), 60 V dc, or less.

Stainless steel and other corrosion-resistant alloys may be used for current-carrying parts regardless of temperature.

21.4 Friction between surfaces is not acceptable as a means to prevent shifting or turning of a live part, but a properly applied lock washer is acceptable.

21.5 A live screwhead or nut on the back of a base or panel is to be countersunk not less than 1/8 inch (3.2 mm) and covered with a waterproof, insulating sealing compound that will not melt at a temperature 15° C (27° F) higher than the normal operating temperature of the component, but not less than 65° C (149°F).

Exception: A part that is staked, upset, or otherwise reliably prevented from loosening need not be recessed and may be insulated from the mounting surface by material other than sealing compound or it may be acceptably spaced.

22 Internal Wiring

22.1 General

22.1.1 Unless it is to be judged as an uninsulated live part, insulated internal wiring – including an equipment-grounding conductor – shall consist of wire of a type or types acceptable for the application, when considered with respect to:

a) The temperature and voltage to which the wiring is likely to be subjected;

b) Exposure to oil, grease, cleaning fluid, or other substances likely to have a deleterious effect on the insulation; and

c) Other conditions of service to which it is likely to be subjected.

22.1.2 If the use of a short length of insulated conductor, such as a short coil lead, is not practical, electrical insulating tubing may be used on each conductor. The tubing shall be located so as not to be subjected to sharp bends, tension, compression, or repeated flexing, nor to contact with sharp edges, projections, or corners. The tubing shall not be used in wet locations. The wall thickness shall comply with the requirements for the tubing as a component.

22.1.3 The length of power supply cord inside a power unit shall be limited to that needed for electrical connections.

22.1.4 Flexible-cord jacket inside the enclosure shall not be stripped to expose the individual conductors unless:

a) The insulation on the individual conductors is equivalent to that required by 22.1.1;

b) The individual conductors are supported in a manner positively separating them from live and dead metal parts; or

c) Supplementary insulation equivalent to that required by 22.1.1 is provided on each individual conductor.

22.2 Protection of wiring

22.2.1 Internal wiring shall be protected if, when judged in accordance with 8.1, it is accessible.

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

22.2.2 Wires within an enclosure, compartment, raceway, or the like shall be located or protected to prevent contact with any sharp edge, burr, fin, moving part, or the like that can damage the conductor insulation.

22.2.3 A hole through which insulated wires pass in a sheet metal wall within the overall enclosure of a power unit shall be provided with smooth, rounded surfaces upon which the wires may bear, to prevent abrasion of the insulation.

22.3 Electrical connections

22.3.1 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for interconnection between current-carrying parts or in a component winding, shall be terminated at each end by a method acceptable for the combination of metals involved at the connection points.

22.3.2 With reference to 22.3.1, a wire-binding screw or a pressure wire connector used as a terminating device shall be acceptable for use with aluminum under the conditions involved – for example, temperature, heat cycling, and vibration.

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

22.3.4 A soldered connection shall be mechanically secured before being soldered.

Exception: A wave- or lap-solder connection to a printed-circuit board is considered acceptable without any further mechanical security. A hand-soldered connection shall be mechanically secured, by a means such as bending or the equivalent, prior to being soldered.

22.3.5 A splice shall be provided with insulation equivalent to that of the wires involved unless permanent spacings are maintained between the splice and other metal parts.

Exception: This requirement does not apply to a splice within a coil winding.

22.3.6 A splicing device such as a pressure wire connector may be employed if it provides mechanical security and insulation acceptable for the voltage and temperature to which it is subjected.

22.3.7 If the voltage involved is less than 250 volts, insulation consisting of two layers of thermoplastic tape, of two layers of friction tape, or of one layer of friction tape and one layer of rubber tape that has been investigated and found acceptable may be used on a splice. In determining if splice insulation consisting of coated fabric, thermoplastic, or other tubing is acceptable, consideration is to be given to such factors as its electrical and mechanical properties and its flammability. Thermoplastic tape wrapped over a sharp edge is not acceptable.

22.3.8 The means of connecting stranded internal wiring to a wire-binding screw shall be such that loose strands of wire will be prevented from contacting other live parts not always of the same polarity as the

wire, and from contacting dead metal parts. This may be accomplished by the use of a pressure terminal connector, a soldering lug, a crimped eyelet, soldering of all strands together, or other acceptable means.

22.3.9 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.

23 Separation of Circuits

23.1 Factory wiring

23.1.1 Insulated conductors of different circuits (see 23.1.2) within a unit, 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: When each insulated conductor is provided with insulation rated for the highest of the circuit voltages, no barrier or segregation is required.

23.1.2 For the purpose of the requirement in 23.1.1, 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 similar components which do not provide isolation are not different circuits.

23.1.3 Segregation methods which satisfy 23.1.1 include clamping, routing, or an equivalent means that maintains permanent separation from insulated and uninsulated live parts and from conductors of a different circuit.

23.1.4 An insulated live part is able to touch any insulated or uninsulated live part of the same circuit when one of the live parts is insulated for the higher potential.

23.2 Separation barriers

23.2.1 A barrier used to provide separation between the wiring of different circuits shall be mechanically supported and reliably held in place to prevent displacement, and it shall be:

a) Grounded metal with a minimum thickness as specified for small surfaces in Table 7.1; or

b) Insulating material complying with 35.3.1 of such thickness such that deformation does not occur to defeat its purpose.

23.2.2 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.

23.3 Field wiring

23.3.1 A unit shall be constructed so that a field-installed conductor of a circuit is capable of being separated as specified in 23.3.2 or separated by barriers as specified in 23.2.1 and 23.2.2 from:

a) Factory-installed conductors connected to any other circuit, where the conductors are not insulated for the field-wiring voltage rating.

b) An uninsulated live part of another circuit, and from an uninsulated live part when short circuit with it results 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 both circuits are Class 2 or Class 3, or both circuits are other than Class 2 or Class 3.

Exception: A field-installed conductor is not required to be separated from a field wiring terminal of a different circuit when the field wiring is insulated for the maximum voltage of either circuit and both circuits are Class 2 or Class 3.

23.3.2 Separation of a field-installed conductor from another field-installed conductor, and from an uninsulated live part connected to another circuit, is able to 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 unit 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. Provisions for maintaining a minimum 1/4 inch spacing between field-installed Class 2 or Class 3 conductors and power, light, or Class 1 conductors are able to be in the form of a marking in accordance with 61.2.19.

23.3.3 With reference to 23.3.2, when the number of openings in the enclosure does not exceed the minimum required for the proper wiring of the unit, and when each opening is located opposite a set of terminals, it shall be assumed that a conductor entering an opening connects to the terminal opposite that opening. When more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than the one opposite the terminal to which it is intended to be connected and the likelihood of it contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit, are to be investigated.

24 Insulating Materials

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

24.2 Insulating material is to be judged with respect to its acceptability for the application. Materials such as mica, some molded compounds, and certain refractory materials are usually acceptable for the sole support of live parts. If an investigation is necessary to determine whether a material is acceptable, consideration is to be given to:

a) Its mechanical strength, resistance to ignition, dielectric strength, insulation resistance, and heat-resistant qualities, in both the aged and unaged conditions;

b) The degree to which it is enclosed; and

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

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

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

25 Motors

25.1 A motor shall be protected from overheating due to overload and locked-rotor conditions.

Exception: A motor that is used for air-handling only – direct drive blower or ventilating fan – is to be protected against locked-rotor conditions but need not be protected against overload conditions.

25.2 The overload protection required by 25.1 may be accomplished by one of the following:

a) Thermal protection complying with the applicable requirements in the Standard for Overheating Protection for Motors, UL 2111 or the Standard for Thermally Protected Motors, UL 1004-3;

b) Impedance protection complying with the requirements in the Standard for Impedance Protected Motors, UL 1004-2; or

c) Protection equivalent to that specified in (a).

25.3 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 is considered to have acceptable overload protection if it is protected against locked-rotor conditions only.

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 identified as 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-Links – Requirements and Application Guide, UL 60691.

26.1.3 A transformer shall be of the isolating type and comply with 26.1.4 when it supplies:

a) LVLE circuits which exit the enclosure; or

b) Accessible signal circuits as described in Section 37, Accessible Signal Circuits.

The acceptability of an insulation system in a transformer used to supply circuits other than noted in (a) or (b) is to be determined by the applicable abnormal tests specified in 54.1, 54.2, 54.7, and 54.10.

26.1.4 A transformer used where isolation is required, in accordance with 26.1.3, shall have its windings electrically isolated from separate windings 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, when such connection results in a risk of fire or electric shock.

26.1.5 With reference to the requirement in 26.1.4, a transformer complying with the requirements in one of the following standards meets the intent of this requirement:

a) The Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3;

b) The Standard for Class 2 Power Units, UL 1310; or

c) The Standard for 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, when used, as specified in 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, d, or i
2.	Insulation between the primary and any secondary winding	a, b, c, d, or i
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 (See also j)

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).

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

c) A generic material having a thickness equivalent to 0.028 inch vulcanized fiber in accordance with 35.3.5, or other material equivalent to note (a) or (b) where the material has a minimum dielectric breakdown strength of 5000 volts for the thickness used as determined by the test described in Tests on Insulating Materials, Section 44.

d) Spacings specified in either Table 35.2, when applicable, or Table 26.2 are able to 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) when 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 when the insulation is in contact with the enclosure.

g) A generic material having a thickness equivalent to that specified in notes (e) and (f) in accordance with 35.3.5, or other material equivalent to notes (e) and (f) where 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 Tests on Insulating Materials, Section 44.

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

Table 26.1 Continued on Next Page

Table 26.1 Continued

Insulation required	Type of insulation
1) The coil withstands the appropriate dielectric withstand potential described in 43.1. 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 43.2. Magnet wire alone shall not be used as insulation (see 35.1.8). i) An insulation system consisting of N multiple layers of any thickness when all possibilities of N minus 1 layers withstand, for one minute, double the test potential specified in the Dielectric Voltage Withstand Test, Section 43, applied using electrodes as described in 44.2. "N" shall be a minimum of 2 layers. j) Any type and thickness of insulation in addition to the magnet wire coating is able to be used between a LVLE secondary crossover lead and: 1) The secondary winding to which the cross over lead is connected; 2) The metallic enclosure; and 3) The core.	

Table 26.2
Spacings within a transformer

Potential involved, volts	Minimum spacing through air and over surface between any uninsulated live part and an uninsulated live part of opposite polarity, or the core[a]	
	Inch	(mm)
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)
Greater than 600	See Table 35.2	

NOTE – This table applies only to transformers that are treated with an insulating varnish and baked or otherwise impregnated.

[a] Includes turns of a coil having a magnet wire coating.

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 Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8, shall comply with note (a) or (c) of Table 26.1.

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 shall be accomplished by employing a 3-flange bobbin for winding the primary and secondary windings adjacent to each other or using a telescoping bobbin construction with each section containing an individual winding where the primary winding is wound over the secondary winding or the secondary winding is wound 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 winding with the primary winding insulated from the secondary winding by means of tape insulation, may be used when:

a) The tape insulation complies with note (a) or (c) of Table 26.1;

b) The tape insulation provides a continuous 1/32 inch (0.8 mm) overlap on the bobbin flanges; and

c) The transformer complies with the tests described in the Flanged Bobbin Transformer Abnormal Test, Section 55 (see 26.2.4).

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, may be used when:

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 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 the Standard for Class 2 Power Units, UL 1310; the Standards for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3; or the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television Type Appliances, UL 1411, meets the intent of this requirement.

Exception No. 4: Physical separation of the primary and secondary windings is not required for units employing multiple layered wire which has been evaluated to the requirements for miscellaneous insulating devices and materials of the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, and the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

26.2.4 With reference to Exception No. 1(c) to 26.2.3, the Flanged Bobbin Transformer Test of Section 55 is not required when the transformer:

a) Is supplied from a LVLE circuit in accordance with 6.15, or a limited energy circuit in accordance with 6.13; or

b) Complies with the requirements in 36.5 – 36.13.

27 Resistors

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

27.2 An assembly employing lock washers may be considered to comply with the requirement in 27.1.

28 Switches and Controls

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

Exception: A switch or other control device not having an inductive rating that is connected in a transformer secondary circuit of 50 volts rms or less and that complies with the requirements for Overload of Switches and Controls, Section 48, need not comply with this requirement.

28.2 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 rated not less than twice the full-load current rating of the load, or the switch shall be investigated for the application.

28.3 Unless acceptably rated, a switch or other device that controls a motor and is not interlocked so that it will not break the locked-rotor motor current shall be subjected to the overload test required by 48.3 and described in 48.4.

28.4 A switch that controls a tungsten-filament lamp shall have a tungsten-filament-lamp current rating not less than the maximum current it will control.

Exception: A switch not having a tungsten-filament-lamp current rating and rated 3 amperes or more may be used to control a 15-watt or smaller lamp.

28.5 A fixed power unit that is intended for connection to more than one source of supply shall be provided with one manually operable disconnect control device (separate switch or breaker, set of contacts, or the like) of an indicating type for each source of supply entering the power unit that involves a risk of electric shock or electrical energy-high current levels. If more than one such disconnect switch or other control is provided on the power unit, all of the following conditions shall apply:

a) All such devices shall be grouped together;

b) Each device shall be marked to identify its function;

c) There shall be a prominent and permanent marking with the group of devices to indicate the switches and controls that must be off to completely disconnect the power unit.

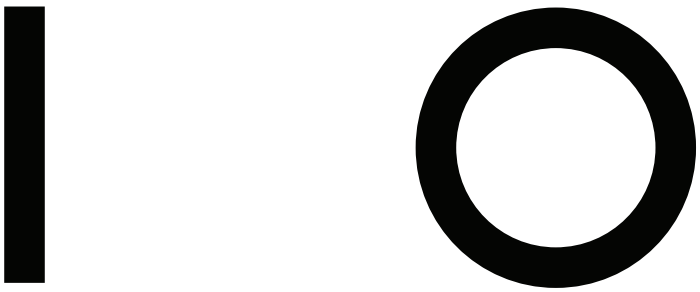
Exception: A clock or timing device on or remote from the power unit may remain energized if there is a marking indicating that the clock remains energized while the power unit is off.

28.6 Both the "on" and "off" positions of the disconnect control devices mentioned in 28.5 and of the main disconnect switch on portable or stationary equipment, if provided, are to be marked with the words "ON" and "OFF." The symbols illustrated in Figure 28.1 may be used for this purpose. Identification by illumination only is not acceptable.

Figure 28.1

On and off symbols

(iec5007b.eps)



IEC 417, Symbol 5007 IEC 417, Symbol 5008

su3937

28.7 A switch provided as part of a power supply shall be acceptable for the maximum potential to ground of the circuit. A nominal 208-volt, single- or 3-phase, or a 120/240-volt, single-phase product is considered to involve a potential to ground of less than 150 volts. A 2-wire, single-phase or a 3-wire, 3-

phase product with a rating in the range from 220 – 240 volts is considered to involve a potential to ground in excess of 150 volts.

Exception: A 2-wire, single-phase or a 3-wire, 3-phase product with a rating in the range of 220 – 240 volts may be connected to a supply circuit having a potential to ground of 150 volts or less if marked as described in 61.1.12.

28.8 If unintentional operation of a switch results in a risk of injury to persons, the switch shall be located or guarded so that such operation is unlikely.

28.9 The actuator of a switch may be guarded by recessing, ribs, barriers, or the like.

28.10 An on-off switch shall have a marked "off" position so that the operator can readily determine by visual inspection when the power unit is de-energized.

Exception No. 1: This requirement does not apply to a switch complying with 28.6.

Exception No. 2: The on-off switch may be marked with both of the symbols in Figure 28.1 in lieu of the marked "off" position.

28.11 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 is not able to be disconnected until the ungrounded conductors of the circuit have been disconnected.

29 Overload-Protective Devices

29.1 A 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 7.5.2).

Exception: A protective device that is unknown to the user because of its location and omission of reference to the device in the operating instructions, circuit diagrams, and other instructional materials provided with the power unit is not required to comply with this requirement.

29.2 With reference to the requirement in 28.1, 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.

29.3 A circuit breaker connected in the input circuit shall open all ungrounded conductors.

Exception: If the power unit has provision for connection of a grounded neutral conductor, individual single-pole circuit breakers are acceptable as the protection for each ungrounded conductor of a 3-wire single phase circuit or for each ungrounded conductor of a 4-wire, 3-phase circuit, provided that no conductor involves a potential to ground in excess of 150 volts. See 61.1.9.

29.4 For a vertically mounted circuit breaker, the down position shall be the "off" position.

29.5 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 when 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 when:

a) The grounded circuit conductor is not depended on to carry a current imbalance, such as in a unit 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 61.1.10.

30 Fuses and Fuseholders

30.1 A fuse and a fuseholder shall have voltage and current ratings acceptable for the circuit in which they are connected.

30.2 A fuse that is used to provide short-circuit protection for output circuits in a household power unit shall not be interchangeable with a fuse of a higher ampere rating.

30.3 A fuse that is used to provide short circuit protection for output circuits in a commercial power unit shall be marked in accordance with 61.1.7.

30.4 The screw shell of a plug-type fuseholder and the upper terminal of an extractor-type fuseholder shall be connected toward the load.

30.5 Unless acceptable for the application, a fuse and fuseholder combination connected, but not required, in an output circuit having an open-circuit voltage not exceeding 50 volts rms shall be subjected to the test described in 54.4.1.

31 Output Alternating Current Power Circuits

31.1 Each ac output power circuit shall be provided with overcurrent protection for all ungrounded conductors as described in 31.3 – 31.5. 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 suitable for use as branch circuit protection.

Exception No. 1: Overcurrent protection is not required to be provided for an output where the current is limited to not more than 110 percent of the receptacle rating by construction of a transformer, one or more resistors, or a regulating network complying with 54.8.1.

Exception No. 2: An appliance protector 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 unit supplied by a transformer in lieu of a branch circuit protection fuse or circuit breaker when all of the following are met:

a) The protector is an overcurrent type or a shunt trip overcurrent type;

b) The protector tripping current rating is not greater than 135 percent of the protector amp rating;

c) The protector complies with the UL 1077 short-circuit test conducted without series overcurrent protection;

d) The protector complies with the UL 1077 recalibration test following short-circuit testing; and

e) The protector short circuit current rating is not less than the maximum fault current available.

Exception No. 3: A fuse having a short-circuit interrupting rating not less than the maximum fault current available from the unit and complying with the requirements in the Standard for Low-Voltage Fuses – Part 14: Supplemental Fuses, UL 248-14, may be used in the output circuit of a unit supplied by a transformer in lieu of a branch circuit protection fuse or circuit breaker.

Exception No. 4: Overcurrent protection is not required to be provided with a unit 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.

31.2 The voltage rating mentioned in 31.1 for a 3-phase circuit shall be based on the phase-to-phase voltage.

31.3 For a unit having provision for permanent wiring connection of the ac output power circuit, the rating of the overcurrent protection shall not exceed the ampacity of the conductors intended to be connected to the unit, as determined in accordance with 12.2.2.

31.4 For a unit provided with a cord and receptacle for connection of the output, the rating of the overcurrent protection shall not exceed the ampacity of the cord or the current rating of the receptacle, whichever is less.

31.5 Overcurrent protection shall be provided for each standard configuration output receptacle. A single overcurrent protection device with a rating not exceeding the ampere rating of any receptacle to which it is connected may be used in conjunction with multiple receptacles 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.

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 ac receptacles do not exceed the current and voltage ratings of the intended input branch circuit overcurrent protection device.

31.6 A standard configuration receptacle in a power unit provided with means for grounding shall be of the grounding type. See 31.9.

31.7 A standard configuration receptacle in a power unit provided with a polarized nongrounding type attachment plug shall be of the polarized nongrounding type when the receptacle is connected to the primary circuit.

31.8 When a standard configuration receptacle is supplied from the input ac supply circuit, the white or silver terminal of the receptacle shall be connected to the grounded supply conductor, and the grounding terminal of the receptacle, when applicable (see 31.7), shall be conductively connected to the equipment grounding means per the requirements specified in Section 17, Bonding of Internal Parts. See also 18.1 and 16.7.

31.9 With reference to 31.6 and 31.8, when a grounding type receptacle other than an isolated-grounding type 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 per the requirements in 20.1, 20.2, and 20.3; and

b) The grounding terminal of the receptacle, when applicable (see 31.7) shall be conductively connected to the equipment grounding means per Section 17, Bonding of Internal Parts, and 16.7.

31.10 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 31.11.

31.11 With reference to the 31.10, a unit 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 unit specified in 16.1 – 16.3 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 16, Grounding Connections.

32 Lampholders

32.1 A lampholder shall be designed or installed so that uninsulated live parts, other than a screw shell, will not be exposed to contact by persons removing or replacing the lamp in intended service.

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

33 Capacitors

33.1 A capacitor connected across the line, such as a capacitor for radio-interference elimination or power-factor correction, shall be housed within an enclosure or container that protects the plates against mechanical damage and prevents the emission of flame or molten material resulting from breakdown of the capacitor.

33.2 The container of a capacitor shall be of metal providing strength and protection not less than that of uncoated steel having a thickness of 0.020 inch (0.51 mm).

Exception: The container may be of thinner sheet metal or may be of material other than metal, if mounted inside a power unit having an enclosure that complies with the requirements in 7.1.1 – 7.1.5.

33.3 A container of an electrolytic capacitor having a thickness less than that required by 33.2 shall employ a means for venting.

34 Printed Wiring

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. The use of material classed V-2 requires the use of a closed bottom in the equipment beneath the material or an equivalent barrier.

34.2 A resistor, capacitor, inductor, or other part that is mounted on a printed-wiring board to form a printed circuit 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 unit.

34.3 With reference to 34.2, consideration is to be given to a barrier or a partition that is part of the power unit assembly and that provides mechanical protection and electrical insulation of a component connected to the printed-wiring board.

35 Spacings

35.1 General

35.1.1 The spacings for a unit intended for use in a general environment shall not be less than the applicable values specified in Table 35.1. Spacings for a unit intended for use in a controlled environment (see 6.8 and 35.1.3) shall not be less than the applicable values specified in Table 35.2. For the purpose of this requirement, a general environment is an environment other than a controlled environment.

Exception No. 1: The spacings of 35.1.1 are not required when the unit complies with 35.3.1 and when liners and barriers are used.

Exception No. 2: The spacing requirements of 35.1.1 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.

Exception No. 3: On printed-wiring boards having a flammability classification of V-0 in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, spacings (other than spacings to dead metal traces, between primary and secondary circuits, and at field wiring terminals) are not specified between traces of different potential connected in the same circuit when:

a) The spacings are adequate to comply with the requirements in 54.11, Evaluation of reduced spacings on printed-wiring boards; or

b) An analysis of the circuit indicates that no more than 12.5 mA of current is available 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). When these foils are in circuits described in 35.1.11 or 35.1.12, no spacing is specified.

Exception No. 5: The spacing requirements in Table 35.1 and Table 35.2 are not required to apply to inherent spacings of a component such as a switch, lampholder, power switching semiconductor, or a motor. See 35.1.6.

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.

Exception No. 8: The spacing requirements of 35.1.1 do not apply when the alternative spacings of 35.2 are met.

Exception No. 9: The spacing requirements of 35.1.1 shall not apply to areas between live parts potted in epoxy or equivalent material. See 35.1.2.

Table 35.1
Spacings for units intended for use in a general environment

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]		Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[b,g]
	Through air	Over surface	Shortest distance
0 – 50	1/16	1/16	1/16
(0 – 70.7)	(1.6)[c,d]	(1.6)[c]	(1.6)[c,d]
Greater than 50 to 150	1/8	1/4	1/4
(70.7 to 212.1)	(3.2)[c,d]	(6.4)[d]	(6.4)
Greater than 150 to 300	1/4	3/8	1/2
(212.1 to 424.2)	(6.4)	(9.5)	(12.7)
Greater than 300 to 600	3/8	1/2	1/2
(424.2 to 848.4)	(9.5)	(12.7)	(12.7)
Greater than 600 to 3000	3/4	3/4	3/4
(848.4 to 4242.0)	(19.1)[e,f]	(19.1)[e,f]	(19.1)
Greater than 3K to 5K	1	1	1
(4243.4 to 7070.0)	(25.4)[e,f]	(25.4)[e,f]	(25.4)
Greater than 5K to 10K	1-1/2	1-1/2	1-1/2
(7070.0 to 14140.0)	(38.1)[e]	(38.1)[e]	(38.1)
	1-1/8	1-1/8	
	(28.6)[f]	(28.6)[f]	
Greater than 10K to 15K	1-1/2	1-1/2	1-1/2
(14140.0 to 21210.0)	(38.1)[e,f]	(38.1)[e,f]	(38.1)

[a] For printed-wiring boards, see Exception Nos. 2 – 4 in 35.1.1.

[b] For the purpose of this requirement, a metal piece attached to the enclosure is evaluated as part of the enclosure when deformation of the enclosure reduces 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.

[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 able to be provided.

[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;

Table 35.1 Continued on Next Page

Table 35.1 Continued

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]		Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[b,g]
	Through air	Over surface	Shortest distance
3) Uninsulated primary-circuit parts.			
[f] Between uninsulated high-voltage parts and the following:			
1) Insulated primary-circuit parts;			
2) Insulated high-voltage parts of opposite polarity, or of different potentials.			
[g] Spacings are able to be less than specified when the enclosure complies with the metal enclosure strength requirements in 45.1 and 45.3.			

Table 35.2
Spacings for units intended for use in a controlled environment

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,h]
	Through air	Over surface	Shortest distance
0 – 50	3/64	3/64	1/16
(0 – 70.7)	(1.2)[c]	(1.2)[c]	(1.6)[c]
Greater than 50 to 150	1/16	1/16	1/4
(70.7 to 212.1)	(1.6)[c,e]	(1.6)[c,e]	(6.4)
Greater than 150 to 300	3/32	3/32	1/2
(212.1 to 424.2)	(2.4)[c,e]	(2.4)[c,d,e]	(12.7)
Greater than 300 to 600	3/8	1/2	1/2
(424.2 to 848.4)	(9.5)	(12.7)	(12.7)
Greater than 600 to 3000	3/4	3/4	3/4
(848.4 to 4242.0)	(19.1)[f,g]	(19.1)[f,g]	(19.1)
Greater than 3K to 5K	1	1	1
(4243.4 to 7070.0)	(25.4)[f,g]	(25.4)[f,g]	(25.4)
Greater than 5K to 10K	1-1/2	1-1/2	1-1/2
(7070.0 to 14140.0)	(38.1)[f]	(38.1)[f]	(38.1)
	1-1/8	1-1/8	
	(28.6)[g]	(28.6)[g]	
Greater than 10K to 15K	1-1/2	1-1/2	1-1/2
(14140.0 to 21210.0)	(38.1)[f,g]	(38.1)[f,g]	(38.1)
[a] For printed-wiring boards, see Exception Nos. 2 – 4 in 35.1.1.			

Table 35.2 Continued on Next Page

Table 35.2 Continued

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,h]
	Through air	Over surface	Shortest distance

[b] For the purpose of this requirement, a metal piece attached to the enclosure is evaluated as part of the enclosure when deformation of the enclosure reduces 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.

[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 is able to be provided.

[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.

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

1) Insulated primary-circuit parts;

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

[h] Spacings are able to be less than specified when the enclosure complies with the metal enclosure strength requirements in 45.1 and 45.3.

35.1.2 With reference to Exception No. 9 to 35.1.1, epoxy or equivalent material is able to be used to reduce spacings, when all of the following are met:

a) Spacings of minimum 1/32 inch (0.8 mm) are maintained prior to application of the encapsulant;

b) There are no significant voids in the encapsulant;

c) The encapsulant is minimum 1/32 inch thick;

d) The area of reduced spacing, with encapsulant applied, withstands the applicable Dielectric Voltage Withstand Test described in Section 43; and

Exception: When the normal operating potential between the parts under consideration does not exceed 600 V rms, the dielectric test is not required to be conducted.

e) The encapsulant temperature during the Temperature Test of Section 42 does not exceed 65°C (117°F) rise [based on an assumed operating ambient rating of 25°C (45°F)] or 90°C (194°F) limit (when tested at an ambient rating of greater than 25°C).

Exception: When the encapsulant has been investigated and rated for a higher operating temperature, the temperatures shall not exceed the material temperature rating.

35.1.3 Units investigated for use in a controlled environment indicated in 35.1.1 shall be marked as described in 61.1.6.

35.1.4 When an uninsulated live part is not rigidly secured in position by means other than friction between surfaces, or when 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 are maintained.

35.1.5 With reference to 35.1.4, a properly applied lock washer rigidly secures a part.

35.1.6 Inherent spacings of the components specified in Exception No. 5 to 35.1.1 shall comply with the requirements for the component in question, when 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.

35.1.7 With respect to evaluating spacings, spacings between uninsulated parts of different circuits shall be based on the highest of the circuit voltages. See 43.3.1 – 43.3.3.

35.1.8 For the purpose of evaluating spacings, film-coated wire is an uninsulated live part.

35.1.9 Spacings at field-wiring terminals shall be measured with conductors installed in the terminals. The gage of these conductors is based on the rating of the circuit containing the terminals. See 12.2.2.

35.1.10 Spacings between uninsulated live parts of different potential and between such parts and dead metal that are able to be grounded in service are not specified for parts of LVLE circuits, in accordance with 6.15, nor in accessible signal circuits described in Section 37, Accessible Signal Circuits.

35.1.11 Spacings between uninsulated live parts of different potential and between such parts and dead metal that is able to be grounded in service are not specified for parts of limited-energy circuits, in accordance with 6.13. Spacings in these circuits are judged by the applicable dielectric voltage-withstand test described in Section 43, Dielectric Voltage-Withstand Test.

35.1.12 When a circuit is not a safety circuit, spacings within the circuit are not specified for isolated secondary circuits supplied by a source with:

a) A maximum output of 200 VA; or

b) A maximum output of 100 volts.

The spacings in these circuits shall be judged on the basis of the Dielectric Voltage-Withstand Test, Section 43. See 35.1.13.

35.1.13 With reference to 35.1.12, spacings within a circuit derived from a source capable of exceeding the maximum limits are not specified, when:

a) The VA or voltage within the circuit is limited to 200 VA or 100 volts by a regulating network complying with the requirement in 36.12; or

b) A fuse or other overcurrent-protective device, other than an automatically reset type, having a current rating in amperes not exceeding (100VA)/(V_{max}), where V_{max} is the maximum rms voltage of the secondary in question.

Maximum available volt-amperes or voltage is to be measured using a variable resistor connected in place of the circuit in question, with the primary connected in accordance with 39.1. For a transformer having

multiple secondary windings, all measurements on one secondary-winding circuit are to be made with all other windings unloaded.

35.1.14 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 43, Dielectric Voltage-Withstand Test.

Exception: A meter complying with the requirements in the Standard for Electrical Analog Instruments – Panel Board Types, UL 1437, is not required to be subjected to a Dielectric Voltage-Withstand Test.

35.2 Alternative Spacings

35.2.1 With reference to 35.1.1 Exception No. 8, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, may be used. The spacing requirements of UL 840 shall not be used for field wiring terminals or for spacings to a dead metal enclosure. In determining the pollution degree and overvoltage category, the end-use application is to be evaluated and is able to modify those characteristics given in 35.2.2 and 35.2.3.

35.2.2 The level of pollution expected or controlled for indoor use equipment is pollution degree 2. For outdoor use equipment, pollution degree 3 is expected. Hermetically sealed or encapsulated enclosures, or coated printing wiring boards in compliance with the Printed Wiring Board Coating Performance Test in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, are pollution degree 1.

35.2.3 It is anticipated the equipment is rated overvoltage category II and overvoltage category I as defined in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

35.2.4 In order to apply Clearance B (controlled overvoltage) clearances, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product.

35.2.5 For the purpose of applying this alternative, all printed wiring boards are evaluated as having a minimum comparative tracking index of 100 without further investigation.

35.3 Insulation liners and barriers

35.3.1 An insulating liner or barrier of material such as vulcanized fiber or thermoplastic used in lieu of required spacings specified in Exception No. 1 to 35.1.1 shall not be less than 0.028 inch (0.71 mm) thick. The material shall not be used as the sole support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current. 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 is capable of being used:

a) In conjunction with an air spacing of not less than 50 percent of the minimum required 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: A generic material as noted in 35.3.5 and Table 35.3 is capable of being used as an insulating liner when the material:

a) Does not serve as sole support of live parts; and

b) Is not subject to inadvertent mechanical stresses by a user or a field installer.

Exception No. 3: An insulating material having a thickness less than that specified is capable of being used when, upon investigation, it is found to be capable of being used for the application and has a dielectric breakdown strength of not less than 5000 volts or 2500 volts in the thickness used for equivalency to 0.028 inch or 0.013 inch thick vulcanized fiber, respectively, as determined by the equivalent insulation test described in Tests of Insulating Material, Section 44.

35.3.2 Other than as indicated in 35.3.3, 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 required 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.

35.3.3 Insulating tubing complying with the Standard for Extruded Insulating Tubing, UL 224, shall not be used as insulation over parts subject to maintenance, such as bolts that are periodically tightened.

35.3.4 A wrap of thermoplastic tape, complying with the requirements in the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510, may be used when all of the following conditions are met:

a) The wrap is not less than 0.013 inch (0.33 mm) thick, is applied in two or more layers, and is used in conjunction with not less than one-half the required through air spacing;

b) The wrap is not less than 0.028 inch (0.71 mm) thick when used in conjunction with less than one-half the required through air spacing;

c) Its temperature rating is not less than the maximum temperature observed during the Temperature Test of Section 42;

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 parts subject to maintenance, such as bolts that are periodically tightened.

35.3.5 With reference to Exception No. 2 of 35.3.1, and notes (c) and (g) of Table 26.1, insulation of a generic material type specified in Table 35.3, is capable of being used where the layer(s) of each generic material is of a minimum thickness such that all layers collectively are greater than, or equal to, the minimum thickness required (T):

$$T \leq A_1(EF_1) + A_2(EF_2) + A_3(EF_3)...$$

in which:

A_1, A_2, and A_3 denote the total thickness of each generic material type;

EF_1, EF_2, and EF_3 denote the equivalency factor specified in Table 35.3 for the generic material type corresponding to A_1, A_2, and A_3; and

T is the thickness requirement for vulcanized fiber.

Table 35.3
Equivalency factors for insulation materials

Generic material	Equivalency factor (EF)
Electrical grade paper, fiber, or pressboard	1
Impregnated rag paper	1.3
Acetate sheet	1.5
Polyvinyl chloride (PVC)	1.3
Silicone rubber (SIR)	0.5
Impregnated glass or acetate cloth	1.2
Polyester	b
Polyethylene terephthalate (PETP)	b
Fluorinated ethylene propylene (FEP)	3
Polytetrafluoroethylene (PTFE)	3
Aramid paper	c
Polyamide (PI)	6
Mica[a]	4.7

NOTE – See 35.3.5.

[a] EF applies when not subject to mechanical damage.

[b] To determine equivalence to 0.028 inch (0.71 mm) thick vulcanized fiber, EF = 4; to determine equivalence to 0.013 inch (0.33 mm) thick vulcanized fiber, EF = 2.

[c] To determine equivalence to 0.028 inch thick vulcanized fiber, EF = 3.3; to determine equivalence to 0.013 inch thick vulcanized fiber, EF = 1.5.

36 Control Circuits

36.1 An LVLE circuit as described in 6.15, or a limited-energy circuit as described in 6.13 is able to be connected to the frame of the unit.

36.2 When the frame is used as a current-carrying part of a secondary circuit, a hinge or other movable part shall not be relied upon to carry current.

36.3 Except as indicated in 36.4, an LVLE circuit (see 6.15) is not required to be investigated. Printed-wiring boards and insulated wire used in such circuits shall be types that are required for the application. See 22.1.1 and 34.1.

36.4 Safety circuits shall comply with the requirements for primary circuits.

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

a) A voltage limit of 42.4 volts peak for ac, 60 volts for dc; 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 36.6.

Printed-wiring boards, insulated wires, and motors used in such circuits shall be types that are required for the application. See 22.1.1, 25.1, 25.2, and 34.1.

Exception: The current is able to exceed the value specified in (b) when the circuit includes an overcurrent protection device as described in 36.9 and 36.10.

36.6 With reference to the current specified in 36.5(b), the maximum current is to be measured under any condition of loading, including short circuit. This is to be accomplished using a resistor that is continuously readjusted during the 1-minute period to maintain maximum load current. This current shall not exceed the value indicated in 36.5(b).

36.7 With reference to the voltage limit specified in 36.5(a), measurement is to be made with the unit connected to the voltage specified in 39.1 and with all loading circuits disconnected. When 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.

36.8 When the control circuit specified in 36.5 is not limited as to available short-circuit current by the construction of a transformer, and the circuit includes either one or more resistors, a fuse, a nonadjustable manual-reset protective device, or a regulating network (see 36.12), the circuits in which the current is limited, in accordance with 36.9, 36.10, or 36.11, is not required to be investigated.

36.9 A fuse or circuit-protective device provided in the control circuit used to limit the current in accordance with 36.8 shall be rated or set at not more than the values specified in Table 36.1.

Table 36.1
Rating for secondary fuse or circuit protector

Circuit voltage (volts, rms)	Maximum overcurrent protection (amperes)
20 or less	5
More than 20 and not greater than 60	100/V[a]
[a] V is the maximum output voltage, regardless of load, with the primary energized in accordance with 39.1.	

36.10 A fuse or circuit-protective device is able to be connected in the primary of a transformer to limit the current, in accordance with 36.8, when the protection is equivalent to that specified in 36.9. This shall be determined by conducting the Overcurrent Protection Calibration Test, Section 52.

36.11 One or more resistors, or a regulating network, used to limit the current in accordance with 36.8 shall be such that the current under any condition of load, including short circuit, does not exceed the values indicated in 36.5(b).

36.12 When a regulating network is used to limit the voltage or current, in accordance with 36.5 – 36.11, and the performance is 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 specified in 36.14 are to be performed; and

b) Critical components shall be derated in accordance with the Electronic Reliability Design Handbook, Military Handbook Number 338-1A.

36.13 In a circuit of the type described in 36.8, 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 evaluated to the applicable requirements in this standard.

36.14 When it is determined that environmental tests in accordance with 36.12 (a) are required, the 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) Electromagnetic Susceptibility Tests;

d) Electrostatic Discharge Test;

e) Thermal Cycling Test;

f) Humidity Test for a unit intended for a general environment; and

g) Effects of Shipping and Storage Test.

Before and after each test, the control is to be checked for normal operation. See 36.15.

36.15 The following test parameters are to be used in the investigation of the control covered by 36.14 for compliance with the Standard for Tests for Safety-Related Controls Employing Solid State Devices, UL 991:

a) Critical components are able to be electrically supervised;

b) Audibility is capable of being used as a 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.

37 Accessible Signal Circuits

37.1 The requirements in 37.2 and 37.3 apply to accessible signal circuits having provision for external connections such as RS232 communication ports and similar equipment.

37.2 A signal circuit that extends out of a unit shall be isolated from internal circuits having a voltage involving a risk of electric shock 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 43.1.1 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 Power Units, UL 1310, or the Standards for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3;

c) An isolation transformer complying with the requirements in 26.1.4 – 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 when:

1) The voltage being isolated is not derived from the ac input circuit; and

2) The network does not show a risk of electric shock at the external signal circuits 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.

37.3 The maximum voltage and current available from an accessible signal circuit shall comply with the requirements in 36.5 – 36.12.

37.4 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 36.5, shall not exceed the values specified in Table 37.1.

Table 37.1
Maximum power of accessible signal circuits

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

38 Class 2 and Class 3 Output Circuits

38.1 When an output is marked or otherwise identified as being Class 2, that output shall comply with the construction, performance, and marking requirements described in the Standard for Class 2 Power Units, UL 1310.

38.2 When an output is marked or otherwise identified as being Class 3, and the output is ac supplied from a linear transformer, that output shall comply with the construction, performance, and marking requirements described in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3. When the output is dc or supplied from other than a linear transformer, that output shall comply with the requirements in Sections 79 – 87.

PERFORMANCE

39 General

39.1 A representative sample of a power unit shall be subjected to the tests described in 39.4 and Sections 40 – 57. Unless otherwise specified, all tests are to be conducted at the applicable voltage specified in Table 39.1, and at rated frequency. A power unit rated 50 – 60 hertz is to be tested at 60 hertz. A power unit marked with an operating voltage range shall comply with the requirements in this Section while connected to a source of voltage adjusted to any value within the specified range.

Table 39.1
Values of test voltages

Rated voltage	Test voltage
110 – 120	120
121 – 219	Rated voltage
220 – 240	240
241 – 253	Rated voltage
254 – 277	277
278 – 439	Rated voltage
440 – 480	480
481 – 525	Rated voltage
550 – 600	600

39.2 The tests of a power unit having an output for a utilization appliance, other specific equipment, or for charging storage batteries shall, if necessary, include consideration of the output voltage and current wave forms under all likely loading conditions.

39.3 Output current measurements of either half-wave or full-wave rectifier circuits are to be based on the average current reading.

39.4 In addition to the applicable performance tests specified in Sections 40 – 57, a polymeric enclosure (see 7.1.5) shall be evaluated to the following tests in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C:

a) Mold Stress Relief Distortion;

b) Resistance to Impact; and

c) Strain Relief Test after Mold Stress Relief Distortion.

40 Leakage Current Test

40.1 The leakage current of a cord-connected power unit when tested in accordance with 40.2 – 40.6 shall not be more than:

a) 0.5 milliampere for a portable power unit; or

b) 0.75 milliampere for a stationary power unit.

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 16, Grounding Connections; or

b) Leakage current does not exceed 5 percent of the input current determined in accordance with Section 41, Power Input Test, and all of the following conditions are met:

1) The unit complies with the grounding requirements in Section 16, Grounding Connections;

2) The unit is not supplied through a standard configuration 125 volt, 15 amp nor 125 volt, 20 amp non-locking type plug;

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 62.1.9.

40.2 All exposed conductive surfaces shall 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 8.1. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to output terminals operating at voltages less than 30 volts rms (42.4 volts peak) or 60 volts dc. If all accessible surfaces are bonded together and connected to the grounding conductor of the power supply cord, the leakage current may be measured between the grounding conductor and the grounded supply conductor.

40.3 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 (3.9 by 7.9 inches) 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 power unit.

40.4 The circuit for the leakage current measurement is to be as illustrated in Figure 40.1. 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. The measurement instrument is to comply with the following:

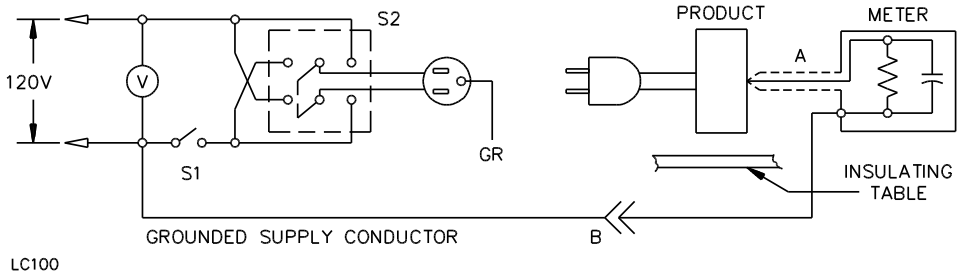
a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.

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

c) Over a frequency range of 0 – 100 kilohertz, the measurement 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.

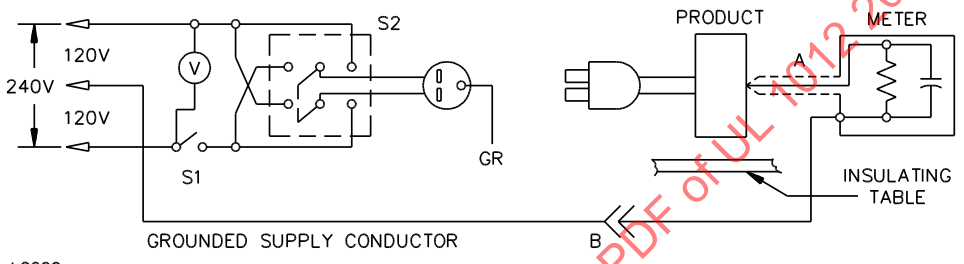
Figure 40.1

Leakage current measurement circuit



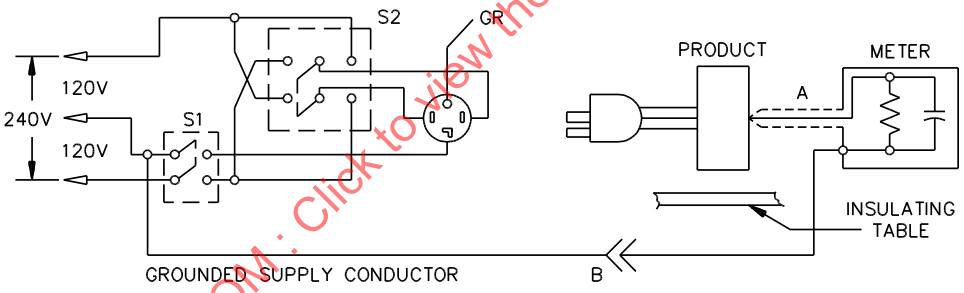
LC100

A. Appliance intended for connection to a 120-volt power supply.



LC200

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



LC300

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

Note:

A. Probe with shielded lead.

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

40.5 Unless the meter is being used to measure leakage from one part of a power unit to another, the meter is to be connected between an accessible part and the grounded supply conductor.

40.6 A sample of the power unit is to be tested for leakage current starting with the as-received condition – the 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 Table 39.1. The test sequence, with reference to the measuring circuit, Figure 40.1, is to be as follows:

a) With switch S1 open, the power unit is to be without load and connected to the measuring circuit. The leakage current is to be measured using both positions of switch S2 and with the power unit switching devices in all their operating positions.

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

40.7 In general, the complete leakage current test program as described in 40.6 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.

41 Power Input Test

41.1 The current or watts input to a power unit, when connected to a supply adjusted to the test voltage specified in Table 39.1 and supplying rated output into a load as described in Table 41.1 shall not be more than 110 percent of the rated value when temperatures stabilize (see 42.15).

Table 41.1
Unit output loading

Type of output current	Intended use	Load for test
Alternating current or rectified	Unspecified	Variable resistor adjusted to result in rated output.
Rectified	Battery charger rated ≤ 20A	Variable resistor in parallel with a 100,000 microfarad capacitor adjusted to result in rated output.[a,b]
	Battery charger rated > 20A	Variable resistor in parallel with a 185,000 microfarad capacitor adjusted to result in rated output.[a,b]

[a] For a power unit having a capacitive filter in the output circuit, only a variable resistor is to be used.

[b] If appropriate, the power unit may be tested with a battery supplemented with a resistive load, or the battery intended to be charged by the power unit (see 41.4 and 41.5).

41.2 A battery charger intended for use with a specific battery pack shall be tested using the battery pack as its intended load.

41.3 If a power unit intended to charge batteries is to be tested using a lead-acid battery or batteries as the load, each battery is to be discharged to 1.75 volts per cell – measured with the load connected – at a rate not to exceed the discharge rate assigned by the battery manufacturer, but in any case, the rate of the discharge is not to exceed one-sixth of the ampere-hour capacity of the battery. See Table 41.1.

41.4 If a battery charger is to be tested with a typical 1.2 volt per cell nickel-cadmium battery or batteries as the load, each battery is to be discharged to 0.9 volts per cell – measured with the load connected – at a rate not to exceed the discharge rate assigned by the battery manufacturer.

41.5 If a battery charger is to be tested with a battery or batteries other than those specified in 41.3 and 41.4, the battery is to be discharged in accordance with the battery manufacturers maximum recommended discharge rate to an appropriate discharge voltage.

42 Temperature Test

42.1 The power unit shall be mounted as in intended service and connected as described in 41.1. With the power unit operating at its maximum marked duty cycle, the power unit shall not reach a temperature at any point high enough to cause a risk of fire, to damage any material used, or to exceed the temperature limits specified in Table 42.1.

Table 42.1
Maximum temperature limits

Materials and components	°C	(°F)
1. A surface upon which a stationary power unit may be mounted in service, and surfaces that may be adjacent to the unit when so mounted	90	(194)
2. Any point on or within a terminal box or compartment of a fixed power unit on which field-installed conductors to be connected may rest	60[a]	(140)[a]
3. Field wiring terminals	75[a]	167[a]
4. Class 105 coil insulation systems of a relay, a solenoid, or the like		
Thermocouple method	90[b]	(194)[b]
Resistance method	110	(230)
5. Class 130 coil insulation systems of a relay, a solenoid, or the like		
Thermocouple method	110[b]	(230)[b]
Resistance method	120	(248)
6. Class 105 transformer insulation systems:		
Thermocouple method	90[b]	(194)[b]
Resistance method	95	(203)
7. Class 130 transformer insulation systems		
Thermocouple method	110[b]	(230)[b]
Resistance method	120	(248)
8. Class 155 transformer insulation systems		
Thermocouple method	135	(275)
Resistance method	140	(284)
9. Class 180 transformer insulation systems		
Thermocouple method	150	(302)
Resistance method	160	(320)
10. Class 200 transformer insulation systems		
Thermocouple method	165	(329)
Resistance method	175	(347)
11. Class 220 transformer insulation systems		

Table 42.1 Continued on Next Page

Table 42.1 Continued

Materials and components	°C	(°F)
Thermocouple method	180	(356)
Resistance method	190	(374)
12. Class 2 transformer enclosure	85	(185)
13. Class A motor coil insulation systems:		
A. In an open motor:		
Thermocouple method	90	(176)
Resistance method	100	(212)
B. In a totally enclosed motor:		
Thermocouple method	95	(203)
Resistance method	105	(221)
14. Class B motor coil insulation systems:		
A. In an open motor:		
Thermocouple method	110	(230)
Resistance method	120	(248)
B. In a totally enclosed motor:		
Thermocouple method	120	(248)
Resistance method	125	(257)
15. Varnished-cloth insulation	85	(185)
16. Fiber employed as electrical insulation	90	(194)
17. 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[c]	(302)[c]
18. Wood or other combustible material	90	(194)
19. Rubber- or thermoplastic-insulated wire and cord	60[c,d]	(140)[c,d]
20. Other types of insulated wires	e	e
21. Capacitor:		
Electrolytic	65[f]	(149)[f]
Other than electrolytic	90[f]	(194)[f]
22. Sealing compound	g	g
23. Selenium rectifier	75[h,i]	(167)[h,i]
24. Silicon rectifier	100[i]	(212)[i]
25. Power switching semiconductor device	100[i]	(212)[i]
26. A handle or knob that is grasped for lifting, carrying, or holding		
Metallic[j]	50	(122)
Nonmetallic[j]	60	(140)
27. A handle or knob that is contacted but does not involve lifting, carrying, or holding and other surfaces subject to contact in operation and user maintenance		
Metallic[j]	60	(140)
Nonmetallic[j]	85	(185)
28. A surface subject to casual contact		
Metallic[j]	70[k]	(158)[k]
Nonmetallic[j]	95[k]	(203)[k]

Table 42.1 Continued on Next Page

Table 42.1 Continued

Materials and components	°C	(°F)
[a] The temperature observed on the terminals and at points within a terminal box of a unit marked in accordance with 61.2.8 may exceed the values specified.		
[b] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature as 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.		
[c] 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.		
[d] A short length of rubber- or thermoplastic-insulated flexible cord inside the power unit 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.		
[e] The maximum allowable temperature shall not exceed the temperature limit of the wire except as noted in (d).		
[f] 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.		
[g] Unless a thermosetting compound, the maximum sealing compound temperature limit is 15°C (27°F) less than the softening point of the compound as determined in accordance with the Test of Softening Point of Resins Derived from Naval Stores by Ball- and Ring-Apparatus, ASTM E28.		
[h] 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).		
[i] A component that operates at a temperature of more than 100°C (212°F) shall be judged on the basis of the manufacturer's rating.		
[j] 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 (0.13 mm) or less, shall be judged as a nonmetallic part.		
[k] A commercial power unit may exceed the temperature limits for surfaces subject to casual contact if all of the following conditions are met: 1) The power unit is intended to be permanently installed so that it is not likely to be contacted by people; 2) The power unit is marked as required by 61.1.8; and 3) The power unit is provided with instructions as specified in 62.1.2.		

42.2 If the load specified in 41.1 includes a variable resistance, the load is to be adjusted after 15 minutes of operation, if necessary, to return the output to the original value. If the load consists of a battery, the battery is to be discharged as specified in 41.4 or 41.5, as applicable.

42.3 If a battery charger which is not likely to be used for consecutive charging of batteries is tested with a battery load, the test is to be continued until temperatures peak. The load is to be replaced by a second discharged battery. The test is terminated when temperatures peak or temperatures stabilize, whichever occurs first during the second load condition.

42.4 A battery charger which is likely to be used for consecutive charging of batteries is to be tested with the intended battery load. The test is to be conducted in accordance with 41.5.

42.5 With respect to 42.4, a consecutive charger is to be tested in accordance with the following:

a) For a charger with no charge status indicator, the test is to be continued until temperatures peak. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

b) For a charger with a visual charge status indicator, the test is to be continued until the visual indicator indicates that the charge cycle is complete. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

c) For a charger with a charge time marking or instruction, the test is to be continued until the specified charge time has elapsed. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

d) For a charger with both a visual charge status indicator and a charge time marking or instruction, the test is to be continued until the specified charge time has elapsed or until the visual indicator indicates that the charge cycle is complete, whichever occurs first. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

42.6 With reference to 42.1, a power unit having primary or secondary voltage adjustment taps for intended use shall operate within the temperature limits at any setting including the maximum and intermediate positions.

42.7 A protective device shall not operate during the temperature test.

42.8 A power 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 (25.4-mm) thick soft-pine boards.

42.9 Unless investigated and found acceptable – see 7.4.2 – a supporting means formed of soft rubber or rubberlike material is to be removed prior to the temperature test. If the supporting means has a metal insert, such as a screw or rivet, the test is to be conducted with the power unit supported by the metal insert. At the request of the manufacturer, the test may be conducted without any means of support.

42.10 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 results from securely taping or cementing the thermocouple in place but, if a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

42.11 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 an alternating-current motor, the thermocouple is to be mounted on the integrally-applied insulation of the coil wire.

42.12 The temperature rise 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:

$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$

in which:

Δt is the temperature rise 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_1 is the room temperature in degrees C at the beginning of the test;

t_2 is the room temperature in degrees C at the end of the test; and

k is 234.5 for copper, 225 for electrical conductor grade (EC) aluminum; values of the constant for other conductors are to be determined.

The winding is to be at room temperature at the start of the test.

42.13 All temperature limit values in Table 42.1 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 42.2.

Table 42.2
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, item 1
2. Range of 25 – 40°C (77 – 104°F)	Range of 20– 40°C (68 – 104°F)	See note a, item 2
3. Above 40°C (104°F)	Rated ambient See note b	c

[a] Correction of temperature, as determined by item 1 or 2 below, shall not exceed the temperature limit specified in Table 42.1:

1) An observed temperature is to be corrected by addition (if the test ambient temperature is lower than 25°C (77°F)) or by subtraction (if the test ambient temperature is higher than 25°C (77°F)) of the difference between 25°C (77°F) and the test ambient temperature.

2) An observed temperature is to be corrected by addition (if the test ambient temperature is lower than the rated ambient temperature) or by subtraction (if the test ambient temperature is higher than the rated ambient temperature) 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 42.1. If the test ambient temperature is other than rated ambient, correction is to be made as described in item 2 of note a.

42.14 Thermocouples are to consist of wires not larger than 24 AWG and not smaller than 30 AWG. When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer type instrument. 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 listed in the "Tolerances on Initial Values of EMF versus Temperature" tables in the Standard Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

42.15 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 further increase.

43 Dielectric Voltage Withstand Test

43.1 General

43.1.1 While still in a heated condition, a power unit shall withstand for 1 minute without breakdown the application of a 60-hertz essentially sinusoidal potential of:

a) One thousand volts plus twice the maximum rated voltage between:

1) The primary circuit and dead metal parts; and

2) The primary and secondary circuits.

b) One thousand volts between live and dead metal parts of a motor.

c) Five hundred volts between a secondary circuit operating at 60 volts dc or less or 50 volts rms (70 volts peak) or less and dead metal parts; 1000 volts plus twice the maximum rated secondary circuit voltage between a secondary circuit operating at more than 60 volts dc or more than 50 volts rms (70 volts peak) but less than 1000 volts (1414 volts peak) and dead metal parts; one thousand seven hundred fifty volts plus 1.25 times the maximum voltage between a secondary circuit operating at more than 1000 volts rms (1414 volts peak), and dead metal parts. Chassis-connected components are to be disconnected at the chassis.

d) One thousand volts plus twice the rated voltage between the terminals of a capacitor used directly across the line prior to a rectifier or similar network, and between terminals of a line-bypass capacitor connected between the line and the enclosure;

Exception No. 1: If a capacitor is connected on the load side of a transient voltage surge suppressor that has been previously evaluated for suppression in accordance with the requirements in the Standard for Surge Protective Devices, UL 1449, the potential is to be equal to the suppression voltage rating of the suppressor.

Exception No. 2: A capacitor complying with either of the following need not be subjected to this potential:

a) The Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414; or

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

e) One thousand volts plus twice the rated voltage between coils of an inductor where the coils are of opposite polarity and share a common coil form.

43.1.2 To determine whether a power unit complies with the requirements in 43.1.1, the power unit is to be tested using a 500 volt-ampere or larger capacity transformer, the output voltage of which can be varied. The applied potential is to be increased from zero until the required test level is reached, and is to be held at that level for 1 minute. The increase in applied potential is to be at a substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

43.1.3 If the current through a capacitor or capacitor-type filter connected across the line, or from line to earth ground, is large enough to make it difficult to maintain the required alternating-current test potential, the capacitor and capacitor-type filter may be tested as described in 43.1.4.

43.1.4 The capacitor or capacitor-type filter mentioned in 43.1.3 is to be subjected to a dc test potential of 1.414 times the rms value of the test voltage specified across the capacitor terminals. The dc test potential is to be maintained for 1 minute without breakdown.

43.2 Induced potential test

43.2.1 With reference to Table 26.1, note (h), item (2), a sample of a magnet coil winding shall be subjected to this test. While in a heated condition from operation as described in the Temperature Test, Section 42, the primary winding of the transformer shall withstand without breakdown an alternating potential of twice the rated voltage of the winding.

43.2.2 The potential is to be:

a) Applied for 7200 cycles if the test potential frequency is 120 hertz or more; or

b) 60 seconds if the frequency is less than 120 hertz.

An increased test frequency may be necessary so the core is not saturated. The test voltage is to be started at one-quarter or less of the full value and increased to full value in 15 seconds or less. After being held for the time specified, the voltage is to be reduced within 5 seconds to one-quarter or less of the maximum value and the circuit is to be opened.

43.2.3 With reference to 43.2.1, a transformer may be conditioned in an oven to obtain the temperature reached in the Temperature Test, Section 42, before conducting the induced potential test.

43.3 Maximum-voltage measurements

43.3.1 The maximum voltage used as a basis for the calculation of the dielectric voltage-withstand test potentials specified in 43.1 and 43.2, and the determination of the minimum spacings specified in Section 35, Spacings, shall be determined in accordance with 43.3.2 and 43.3.3.

43.3.2 A connector or comparable part that is capable of being disconnected during intended operation is to be both connected and disconnected during the test so that the maximum voltage is obtainable.

43.3.3 When 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 value, respectively, is to be measured.

44 Tests on Insulating Materials

44.1 When required by Exception No. 2 of 35.3.1, or item (c) or (g) of Table 26.1, insulating material shall be subjected to the test described in 44.2.

44.2 The test sample 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 moveable electrode is to weigh 50 ±2 grams (1.76 ±0.08 ounces) to exert pressure on the sample to provide intended electrical contact. The applied test potential is to be increased to the test value and held at that value for 1 second. There shall be no dielectric breakdown.

45 Mechanical Strength Tests for Metal Enclosures

45.1 In accordance with Table 35.1, item (g), or Table 35.2, item (h), or the Exception to 7.1.3, an enclosure shall withstand the two tests described in 45.2 and 45.3:

a) Without permanent distortion to the extent that spacings are reduced below the values specified in Table 35.1 or Table 35.2, as applicable;

b) Without transient distortion that results in contact with live parts other than those connected in a low-voltage circuit; and

c) Without development of openings that expose parts that involve a risk of electric shock or injury. Any openings resulting from the test are to be judged under the requirements for Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8.

45.2 For the first test specified in 45.1, the enclosure is to be subjected to a 25 pound-force (111 N) for 1 minute. The force is to be applied by means of a steel hemisphere 1/2 inch (12.7 mm) in diameter.

45.3 For the second test specified in 45.1, the enclosure is to be subjected to an impact of 5 foot-pounds (6.8 J). The impact 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 51 inches (1.29 m).

46 Strain Relief and Bushing

46.1 The strain relief means provided on a flexible cord shall withstand for 1 minute without displacement a direct pull of 35 pounds (156 N) applied to the cord, with the connections within the power unit 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 would have resulted.

Exception: The strain-relief means provided for the output cord on a power unit with a Class 2 output 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 the transformer or enclosure, or interruption of the output-circuit wiring.

46.2 A 35-pound (16-kg) or a 20-pound (9-kg) weight, as applicable, is to be suspended from the cord and supported by the power unit so that the strain relief means will be stressed from any angle the construction of the power unit permits.

47 Push-Back Relief Test

47.1 To determine compliance with 12.4.4, a product shall be tested in accordance with 47.2 without occurrence of any of the conditions specified in or 12.4.4 (a) – (d).

47.2 The supply cord or lead is to be held 1 inch (25.4 mm) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing which extends further than 1 inch is present, it is to be removed prior to the test. When the bushing is an integral part of the cord, the test is to be carried out by holding the bushing. The cord or lead is to be pushed back into the product in 1-inch (25.4-mm) increments until the cord buckles or the force to push the cord into the product exceed 6 pounds-force (26.7 N). The supply cord or lead within the product is to be manipulated to determine compliance with 12.4.4.

48 Overload of Switches and Controls

48.1 Unless known to be acceptable for the application, a switch or other device that controls a solenoid, a relay coil, or the like, shall perform acceptably when subjected to an overload test consisting of 50 cycles of operation making and breaking the applicable load, and to an endurance test consisting of 6000 cycles of operation at rated load. There shall be no electrical or mechanical breakdown of the device, undue

burning or pitting of the contacts as a result of the overload or endurance test, or opening of the fuse in the grounding connections.

48.2 To determine whether a switch or other control device complies with the requirements in 48.1, the power unit is to be connected to a supply circuit of rated frequency and 110 percent of maximum rated voltage. The load for the device under test is to be the same as that which it is intended to control in regular service. During the test, exposed dead metal parts of the power unit are to be connected to ground through a 3-ampere plug fuse. The device is to be operated at a rate of not more than 10 cycles per minute, except that a faster rate of operation may be employed if agreeable to those concerned.

48.3 A switch or other device that controls a motor and has not been shown to be acceptable for the purpose, unless interlocked so that it does not break the locked rotor current of the motor, shall perform acceptably when subjected to an overload test consisting of 50 cycles of operation, making and breaking the locked-rotor current of the motor. There shall be no electrical or mechanical breakdown of the device, undue pitting or burning of the contacts, or opening of the fuse in the grounding connection.

48.4 To determine whether a switch or other control device complies with the requirement in 48.3, the power unit is to be connected to a grounded supply circuit of rated frequency and maximum rated voltage – see Table 39.1 – with the rotor of the motor locked in position. During the test, exposed dead metal parts of the power unit are to be connected to ground through a 3-ampere plug fuse, and the connection is to be such that any single-pole, current-rupturing device will be located in the ungrounded conductor of the supply circuit. If the power unit is intended for use on direct current, or on direct and alternating current, the exposed dead metal parts are to be connected to be positive with respect to a single-pole, current-rupturing control device. The device is to be operated at a rate of not more than 10 cycles per minute, except that a faster rate of operation may be employed if agreeable to those concerned.

49 Static Load Test

49.1 A mounting means for a fixed power unit shall withstand the load test referenced in 49.2 without permanent deformation, breakage, or cracking of the mounting supports.

49.2 When mounted as recommended by the manufacturer, a power unit shall comply with the test specified in 49.3.

49.3 Regarding 49.2, the supporting means of a power unit shall support a static load of four times the load supported by the mounting means but not less than 20 pounds (9.1 kg):

a) Applied through the center of gravity of the power unit in the downward direction; or

b) Applied evenly over the horizontal plane of the power unit.

50 Stability Test

50.1 A portable or stationary power unit shall not overturn and shall return to its intended at-rest position on a level surface when:

a) Either:

1) Tipped through an angle of 10 degrees from an at-rest position on a horizontal surface; or

2) Placed on a plane inclined at an angle of 10 degrees from the horizontal; and

b) For a floor-standing unit only, subjected to an externally-applied horizontal force of 20 percent of the weight of the power unit or 50 pounds (22.8 kg), whichever is less.

50.2 The power unit is not to be energized during the test required by 50.1. The test is to be conducted under the conditions most likely to cause the power unit to overturn. The following conditions of test are to be such as to result in the least stability:

a) Position of all adjustable or movable parts such as doors, drawers, or casters;

b) Supply cord and output leads resting on the supporting surface;

c) Provision for or omission of any normal mechanical load in the power unit such as stored parts; and

d) Direction in which the power unit is tipped, or the supporting surface is inclined.

50.3 With reference to the requirements in 50.1, the force specified in 50.1(b) is to be applied in a horizontal direction at that point on the floor-standing power unit most likely to overturn the power unit but is not to be applied more than 5 feet (1.52 m) above floor level. The legs or points of support may be blocked to prevent the unit from sliding during the application of the force.

50.4 With reference to the requirement in 50.1(a)(1) for an appliance that is constructed so that while being tipped through an angle of 10 degrees a part or surface of the power unit not intended to be in contact with the horizontal supporting surface touches the supporting surface before the power unit 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 power unit originally in contact with the horizontal supporting surface is at an angle of 10 degrees from the horizontal supporting surface.

51 Isolated Limited Energy Circuit Capacity

51.1 To determine if a power unit has limited output circuit capacity as defined in 6.13, the power unit shall be subjected to the test described in 51.2 and 51.3. The unit is to be energized from a circuit of rated frequency at the voltage specified in Table 39.1.

51.2 An isolated limited-energy circuit of a linear or switch mode power unit shall have an output circuit capacity of 100 volt-amperes or less when measured one minute after energization of the power unit. Any additional circuits derived from the same transformer are to have the circuits loaded to maximum normal operating conditions.

51.3 Each secondary winding of an isolated limited-energy multisecondary transformer is to be loaded in turn with a variable resistor. The transformer is to be at room temperature at the beginning of each part of the test. The load resistance is to be decreased from open-circuit to short-circuit in such a manner that the elapsed time is between 1-1/2 and 2-1/2 minutes. Depending upon the open-circuit voltage of the winding, the maximum outputs obtained by this method are to be as follows:

a) 350 volt-amperes for 0 – 15 volts.

b) 250 volt-amperes for 15.1 – 30 volts.

c) 200 volt-amperes for 30.1 – 1000 volts.

52 Overcurrent Protection Calibration Test

52.1 A fuse, or circuit-protective device, provided in the primary of a transformer for protection of the secondary circuit, in accordance with 36.10, shall operate to open the circuit in not more than the time indicated in Table 52.1, when the transformer is delivering the specified secondary current.

Table 52.1
Maximum required 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.

52.2 To determine whether a fuse or circuit-protective device complies with the requirement in 52.1, the transformer is to deliver the test current to a resistive load, with the primary connected to a circuit as described in 50.1. 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.

52.3 When the fuse or circuit protective device is used to protect more than one secondary winding or tap, each winding or partial winding is to be tested as indicated in 52.1 or 52.2, with the remaining windings delivering rated load.

53 Neutral to Ground Potential Measurement Test

53.1 In accordance with 20.12, a unit having a grounding type receptacle or a lead or terminal identified as a grounded circuit that is not grounded at the unit itself shall be subjected to this test. The unit is to:

a) Operate with no load connected to the output terminals; and

b) Deliver maximum rated output into a variable resistor adjusted to result in rated load.

The electric energy available between the grounded conductor and ground shall not produce a risk of electric shock.

54 Abnormal Tests

54.1 General

54.1.1 A power unit shall not emit flame or molten metal or result in a risk of fire or electric shock when subjected to the tests specified in 54.2 – 54.12.

54.1.2 During each test:

a) The grounding means of the power unit, if provided, are to be connected directly to ground;

b) The unit is to be placed on a softwood surface covered with white tissue paper; and

c) 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 (26 – 28 m^2/kg) and for any square inch, a count of 32 threads in one direction and 28 in the other direction.

Exception: For a power unit without openings in the bottom panel, it is not necessary to place the unit on a softwood surface covered with white tissue paper.

54.1.3 The supply circuit is to have branch circuit overcurrent protection, the size of which equals 125 percent of the input current rating (20-amperes minimum).

Exception: If the size of protection does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating is to be used.

54.1.4 A protective device such as a fuse or a circuit breaker provided as part of a power unit is to remain in the circuit. The highest rated fuse the fuseholder will accept is to be installed.

Exception No. 1: A commercial power supply may be tested with the fuse recommended by the manufacturer.

Exception No. 2: An internal fuse that is not referenced by markings, wiring diagrams, or the instruction manual need not be replaced.

54.1.5 The test voltage is to be adjusted to the value specified in Table 39.1.

54.1.6 Any user operated control is to be adjusted to the position representing the most adverse operating condition.

54.1.7 If a manual or automatic reset protector does not function during these tests, each test is to be continued until there is no indication of further change as a result of the test condition. If an automatically reset protector functions during the tests, the test is to be continued for 7 hours. If a manual reset protector functions during the test, it is to be operated for 10 cycles using the minimum resetting time, but not at a faster rate than 10 cycles of operation per minute. The protector should be operative upon completion of the test. The following are considered as an acceptable termination of the test:

a) Opening or shorting of one or more capacitors, diodes, resistors, semiconductor devices, printed wiring board traces, or the like, if there is no indication of further change;

b) Opening of the intended branch-circuit overcurrent protective device; 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: For the reverse polarity test, the seven hour duration does not apply. See 54.10.2.

54.1.8 Following each test, the dielectric voltage withstand test specified in 43.1.1(a) is to be conducted. A risk of fire or electric shock is considered to exist if any of the following occur:

a) Flame or molten metal is emitted from the enclosure of the equipment as evidenced by ignition, glowing, or charring of the cheesecloth or tissue paper;

b) A breakdown results from the dielectric voltage withstand test; or

c) Live parts are made accessible. See 8.1.

Exception: The dielectric evaluation from primary to ground required by 43.1.1 (a) (2) need not be conducted following the transformer overload tests specified in 54.7.

54.1.9 Each test is to be conducted on a separate sample unless more than one test on the same sample is agreeable to those concerned.

54.2 Output short-circuit test

54.2.1 The external output connections are to be short circuited. A power supply having more than one output circuit is to be subjected to a separate test on each output with the other outputs loaded or unloaded as may occur in actual service, unless it can be determined that one condition will produce the most unfavorable result.

54.3 Blocked fan test

54.3.1 A power unit having a fan motor is to be operated as in the temperature test and in 54.1.7 with the rotor of the fan motor blocked. For a power supply having more than one fan motor, the test is to be conducted with the rotor of each blower motor blocked, 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.

54.4 Fuse short circuit test

54.4.1 If required by 30.4, five fuses are to be short-circuited directly across the output-circuit of the power unit.

54.5 Voltage selector test

54.5.1 In accordance with 12.3.7 and 12.3.8, a product equipped with an operator adjustable voltage selector shall be subjected to this test. The selector is to be adjusted to the lowest voltage within the selector range. The unit is to then be connected and operated at the highest voltage within the selector range.

54.6 Relay and solenoid burnout

54.6.1 An open-coil electromagnetic relay or solenoid is to be tested by blocking the armature or the plunger in the de-energized position.

54.7 Transformer overload tests

54.7.1 A transformer rated 10 kilovolt amperes or less shall be tested in accordance with 54.7.2.

54.7.2 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) or (b). For a tapped winding, the load is to be connected between the outer winding legs. Opening of the intended branch circuit overcurrent protection device described in 54.1.3, or an internal overcurrent protection device connected in the primary-winding circuit, is capable of being used as 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 while not resulting in more than three times the maximum normal current – as measured during the input test – 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 unit. When the test current is not obtainable due to the transformer being supplied from a means limiting the current to less than three times the normal load current, the winding is to be loaded to a condition resulting in maximum obtainable input current.

Exception No. 1: When a transformer employed in a switch-mode inverter or converter circuit is subjected to the transformer overload test described in 54.7.5, this test is not required to be performed.

Exception No. 2: A transformer complying with the Standards for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2; or the Standard for Dry-Type General Purpose and Power Transformers, UL 1561, is not required to be subjected to this test.

Exception No. 3: A transformer which complies with the requirements in any of the following standards is not required to be subjected to this test:

a) The Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3;

b) The Standard for Class 2 Power Units, UL 1310; or

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

Exception No. 4: 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 is not required to comply with this requirement.

54.7.3 A ferroresonant transformer is to be tested with the secondary winding loaded to obtain the maximum input current.

54.7.4 During the tests described in 54.7.2 and 54.7.3, 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.

54.7.5 In reference to Exception No. 1 to 54.7.2, the power circuit supplied by the transformer is to be connected to a resistive load that draws maximum obtainable current 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 similar component.

54.8 Component short- and open-circuit test

54.8.1 Components in the input power circuit, whose failure results in an increased risk of fire and electric shock, shall be subjected to a short of any two terminals, or an open at any single connection, one test at a time, during any condition of operation. Also, with reference to Exception No. 1 of 31.1, components in a regulating network shall be similarly tested. These components include electrolytic capacitors, diodes, and solid state devices or any other component not previously investigated and found to meet the requirements for the application.

Exception No. 1: An electromagnetic and radio frequency interference capacitor that complies with the dielectric voltage withstand test in 43.1.1(d), a resistor, a transformer, an inductor, or an optical isolator is not required to be subjected to this test.

Exception No. 2: This test is not required to be conducted when the components have been investigated and found to have permanence and stability as to not decrease their limiting capabilities. For the purpose of this test, capacitors connected across the output are not required to be subjected to an open.

54.8.2 Three tests of each combination, using untested components for each test, shall be conducted.

Exception: If analysis of the test results and circuit indicate that the result obtained is the only one likely to occur, the test need be conducted only once.

54.9 Backfeed protection

54.9.1 A battery charger provided with backfeed protection in accordance with 15.2 shall be subjected to simulated component faults, one at a time, of open or short circuit which may result in backfeed of current into the secondary circuit (refer to 54.9.2). During the test the output connector shall be connected to a source consisting of either:

a) A fully charged battery of the size, type, and number specified by the manufacturer; or

b) A dc source with a no load voltage rating equal to the output voltage rating of the battery charger and a nominal short-circuit capacity of 200 amperes.

The test is to be continued until ultimate results are obtained. One minute after the test, the unit shall be subjected to the dielectric voltage withstand test of 43.1.1 (a) and (c). As a result of the test, there shall be no emission of flame or molten material from the enclosure or output cord, and no indication of dielectric breakdown.

54.9.2 In accordance with 54.9.1, faults shall be simulated for components such as diodes, transistors, capacitors, and the like unless the components have permanence and reliability. If an overcurrent protector, such as a fuse or PTC, operates to limit the backfeed current, the protector shall comply with requirements applicable to the component.

54.10 Autotransformer

54.10.1 A power unit having a primary- or secondary-circuit autotransformer for voltage adjustment is to be subjected to the abnormal conditions described in 54.10.2 and 54.10.3.

54.10.2 With the movable element of the autotransformer set at the midpoint position, the power unit is to be connected to a supply adjusted to the voltage specified in Table 39.1. The output is to be connected to a resistive load adjusted to draw 125 percent of rated output current.

Exception: A nonadjustable autotransformer having tap adjustments is to be connected as near 50 percent of the highest position as possible.

54.10.3 Under the conditions described in 54.10.2, the output resistive load is to be readjusted to draw rated current. The movable element of the autotransformer is then to be moved from its minimum to its maximum position and back for 100 cycles – the first 15 cycles as rapidly as possible, and the remainder at a rate of approximately 10 cycles per minute.

54.11 Evaluation of reduced spacings on printed-wiring boards

54.11.1 In accordance with Exception No. 3(a) of 35.1.1, printed-wiring board traces of different potential having reduced spacings shall comply with:

a) The dielectric voltage-withstand test described in 54.11.2 and 54.11.3, for a unit investigated for use in a controlled environment; or

b) The shorted trace test described in 54.11.4 and 54.11.5, for a unit investigated for use in either a controlled or general environment.

54.11.2 A printed-wiring board, as specified in 54.11.1(a), shall withstand for 1 minute without breakdown the application of a dielectric withstand potential between the traces having reduced spacings, in accordance with 43.1, as appropriate.

54.11.3 Power-dissipating component parts, electronic devices, and capacitors connected between traces having reduced spacings, are to be removed or disconnected so that the spacings and insulations, rather than these component parts, are subjected to the full dielectric voltage-withstand test potential.

54.11.4 Printed-wiring board traces, as specified in 54.11.1(b), are to be short-circuited, one location at a time, and the test is to be conducted as described in 54.1. As a result of this test:

a) The overcurrent protection associated with the branch circuit to the unit shall not open; and

b) A wire shall not open.

When the circuit is interrupted by opening of a component, the test is to be repeated twice, using new components when required. When a printed wiring board trace opens, the gap is to be electrically shorted and the test continued until ultimate results occur, and the procedure is to be repeated for each occurrence of a trace opening.

Exception: After opening of an internal overcurrent protective device, the test is not required to be repeated.

54.11.5 The test of 54.11.4 is to be continued for 1 hour, or until one of the conditions described in 54.1.8 occurs. When, at the end of 1 hour, no condition described in 54.1.8 has occurred, and it is indicated that such a condition is imminent, the test is to be continued until ultimate results are obtained (usually 7 hours).

54.12 Reverse polarity test

54.12.1 The external output leads are to be connected in reverse polarity to a fully charged, lead-acid battery.

Exception: A battery charger having output terminals or leads for fixed wiring, or leads terminating in a polarized plug or plugs need not be subjected to the reverse polarity test.

54.12.2 This test is to be continued for 4 hours if an automatically reset protector functions during the test. See 54.1.7 if other than an automatically reset protector functions during the test.

55 Flanged Bobbin Transformer Abnormal Test

55.1 A flanged bobbin transformer required to be tested, as outlined in Exception No. 1(c) to 26.2.3 (also see 26.1.3 and 26.2.4), is to 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) Loading the secondary winding to maximum current;

b) Loading the secondary winding to a current equal to maximum normal current plus X percent of the difference between the maximum current and the maximum normal current – where X equals 75, 50, 25, 20, 15, 10, and 5, respectively; and

c) Loading the secondary winding to maximum normal current.

Exception: A transformer satisfies the intent of this requirement when it complies with the construction and performance requirements in one of the following:

a) The Standard for Class 2 Power Units, UL 1310;

b) The Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3; or

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

55.2 The results of the test shall not indicate glowing or flaming of the cheesecloth, nor indicate a breakdown, when the tests described in 43.1 are conducted.

55.3 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 unit enclosure as intended under the conditions described in 54.1.2 (b) and (c); or

2) On a test bench with the cheesecloth specified in 54.1.2(c) draped over the transformer; and

b) All secondary windings are to be loaded to rated current before the abnormal condition is introduced. Afterward, the loads, other than that connected to the winding to be overloaded, are not to be readjusted.

55.4 While still in a heated condition from the tests described in 55.1, a transformer shall withstand the dielectric voltage-withstand test described in 43.1.1(a)(1). The dielectric voltage-withstand-test potential is to be applied to the transformer 1 minute after completion of the abnormal-operation test.

55.5 The abnormal tests are able to be conducted with a protective device built into the transformer or with an external protective device used with the transformer in the unit connected in either the primary or secondary circuit, or in both. A protective device that is relied on to open the circuit as a result of an abnormal test is to be investigated and found capable of being used for the purpose.

55.6 For the purpose of these requirements, each secondary winding tap and each primary winding tap used to supply power to a load in the unit is the equivalent of a secondary winding.

55.7 For the sequence of tests described in 55.1, when an abnormal-operation test continues for 15 days without a winding or a protective device opening, the remaining tests are not required to be conducted. For

example, when the test described in 55.1(a) continues for 15 days, the tests described in (b) and (c) are not required to be conducted.

55.8 For a transformer that employs more than one secondary winding, each of the secondary windings is to be loaded for each condition specified in 55.1, with the other windings loaded to rated current. The test conditions are to be as described in 55.9 – 55.13.

55.9 To determine the short-circuit current value for conducting the tests described in 55.1 (b), the transformer is to be at room temperature at the beginning of the measurement, and the short-circuit current is to be measured 1 minute after the voltage is applied to the primary winding. A protective device outside the transformer, when provided, is to be short-circuited during the measurement of the short-circuit current. When the line fuse or transformer winding opens within 1 minute after the application of the primary voltage, the short-circuit current is 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.

55.10 For loading conditions, a variable resistor is to be connected across the secondary winding. Each test described in 55.1 (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 55.1 (b) and (c), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, when required, 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.

55.11 When short-circuiting the secondary winding results in one of the windings to open before 15 days, the next test in the sequence described in 55.1 (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 in order to result in transformer burn out.

55.12 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 55.1 (a) – (c) is to be discontinued when the protective device opens the circuit, and the next test in the sequence is to be started. The protective device specified above includes automatic reset, manual reset, or replaceable types.

55.13 When a protective device or winding opens while a sample is unattended, another sample is to be tested.

55.14 As an option to 55.13, another sample is to be tested at the appropriate load condition until temperatures stabilize. The load is to be increased 10 percent, by reducing the variable resistance, and the sample is to be operated until temperatures stabilize. The sequence is to be repeated until the protective device or winding opens, then the dielectric voltage-withstand test described in 55.4 is to be performed, while the sample is in a heated condition. The next test in the sequence specified in 55.1 is then to be performed.

56 Capacitor Test

56.1 The voltage measured across capacitor terminals shall not exceed the marked voltage or the voltage specified by the capacitor manufacturer under any normal condition of loading including open circuit.

Exception: Voltage measurements are not required for a limited-energy circuit of 100 volt-ampere capacity or less, such as that derived from an isolated limited-energy transformer in combination with circuit impedances.

57 Bonding Conductor Test

57.1 A bonding conductor that does not comply with 17.2.6(a) or 17.2.6(b) is able to be used when, using a separate sample 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 57.1; and

b) Three samples are subjected to a limited short circuit test using a test current as specified in Table 57.2 while connected in series with a nonrenewable fuse rated in accordance with Table 57.1.

Exception: When 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.

Table 57.1
Duration of overcurrent test

Rating or setting of branch-circuit overcurrent protective device, amperes	Test time, minutes	
	135 percent current	200 percent current
0 – 30	60	2
31 – 60	60	4
61 – 100	120	6
101 – 200	120	8

Table 57.2
Circuit capacity for bonding conductor short-circuit test

Rating of power supply				Capacity of test circuit, amperes
Volt-amperes				
Single phase	3-phase	Direct current	Volts[a]	
0 – 1176	0 – 832	0 – 624	0 – 250	200
0 – 1176	0 – 832	0 – 624	251 – 600	1000
1177 – 1920	833 – 1496	625 – 1128	0 – 600	1000
1921 – 4080	1497 – 3990	1129 – 3000	0 – 250	2000
4081 – 9600	3991 – 9145	3001 – 6960	0 – 250	3500
9601 or more	9146 or more	6961 or more	0 – 250	5000
1921 or more	1497 or more	1129 or more	251 – 600	5000

[a] The nominal test voltages are 120, 240, 277, 480, or 600

57.2 The test circuit described in 57.1(b) is to have a power factor of 0.9 – 1.0 and a closed-circuit test voltage as specified in 39.1. The open-circuit voltage is to be 100 – 105 percent of the closed-circuit voltage.

58 Hot, Flaming Oil Test

58.1 In accordance with Exception No. 2 to 7.1.9, a ventilated, bottom-panel construction may be evaluated by conducting the tests described in 58.2 – 58.5.

58.2 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 poured three times onto the openings from a position above the panel is extinguished as it passes through the openings.

58.3 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, 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.

58.4 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 (0.61 cubic inches) 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). 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 (0.061 cubic inch) 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.

58.5 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 (0.61 cubic inches) 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.

MANUFACTURING AND PRODUCTION TESTS

59 Dielectric Voltage Withstand Test

59.1 Each power unit shall withstand without electrical breakdown, as a routine production-line test, the application of an ac potential at a frequency within a range of 40 – 70 hertz or a dc 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 live parts, including terminals.

59.2 The production-line test shall be in accordance with either Condition A or Condition B of Table 59.1. The test potential may be gradually increased to the required value but the full value is to be applied for either 1 second or 1 minute as required.

Table 59.1
Production line test conditions

Power supply rating and form	Condition A			Condition B		
	Potential, Vac	Volts Vdc	Time, seconds	Potential, Vac	Volts Vdc	Time, seconds
250 volts or less with no motor rated more than 1/2 horsepower (375 W)	1000	1400	60	1200	1700	1
More than 250 volts or with a motor rated more than 1/2 horsepower	1000+2V[a]	1400+2.8V[a]	60	1200+2.4V[a]	1700+3.4V[a]	1

[a] Maximum marked voltage but not less than 250 volts.

59.3 The power unit may be in a heated or unheated condition for the test.

59.4 The test shall be conducted when the power unit is fully assembled. It is not intended that the power unit be unwired, modified, or disassembled for the test.

Exception No. 1: A part such as a snap cover or a friction-fit knob that interferes with performance of the test need not be in place.

Exception No. 2: The test may be performed before final assembly if the test represents that for the completed power unit.

59.5 A power unit employing a solid-state component that is not relied upon to reduce a risk of shock and that can be damaged by the dielectric potential may be tested before the component is electrically connected provided that a random sampling of each day's production is tested at the potential specified in 59.2. The circuitry may be rearranged for the purpose of the test to minimize the likelihood of solid-state-component damage while retaining representative dielectric stress of the circuit.

59.6 The test equipment shall include a means of indicating the test potential, an audible or visual indicator of electrical breakdown, and either a manually reset device to restore the equipment after electrical breakdown or an automatic reject feature of any unacceptable unit. If an ac test potential is applied, the test equipment shall also include a transformer having an essentially sinusoidal output.

59.7 If the output of the test equipment transformer is less than 500 volt-amperes, the equipment shall include a voltmeter in the output circuit to directly indicate the test potential.

59.8 If the output of the test equipment transformer is 500 volt-amperes or larger, the test potential may 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) In the case of equipment having a single test-potential output, by a marking in a readily visible location to indicate the test potential. When marking is used without an indicating voltmeter, the equipment shall include a positive means, such as an indicator lamp, to indicate that the manually reset switch has been reset following a dielectric breakdown.

59.9 Test equipment, other than that described in 59.6 – 59.8, may be used if found to accomplish the intended factory control.

59.10 During the test, the primary switch is to be in the "on" position, both sides of the primary circuit of the power unit are to be connected together and to one terminal of the test equipment, and the second test-equipment terminal is to be connected to accessible dead metal.

Exception No. 1: A power unit having circuitry – resistive, high-impedance winding, and the like – not subject to excessive secondary-voltage build-up in case of electrical breakdown during the test may be tested:

a) With a single-pole primary switch, if used, in the "off" position; or

b) With only one side of the primary circuit connected to the test equipment when the primary switch is in the on position, or when a primary switch is not used.

Exception No. 2: The primary switch is not required to be in the "on" position if the testing means applies full test potential between primary wiring and dead metal parts with the switch not in the "on" position.

60 Grounding Continuity Test

60.1 Each power unit that has a power supply cord having a grounding conductor shall be tested, as a routine production-line test, to determine that electrical continuity exists between the grounding blade of the attachment plug and accessible dead metal parts of the power unit that are likely to become energized.

60.2 Only a single test need be conducted if the accessible metal selected is conductively connected by design to all other accessible metal.

60.3 Any indicating device – an ohmmeter, battery-and-buzzer combination, or the like – may be used to determine whether a power unit complies with the requirement in 59.1.

MARKING

61 Details

61.1 Cautionary markings

61.1.1 A cautionary marking shall be prefixed by the word "CAUTION," "WARNING," or "DANGER" in letters not less than 1/8 inch (3.2 mm) high. The remaining letters shall not be less than 1/16 inch (1.6 mm) high.

61.1.2 A live heat sink or other part shall be marked "CAUTION – Risk of Electric Shock. Plates (or other word describing the type of part) are live. Disconnect power unit before servicing." if the part:

a) Is likely to be mistaken for dead metal;

b) Is at a potential that exceeds 30 volts rms (42.4 volts peak) or 60 volts dc; and

c) Is not guarded as specified in 9.1.5.

The marking shall be located on the live part so as to make the risk of electric shock known before the part is likely to be touched. See 61.1.13 and 61.1.14.

61.1.3 With reference to Exception No. 2 of 17.1.2, ungrounded dead metal parts 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.

Exception: This requirement does not apply to an inductor core, a transformer core, and a heat sink mounted on a printed wiring board.

61.1.4 A portable household power unit shall be marked "CAUTION – Do not expose to rain" or "CAUTION – Indoor use only."

61.1.5 A power unit with output connections in accordance with 13.1 shall be marked "CAUTION" and the following or the equivalent: "Risk of Fire. Use only type SPT-2 cord or heavier duty cord, minimum __ AWG copper." The minimum acceptable gauge size is 18 AWG. The marking shall be adjacent to the terminals, connectors, or wiring compartment.

61.1.6 With reference to 35.1.3, a power unit shall be marked with the word "WARNING" and the following or the equivalent: "To reduce the risk of fire and electric shock, install in a temperature- and humidity-controlled indoor area relatively free of conductive contaminants."

Exception No. 1: This requirement does not apply to a power unit provided with its own equivalent environment as described in 6.8.

Exception No. 2: When the marketing of the unit is such that the unit is intended for use in a controlled environment, this marking is not required.

61.1.7 There shall be a legible and durable marking for each interchangeable fuse as described in 30.3, indicating the ampere rating and the voltage 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. A single marking is acceptable for a group of fuses. The marking shall be adjacent to the fuseholder and shall consist of the word "CAUTION " and the following or the equivalent: "For continued protection against risk of fire, replace only with same type and ratings of fuse."

61.1.8 A commercial fixed power unit that exceeds the temperature limits specified in Table 42.1 – see footnote k to Table 42.1 – shall be legibly marked where readily visible after installation with the word "CAUTION" and the following or the equivalent "Hot surfaces – To prevent burns – Do not touch."

61.1.9 A power unit provided with single-pole circuit breakers in the input circuit in accordance with the Exception to 29.3 shall be marked with the word "CAUTION " and the following or the equivalent: "Risk of Electric Shock and Fire. Do not connect to a circuit operating at more than 150 Volts to ground."

61.1.10 A unit incorporating an overcurrent protective device in the grounded circuit conductor as specified in Exception No. 2, item (d) to 29.5 shall be plainly marked with the word "CAUTION" and the following or 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.

61.1.11 A battery charger shall be marked, where readily visible to the user when charging batteries, with the word "CAUTION" and the following or equivalent: "Charge only ___ type rechargeable batteries. Other types of batteries may burst causing personal injury and damage."

Exception: A reference to a specific rechargeable battery or battery pack for which the charger is intended may be used in lieu of marking the type of batteries to be charged.

61.1.12 A power supply intended to be connected as described in the Exception to 28.7 shall be marked on an inside or outside surface or in a separate operating manual as follows:

a) A 2-wire, 220 – 240-volt power unit intended for connection to a circuit operating at 150 volts or less to ground shall be marked with the word "DANGER" and the following or the equivalent: "Risk of Electric Shock – Do not connect to a circuit operating at more than 150 volts to ground."

b) A 3-wire, 3-phase, 220 – 240-volt power unit intended for connection to a circuit operating at 150 volts or less to ground shall be marked with the word "DANGER" and the following or the equivalent: "To reduce the risk of electric shock – Do not connect to a circuit operating at more than 150 volts to ground." The marking shall identify the leads or terminals that are to be supplied by circuit conductors of 150 volts or less to ground.

61.1.13 A cautionary marking shall be permanent and shall be located on a part that cannot be removed without impairing the operation of the power unit. See 61.3.1.

61.1.14 A cautionary marking to instruct the operator shall be visible and legible to the operator during the intended operation of the power unit. With reference to the Exception to 7.6.6, a marking shall be located adjacent to the part being guarded to indicate that the cover or guard is to be replaced before operation of the power unit.

61.1.15 A warning to the serviceman that a removable panel covering a capacitor should not be removed for whatever time – 5 minutes maximum – is required for the capacitor to discharge to the values specified in 9.1.6 after the power unit has been disconnected from its source of power shall be clearly marked on or near the panel.

61.2 General markings

61.2.1 A power unit shall be plainly and permanently marked where it is readily visible – after installation in the case of a fixed power unit – with the following:

a) The manufacturer's name, trade name, or trademark.

b) A distinctive catalog number or the equivalent.

c) The input and output ratings in voltage, frequency, and amperes, watts, or volt-amperes.

Exception No. 1: The output ratings are not required to be included on a unit complying with 13.1.

Exception No. 2: The output rating need not be included in a power unit intended to charge a specific battery or battery pack provided the unit is marked to indicate the battery or battery pack to be used.

d) The date or other dating period of manufacture not exceeding any three consecutive months.

Exception: The date of manufacture may be abbreviated; or may be in a nationally accepted conventional code or in a code affirmed by the manufacturer provided that the code:

1) Does not repeat in less than 20 years; and

2) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.

e) The number of phases if the product is intended for use on a polyphase circuit. The symbol "∅" may be used in place of the word "phase."

61.2.2 With respect to the frequency marking mentioned in 61.2.1:

a) Equipment intended to operate only from a direct-current supply shall bear markings indicating that the supply shall be direct current. The symbol illustrated in Figure 61.1 may be used for this marking.

b) Equipment intended to operate only from an alternating-current supply shall bear markings indicating that the supply shall be alternating current. The symbol illustrated in Figure 61.2 may be used for this marking. The markings shall include the equipment supply-circuit frequency or supply-circuit frequency-range rating (cycles per second, cycles/second, hertz, c/s, cps, or Hz).

c) Equipment intended to operate from either direct- or alternating-circuit supplies shall bear markings indicating that the supply may be either direct current or alternating current. The symbol illustrated in Figure 61.3 may be used for this marking. The markings shall include the equipment supply-circuit frequency or supply-circuit frequency-range rating (cycles per second, cycles/second, hertz, c/s, cps, or Hz).

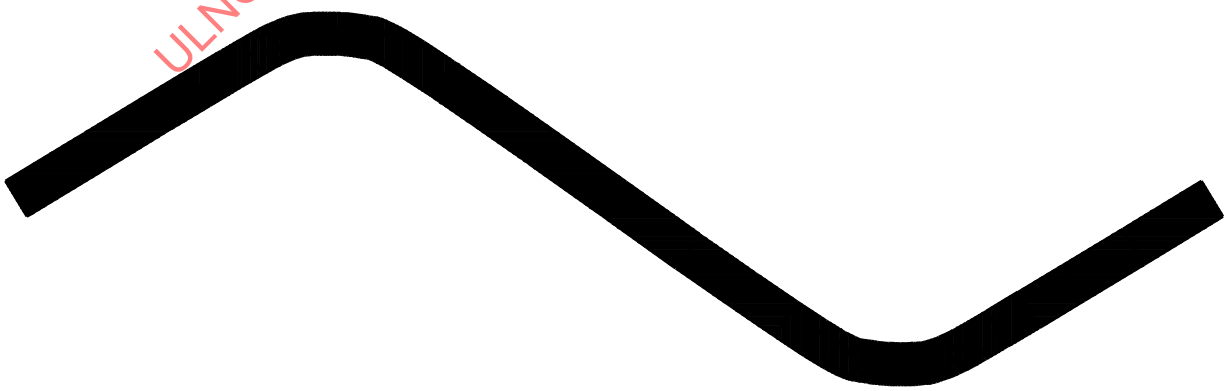
Figure 61.1

Direct current

IEC5031C

Figure 61.2

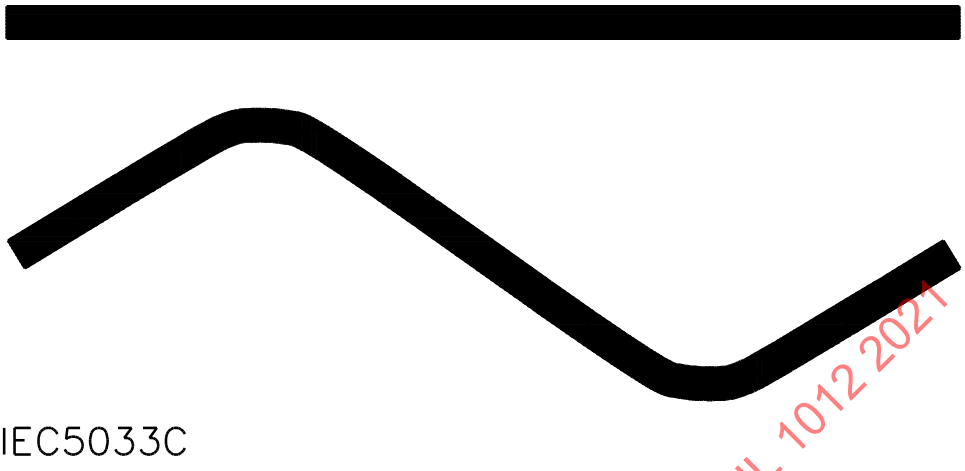
Alternating current



IEC5032C

Figure 61.3

Direct or alternating current



61.2.3 If a duty cycle is necessary for proper performance, the time relationship shall be marked on the product.

61.2.4 A duty cycle marking may consist of a maximum on and a minimum off time; or a maximum on time and an on/off ratio. The time may be indicated in seconds or minutes, or fractions thereof.

61.2.5 The polarity of the output leads shall be plainly indicated by:

a) The words "positive" and "negative";

b) The signs "+" for positive and "–" for negative;

c) The abbreviations "pos" for positive and "neg" for negative; or

d) Color coding of red for positive and black for negative.

61.2.6 Unless provided with a polarized termination, the polarity of a direct-current output shall be plainly indicated.

61.2.7 If a manufacturer produces or assembles a power unit at more than one factory, each power unit shall have a distinctive marking – which may be in code – by which it may be identified as the product of a particular factory.

61.2.8 If any point within a terminal box or wiring compartment of a fixed power unit in which the power unit conductors are intended to be connected, including such conductors themselves, attains a temperature of more than 60° C (140° F) during the normal temperature test, the power unit shall be marked "For supply connection, use wires suitable for at least __° C (__° F)," or with an equivalent statement, and the temperature value shall be in accordance with Table 61.1. This statement shall be located at or near the point where the supply connections are to be made, and shall be clearly visible both during and after installation of the power unit.

Table 61.1
Outlet box marking

Temperature attained in terminal box or compartment during test	Marking
61 – 75°C (142 – 167°F)	75°C (167°F)
76 – 90°C (169 – 194°F)	90°C (194°F)

61.2.9 A power unit shall not be marked "charger " or the equivalent unless it employs a rectifying component.

61.2.10 A battery charger with backfeed protection in accordance with 15.1 shall be marked "Backfeed Protection", "BFP", or the equivalent.

61.2.11 A power unit shall be permanently marked in accordance with 61.2.12 with "For Grounding Conductor, Use ____ AWG Minimum" or with an equivalent statement if the power unit:

a) Has a metal enclosure;

b) Has an ac output rating; and

c) Is intended to supply a Class 1 circuit having an output rating of 1000 volt-amperes or less.

Exception No. 1: A power unit is not required to be marked as specified if provided with a cord and plug for input connections in which the size of the grounding conductor is not less than that specified in 61.2.12(a) or 61.2.12(b).

Exception No. 2: A power unit is not required to be marked as specified if all of the following conditions are met:

a) The power unit is intended to be permanently connected electrically; and

b) The input conductors and the equipment-grounding conductor intended for such connection, with the conductor ampacity based on 125 percent of the input rating of the power unit, would not be smaller than that specified in 61.2.12(a) or 61.2.12(b).

Exception No. 3: In lieu of the specified marking a power unit may be marked "CAUTION" and with the following or the equivalent: "Risk of Fire. Do not ground the secondary circuit to the enclosure of this power unit."

61.2.12 The marking required by 61.2.11 shall be located at or near the point where the equipment-grounding connection is to be made, and shall be clearly visible both during and after installation of the power unit as intended. The grounding conductor size marked in the indicated space shall be:

a) Based on Column 2 of Table 17.2, using the rating of the secondary circuit overcurrent protective device when provided; or

b) Not less than the size of the internal wiring employed for the output power circuits when no secondary overcurrent protection is provided.

61.2.13 A unit having an output circuit intended to be grounded in the field shall be marked with the following or equivalent words: "The output circuit is considered 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."

61.2.14 A terminal in a fixed unit, as described in 20.11, intended for connection to the grounding electrode conductor shall be marked "Grounding Electrode Terminal."

61.2.15 In accordance with 12.2.11(a)(2), if a pressure terminal connector is not provided with the power unit as shipped, the power unit shall be marked to indicate which pressure terminal connector or component terminal assembly packages are to be used with the power unit. This marking may be provided on the unit or on a tag attached to the unit.

61.2.16 The terminal assembly packages specified in 61.2.15 shall be marked with an identifying marking, wire size, manufacturer's name, and trade mark or other descriptive marking by which the organization responsible for the product is able to be identified.

61.2.17 If a pressure terminal connector provided with the power unit [or in a terminal assembly as mentioned in 12.2.11(d)] for a field installed conductor requires the use of a special tool for securing the conductor, necessary instructions for using the tool shall be provided. The instructions shall be included in a readily visible location such as on the connector, on a wiring diagram, on a tag secured to the connector or in an assembly package provided with the power unit.

61.2.18 If Class 2 and Class 3 limited-energy circuits terminate in the same wiring compartment, a marking shall be provided adjacent to the wiring terminals indicating that all output circuits are to comply with the requirements for Class 3 wiring.

61.2.19 With reference to 23.3.2, a unit that relies on the installing electrician to maintain the 1/4 inch (6.4 mm) spacing associated with Class 2 or Class 3 conductors shall be marked with the following or equivalent: "Dress ___ circuits at least 1/4 inch away from ___ circuits," where the blanks are to be completed appropriately with power, light, or Class 1 and Class 2 or Class 3, respectively.

61.2.20 A power unit not furnished with a detachable power supply cord as described in the Exceptions to 12.3.1 and 12.3.7 shall be marked adjacent to the appliance coupler to inform the user to see the instruction manual (see 61.1.10) 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.

61.2.21 In accordance with 12.3.8, a power unit intended for use by travelers shall be marked with the following or equivalent:

a) "See instruction manual for use in countries other than the U.S.A.";

b) “See instructions for input voltage conversion”; or

c) “See instructions if the input plug does not fit the power outlet.”

61.2.22 In accordance with 7.7.1, individual modules of a modular power unit shall be marked with:

a) Information identifying the module consistent with its function in the assembled system, such as "voltage regulation section of Model XYZ POWER SUPPLY"; 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 62.1.11.

61.3 Application

61.3.1 Unless stated otherwise, markings required by this Standard shall be permanent. A permanent marking shall be molded, die-stamped, paint-stenciled; stamped or etched metal that is permanently secured; or indelibly stamped on a pressure-sensitive label secured by adhesive. The marking means shall comply with the Standard for Marking and Labeling Systems, UL 969. Ordinary usage, handling, storage, and the like of the unit are to be considered in determining whether a marking is permanent.

62 Instructions

62.1 General

62.1.1 Instructions for mounting shall be furnished with each power unit intended for permanent mounting.

62.1.2 A commercial stationary or fixed power unit that exceeds the temperature limits specified in Table 42.1 [see footnote (k) to Table 42.1] shall be provided with instructions specifying that "The power unit is to be installed so that it is not likely to be contacted by people " or equivalent wording.

62.1.3 Multiple-voltage equipment intended 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 shall be on a paper tag or other equivalent nonpermanent material.

62.1.4 Multiple-voltage cord-connected equipment shall be provided with instructions to indicate the type of attachment plug that is to be used for connection to the alternate voltage in accordance with 12.3.6.

62.1.5 Multiple voltage equipment intended for use with a detachable power supply cord shall be provided with instructions to indicate the type of detachable power supply cord that is to be used for connection to the alternate voltage in accordance with 12.3.7.

62.1.6 With reference to 12.3.7, a product with an operator adjustable voltage selector shall be marked to instruct the operator to set the voltage selector to the voltage to which the product will be connected.

62.1.7 With reference to 12.3.8, the instructions for a power unit intended for use by travelers shall include (a) – (c) or the equivalent, as appropriate. The items shall be preceded by "IMPORTANT SAFETY INSTRUCTIONS – SAVE THESE INSTRUCTIONS" and "DANGER – TO REDUCE THE RISK OF FIRE OR ELECTRIC SHOCK, CAREFULLY FOLLOW THESE INSTRUCTIONS" in letters of 1/8 inch (3.18 mm) high or in a readily visible contrasting text:

a) "Be sure voltage selector is in correct voltage position before plugging in." The instructions shall also specify the procedures to follow for changing the voltage selector.

b) "For use in the U.S.A., the voltage selector switch must be placed in the 120 volt position. For use in countries other than the U.S.A, the voltage selector may need to be placed in other than the 120 volt position. Confirm the voltage available at each country location before using the product."

c) "For connection to a supply not in the U.S.A., use an attachment plug adapter of the proper configuration for the power outlet, if needed." Or, “If the shape of the plug does not fit the power outlet, use an attachment plug adaptor of the proper configuration for the power outlet."

62.1.8 In accordance with 54.1.7, if an abnormal test is terminated by operation of the intended branch-circuit overcurrent protective device, the power unit shall have the following statement, or the equivalent, in an installation manual provided with the unit: "CAUTION – To reduce the risk of fire, use only on circuits provided with ___ ampere branch-circuit 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 54.1.3.

62.1.9 For a power unit judged in accordance with item b of the Exception to 40.1, the instruction manual shall include all the following conditions of installation:

a) 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.

b) The grounding conductor described in (a) 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.

c) 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.

62.1.10 In accordance with the Exceptions to 12.3.1 and 12.3.7, the instructions for a power unit intended for use with a detachable power supply cord which is not provided with the unit shall contain complete details concerning proper selection of the power supply cord. The instructions shall specify selection of a cord complying with the requirements in 12.3.1 – 12.3.5 and 12.3.10.

Exception: For a power unit intended for use in a country other than the U.S.A., the instructions shall specify the appropriate cord to be used (see Exception No. 4 to 12.3.1).

62.1.11 In accordance with 7.7.1 and 61.2.22, instructions for field assembly of modules of a modular unit, including an interconnection wiring diagram, shall be either:

a) Packaged with the modules; or

b) Contained in the instruction manual provided that the marking on the module makes reference to the instruction manual.

62.2 Battery chargers

62.2.1 A battery charger shall be provided with explicit important safety, operation, and maintenance instructions for the user, and, if applicable, with assembly and moving and storage instructions.

62.2.2 The important safety instructions and instructions for user assembly, operation, maintenance, and moving and storage shall be in the same manual. The important safety instructions shall appear before the instructions for user assembly, operation, maintenance, and moving and storage.

62.2.3 In an instruction manual intended for use with more than one model or type of battery charger, the instructions applicable to each model or type of battery charger shall be explicitly identified.

Exception: This requirement does not apply to instructions that are exactly the same for more than one model or type of battery charger, and that could not result in confusion or misunderstanding due to different location of controls, operating modes, and the like.

62.2.4 Instructions shall be legible and shall contrast with the background.

62.2.5 The headings for the user assembly, operation, maintenance, moving and storage, and important safety instructions, and the opening statements of the instructions specified in 61.2.11 – "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.

62.2.6 There shall be no substitute for the word "CAUTION," "WARNING," or "DANGER" in the text of the instructions.

62.2.7 The text of the instructions required by 62.2.11 shall be verbatim, or in equally definitive terminology.

Exception: When a specific conflict in the application to a battery charger exists, or when the wording is inappropriate, variations from the specified wording are able to be used.

62.2.8 An illustration may be used with a required instruction to clarify the intent, but shall not replace the instruction.

62.2.9 Important safety instructions shall warn the user of reasonably foreseeable risks of fire, electric shock, or injury to persons; and shall state the precautions that should be taken to reduce such risks.

62.2.10 The items listed in 62.2.11 shall be numbered, and other instructions deemed necessary by the manufacturer to reduce the risk of fire, electric shock, or injury to persons may be included.

62.2.11 The important safety instructions shall include those items in the following list that are applicable to the particular battery charger. The statement "IMPORTANT SAFETY INSTRUCTIONS," shall precede the list and the statement "SAVE THESE INSTRUCTIONS" shall either precede or follow the list. The word "CAUTION," "WARNING," or "DANGER" shall be entirely in upper case letters.

Exception: With reference to item number 1 in the Important Safety Instructions, the specific model numbers are not required to be included when the instructions are identical for all models.

IMPORTANT SAFETY INSTRUCTIONS

1. SAVE THESE INSTRUCTIONS – This manual contains important safety and operating instructions for battery charger Models ____.

2. Before using battery charger, read all instructions and cautionary markings on battery charger, battery, and product using battery.

3. CAUTION – To reduce risk of injury, charge only ____ type rechargeable batteries. Other types of batteries may burst causing personal injury and damage.

SPECIFIC POWER UNITS

OUTDOOR-USE POWER UNITS

63 General

63.1 The requirements in Sections 64 and 65 supplement and, in some cases, modify the general requirements in Sections 7 – 62. The corrosion protection requirements specifically cover power units constructed of sheet metal. Similar requirements would be applicable to other metals, including coated aluminum.