UL 1564

STANDARD FOR SAFETY

Industrial Battery Chargers

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UL Standard for Safety for Industrial Battery Chargers, UL 1564

Fifth Edition, Dated February 13, 2024

Summary of Topics

This new edition of ANSI/UL 1564 dated February 13, 2024 includes the following:

- ***Addition of NOTE to to Align with the Dielectric Voltage-Withstand Test of Section 32***

- ***Editorial Updates: 2.1, 2.2, 2.3, 2.4, and Section 4***

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated December 15, 2023.

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FEBRUARY 13, 2024

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UL 1564

Standard for Industrial Battery Chargers

Prior to the first edition, the requirements for the products covered by this standard were included in the Standard for Electric Battery Chargers, UL 1236.

Prior to the third edition, the requirements for Outdoor-Use Industrial Battery Chargers were included in the Outline of Investigation for Outdoor-Use Industrial Battery Chargers, UL 1564A.

First Edition – December, 1982
Second Edition – November, 1993
Third Edition – August, 2006
Fourth Edition – May, 2015

Fifth Edition

February 13, 2024

This ANSI/UL Standard for Safety consists of the Fifth Edition.

The most recent designation of ANSI/UL 1564 as an American National Standard (ANSI) occurred on February 13, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover battery chargers rated 600 volts or less. They are intended to be used in accordance with the National Electrical Code, NFPA 70, to charge industrial storage batteries which are used to provide power for material handling trucks, tractors, personnel carriers, and similar motive equipment. These chargers may be either cord and plug connected or permanently connected.

1.2 A battery charger that is not a complete assembly and depends upon installation in an end product for compliance with the requirements in this Standard is investigated under the requirements of this Standard and the standard for the end product.

1.3 These requirements do not cover:

a) Battery chargers for use in a marina, boatyard, or other marine application;

b) Battery chargers for fire protection signaling service;

c) Household battery chargers;

d) Automotive battery chargers;

e) Battery chargers for use with an internal combustion engine driving a centrifugal fire pump; or

f) Appliances or systems in which a battery charger is used.

2 Components

2.1 A component of a product covered by this Standard shall:

a) Comply with the requirements for that component as specified in this Standard;

b) Be used in accordance with its rating(s) established for the intended conditions of use; and

c) Be used within its established use limitations or conditions of acceptability.

2.2 A component of a product covered by this Standard is not required to comply with a specific component requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product;

b) Is superseded by a requirement in this Standard; or

c) Is separately evaluated when forming part of another component, provided the component is used within its established ratings and limitations.

2.3 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.

2.4 A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable standard(s) that cover devices that provide those functions.

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3 Units of Measurement

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

4 Referenced Publications

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

4.2 The following publications are referenced in this Standard:

ASTM A653/A653M, *Standard Specification for Steel Sheet, Zinc-Coated (Galvanized), or Zinc-Iron Alloy-Coated (Galvannealed) by Hot-Dip Process*

ASTM D412, *Standard Test Method for Rubber Properties in Tension*

ASTM E28, *Standard Test Method for Softening Point by Ring-And Ball Apparatus*

ASTM E230, *Standard Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples*

UL 50E, *Enclosure for Electrical Equipment, Environmental Considerations*

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 224, *Extruded Insulating Tubing*

UL 310, *Electrical Quick-Connect Terminals*

UL 486A-486B, *Wire Connectors*

UL 510, *Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape*

UL 514B, *Conduit, Tubing, and Cable Fittings*

UL 746C, *Polymeric Materials*

UL 796, *Printed-Wiring Boards*

UL 840, *Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*

UL 969, *Marking and Labeling Systems*

UL 1004-2, *Impedance Protected Motors*

UL 1004-3, *Thermally Protected Motors*

UL 1236, *Electric Battery Chargers*

UL 1310, *Class 2 Power Units*

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UL 1332, *Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment*

UL 1437, *Electrical Analog Instruments – Panel Board Types*

UL 1977, *Component Connectors for Use in Data, Signal, Control and Power Applications*

UL 2251, *Plugs, Receptacles, and Couplers for Electric Vehicles*

UL 2353, *Single- and Multi-Layer Insulated Winding Wire*

UL 5085-1, *Low Voltage Transformers – Part 1: General Requirements*

UL 5085-3, *Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers*

UL 60691, *Thermal-Links – Requirements and Application Guide*

5 Glossary

5.1 In the following text, the term "product" is used to mean an industrial battery charger.

5.2 For the purpose of this standard, the following definitions apply.

5.3 CLASS 2 TRANSFORMER – A step-down transformer complying with the applicable requirements in UL 5085-1 and UL 5085-3, or UL 1310.

5.4 INDUSTRIAL BATTERY – A battery that is intended for cycling service and is rated in number of cells and in ampere-hours delivered at the 6-hour discharge rate.

5.5 LIMITED-ENERGY CIRCUIT – An ac or dc circuit having a voltage not exceeding 1000 volts and the energy limited to 100 volt-amperes by either a secondary winding of a transformer, one or more resistors complying with 24.4.10 and 24.4.11, or a regulating network complying with 24.4.1.

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

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

1) Not of the automatic reclosing type;

2) Trip-free from the reclosing mechanism; and

3) Either not readily interchangeable with a device of a different rating or a marking in accordance with 48.5 is provided.

b) A combination of an isolated transformer secondary winding and one or more resistors or a regulating network complying with 24.4.10 that complies with all the performance requirements for an inherently limited Class 2 transformer or power source.

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CONSTRUCTION

6 Frame and Enclosure

6.1 A product 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 a total or partial collapse resulting in a reduction of spacings, loosening or displacement of parts, or other serious defects.

6.2 A product that complies with the requirements in 6.3 – 6.8 is considered to comply with the requirements in 6.1.

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

6.4 The thickness of a sheet-metal enclosure shall not be less than that specified in Table 6.1 and Table 6.2, except that uncoated steel shall not be less than 0.032 inch (0.81 mm) thick, zinc-coated steel shall not be less than 0.034 inch (0.86 mm) thick, and nonferrous metal shall not be less than 0.045 inch (1.14 mm) thick at points at which a wiring system is to be connected.

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Table 6.1
Thickness of Sheet Metal for Enclosures – Carbon Steel or Stainless Steel

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

Table 6.1 Continued on Next Page

Table 6.1 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness, inch (mm)			
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]					
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	Uncoated		Zinc coated	
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)				
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123	(3.12)	0.126	(3.20)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)				

[a] See 6.5.

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

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

Table 6.2
Thickness of Sheet Metal for Enclosures – Aluminum, Copper, or Brass

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

[a] See 6.5.

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

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

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6.5 With reference to Table 6.1 and Table 6.2, a supporting frame is a structure of angle, channel, or a folded rigid section of sheet metal, that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and that has sufficient torsional rigidity to resist the bending

moments that may be applied by the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that produce a structure that is as rigid as one built with a frame of angles or channels. Construction considered to be without a supporting frame includes:

a) A single sheet with single formed flanges (formed edges);

b) A single sheet that is corrugated or ribbed; and

c) An enclosure surface loosely attached to a frame (for example, by means of spring clips).

6.6 An enclosure consisting of wire mesh, perforated screens, or grillwork shall be provided with a rigid supporting frame such that the deformation of a guard or enclosure does not result in contact with live parts.

6.7 The diameter of the wires of a screen shall not be less than 0.0598 inch (1.519 mm) if the screen openings are 1/2 square inch (3.2 cm^2) or less in area and shall not be less than 0.100 inch (2.54 mm) for larger screen openings.

6.8 Perforated sheet steel and sheet steel used for expanded metal mesh shall not be less than 0.042 inch (1.07 mm) thick, 0.058 inch (1.47 mm) thick if nonferrous, if the mesh openings or perforations are 1/2 square inch (3.2 cm^2) or less in area, and shall not be less than 0.080 inch (2.03 mm) thick, 0.112 inch (284 mm) thick if non-ferrous, for larger openings.

Exception: In a small charger where the indentation of a guard or enclosure does not affect the clearance between uninsulated, movable, current-carrying parts and grounded metal, 0.020 inch (0.51 mm) steel or 0.029 inch (0.74 mm) nonferrous expanded metal mesh may be employed, provided that:

a) The exposed mesh on any one side or surface of the battery charger that is so protected has an area of 72 square inches (465 cm^2) or less and does not have any dimension greater than 12 inches (305 mm); or

b) The width of the protected opening is 3-1/2 inches (88.9 mm) or less.

6.9 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: This requirement does not apply to an electrical instrument connected in a secondary circuit where damage to or deterioration of the materials of which the housing is made does not result in a risk of fire or electric shock.

Exception No. 2: This requirement does not apply to a meter complying with UL 1437.

6.10 Material supporting terminals or used as internal electrical insulation of an electrical instrument shall comply with the requirements in Insulating Materials, Section 15. The acceptability of spacings between live and dead metal parts connected to the enclosure within the instrument shall be determined by compliance with the requirements in 32.1.1.

Exception No. 1: This requirement does not apply to an electrical instrument connected in a secondary circuit where damage to or deterioration of the materials does not result in a risk of fire or electric shock.

Exception No. 2: This requirement does not apply to a meter complying with UL 1437.

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6.11 Supporting feet of a product that form part of the enclosure or are needed for ventilation shall be reliably secured and the aging, physical, and flammability properties of the material shall be investigated. The effect of oil and the absorption of moisture on the mounting feet are also to be considered.

Exception: Supporting feet may be accepted without testing if they do not form part of the enclosure and are not needed to provide ventilation.

6.12 An enclosure, frame, or cover of a material other than sheet metal shall provide protection equivalent to that required by 6.4.

6.13 Among the factors taken into consideration when judging the acceptability of a nonmetallic enclosure are:

a) Mechanical strength;

b) Resistance to impact;

c) Moisture-absorptive properties;

d) Combustibility;

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

f) Resistance to arcing.

The enclosure material shall not display a loss of a property beyond the minimum acceptable level as a result of aging. See UL 746C.

6.14 The combination of enclosure and internal barriers of a product shall prevent molten metal, burning insulation, flaming particles, or the like, from falling onto combustible materials, including the surface upon which the charger is supported. See Figure 6.1. An internal barrier may be an integral part of a component or of the charger enclosure. Compliance shall be determined in accordance with 6.15 and 6.16.

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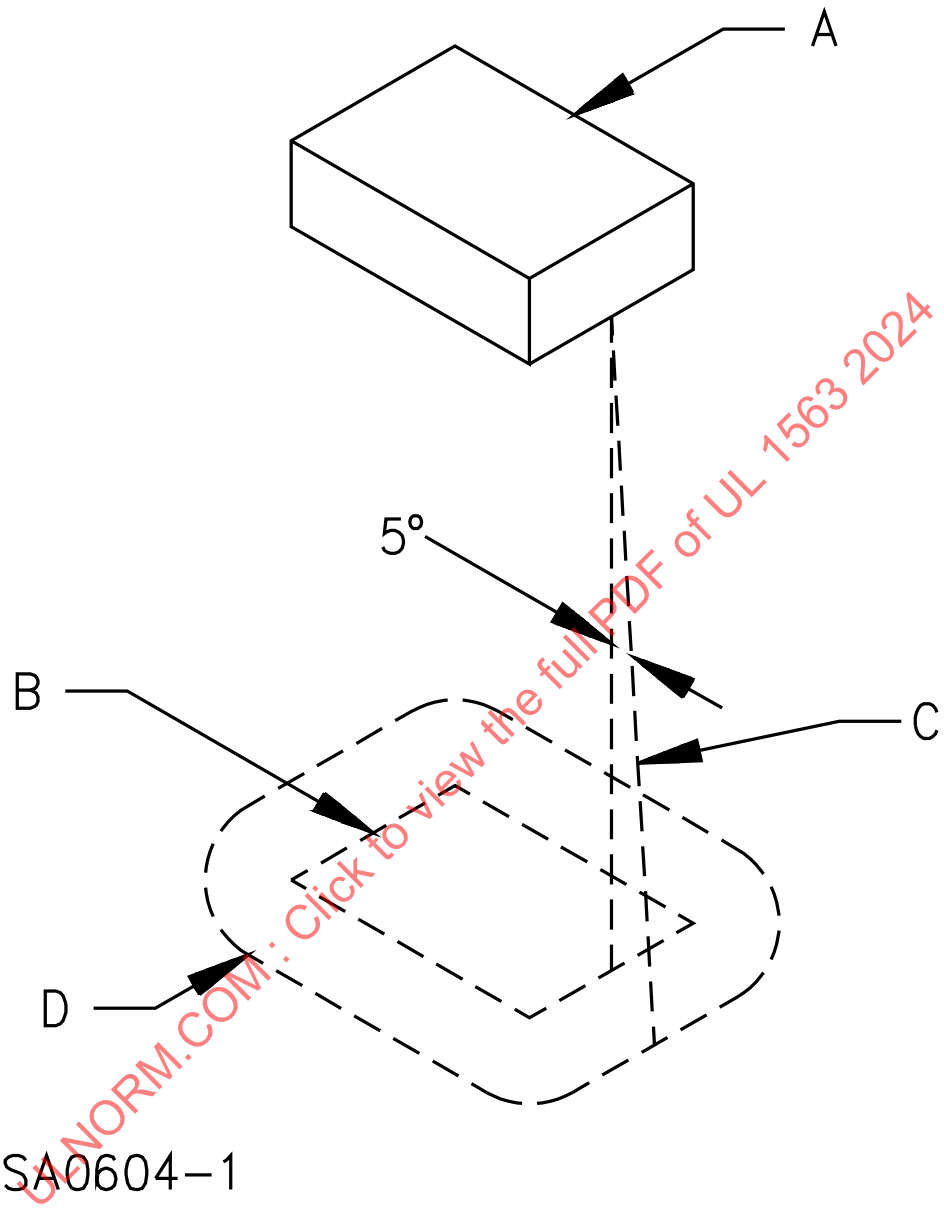
Figure 6.1

Location and Extent of Barrier



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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. When moving, 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.

6.15 To comply with the requirement in 6.14, an enclosure having openings in the bottom wall shall be provided with a barrier in accordance with Figure 6.1 unless the components enclosed are as described in the following:

a) Individually enclosed when arcing parts such as a switch, relay, or contactor are involved.

b) A motor without openings in the bottom of the housing unless:

1) The overload protection provided with the motor is such that no burning insulation or molten material falls to the surface that supports the product when the motor is energized under each of the following fault conditions:

i) Open main winding;

ii) Open starting winding; and

iii) Starting switch short-circuited;

2) The motor is provided with a thermal protector that is sensitive to temperature and current and that will prevent the temperature of the motor winding from exceeding:

i) 125 °C (257 °F) when the motor is running at the maximum load at which it can operate without causing the protector to cycle; and

ii) 150 °C (302 °F) with the rotor of the motor locked; or

3) The motor complies with the requirements for impedance-protected motors and the temperature of the motor winding does not exceed 150 °C during the first 72 hours of operation with the rotor locked.

c) Internal wiring insulated with neoprene, thermoplastic, impregnated fiber-glass, or an equally flame-retardant material.

d) An individually enclosed fuse, such as an extractor type. Consideration shall be given to a fuse enclosed within a transformer winding.

Exception: A battery charger marked in accordance with 49.5 need not comply with (a) and (d).

6.16 If a ventilating opening is located in the bottom of the enclosure, a component having a magnetic winding or coil, such as a relay or solenoid shall either be:

a) Individually and completely enclosed; or

b) If applicable, subjected to the burnout tests described in 40.1 and 40.2.

7 Accessibility of Live Parts

7.1 To reduce the risk of unintentional contact by persons with an uninsulated live part, an opening in the enclosure shall comply with 7.2.

7.2 Openings in an enclosure, including holes, louvers, and openings protected by means of wire screening, expanded metal, or perforated covers, shall be of such size or shape that no opening permits passage of a rod having a diameter of 1/2 inch (12.7 mm).

Exception: If the distance between any live part and the enclosure is 4 inches (102 mm) or more, an opening may be larger than 1/2 inch but shall not permit passage of a rod having a diameter of 3/4 inch (19.1 mm).

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7.3 A door or cover that provides access to a live part that can result in a risk of electric shock shall be securely held in place so that a tool is required to open or remove it.

7.4 A door or cover that does not provide access to a live part that involves a 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 A door or cover of an enclosure shall be hinged or attached in an equivalent manner if it provides access to an overload-protective device, the normal functioning of which requires renewal, or if it is necessary to open the door or cover in connection with the normal operation of the protective device. A door or cover providing access to a fuseholder shall be tight-fitting and shall be reliably held closed.

7.6 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.

7.7 Glass or thermoplastic covering an opening for user servicing, such as replacing a pilot lamp, and that is intended to reduce the risk of unintentional contact with live parts, shall be:

a) A material complying with the:

1) Impact test specified in 42.2;

2) Abnormal Operation Tests, Section 39; and

3) Enclosure flammability tests for thermoplastics as specified in UL 746C; and

b) Reliably retained in place.

8 Assembly

8.1 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 normal stresses when such movement results in a reduction of spacings below the minimum acceptable values. See 24.1.1.

8.2 A component, such as a rectifier element, control switch, lampholder, attachment plug receptacle, or plug connector shall be mounted securely and shall be prevented from turning by means other than friction between surfaces, such as a properly applied lockwasher.

Exception No. 1: A switch need not be mounted as described if 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) Normal 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, if rotation cannot reduce spacings below the minimum acceptable value.

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9 Protection Against Corrosion

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

Exception No. 1: Bearings, laminations, and other similar parts of iron or steel, such as washers and screws, do not need to be protected from corrosion.

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

10 Supply Connections – Permanently-Connected Products

10.1 General

10.1.1 The provisions for the input connections to a product shall consist of either a means of permanent wiring connections as specified in this Section or a power supply cord in accordance with Supply Connections – Cord- and Plug-Connected Products, Section 11.

10.1.2 A product intended for permanent connection to the power supply shall have provision for the connection of a wiring system.

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

10.1.4 A knockout shall be surrounded by a flat surface large enough to seat a conduit bushing or locknut of the appropriate size.

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

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

10.1.7 A field-wiring compartment shall provide protection for wiring from sharp edges, including screw threads, burrs, fins, moving parts, and the like, that may abrade the insulation on conductors or otherwise damage the wiring.

10.1.8 If a separate field-wiring compartment is not provided, space for field-wiring connections shall be located near the connecting means and shall permit routing of the wiring away from live parts and from sharp edges, including screw threads, burrs, fins, moving parts, and the like.

10.2 Field-wiring terminals and leads

10.2.1 A field-wiring terminal is a terminal to which power-supply, control, output, or other permanent connections will be made in the field when the charger is installed.

10.2.2 Field-wiring terminals or leads shall be acceptable for the connection of conductors having an ampacity appropriate for the rating of the charger.

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

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Exception: A wire-binding screw or stud-and-nut terminal may be employed for connection of a 10 AWG (5.3 mm^2) or smaller or conductor. A stud-and-nut terminal is one in which the conductor is wrapped around a stud and retained by a nut.

10.2.4 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 by a lockwasher; or by an equivalent method.

10.2.5 A wire-binding screw or stud at a field-wiring terminal shall not be smaller than No. 10.

Exception No. 1: A No. 8 screw or stud 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 screw or stud may be used for the connection of a 16 AWG (1.3 mm^2) or 18 AWG (0.8 mm^2) circuit conductor.

10.2.6 A wire binding screw or stud-and-nut terminal shall be capable of accommodating a three-quarter loop.

10.2.7 A wire-binding screw shall thread into metal.

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

Exception: A plate not less than 0.030 inch (0.76 mm) thick is acceptable for use with a 14 AWG (2.1 mm^2) or smaller conductor.

10.2.9 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.

10.2.10 Upturned lugs, a cupped washer, or the equivalent shall be capable of retaining a conductor of the size required in 10.2.2 but not smaller than 14 AWG (2.1 mm^2) under the head of the screw.

10.2.11 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.

Exception: A lead may be less than 6 inches long if it is evident that the use of a longer lead might result in a risk of fire or electric shock.

10.2.12 A field-wiring terminal intended for connection of a grounded circuit conductor shall be made of, or plated with, metal substantially white in color and shall be readily distinguishable from other terminals; or properly and clearly identified in some other manner, such as on an attached wiring diagram.

10.2.13 The surface of a lead for the connection of a grounded circuit conductor shall be white or gray and shall be readily distinguishable from other leads.

10.2.14 A product provided with wiring terminals or leads and rated 125 or 125/250 volts or less and employing one or more of the following shall have one terminal or lead identified for connection of the grounded conductor of a supply circuit:

a) A lamp or element-holder of the Edison-screw-shell type;

b) A single-pole switch; or

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c) A single-pole automatic control.

The terminal or lead intended to be connected to a grounded conductor of a supply circuit shall be the one that is connected to screw shells of lamp-holders or element-holders, and to which are connected no single-pole switches or single-pole automatic controls.

11 Supply Connections – Cord- and Plug-Connected Products

11.1 General

11.1.1 The provisions for input connections that do not comply with Supply Connections – Permanently-Connected Products, Section 10, shall have a power supply cord that complies with the requirements of this Section.

11.1.2 A product shall employ a Type S, SE, SO, ST, STO, SJ, SJE, SJO, SJT, or SJTO power-supply cord and an attachment plug for connection to the supply circuit.

11.1.3 The length of cord external to the charger and including the attachment plug shall be not less than 6 feet (1.83 m) as measured to the face of the attachment plug.

11.1.4 The current and voltage ratings of a flexible cord and attachment plug for a product shall not be less than the input rating of the charger; except that if the product load is continuous for 3 hours or more, the ampacity of the attachment plug shall not be less than 125 percent of the input rating.

11.1.5 In a product rated 125 or 125/250 volts (3-wire) or less, 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.

11.2 Strain relief

11.2.1 Strain relief shall be provided to prevent mechanical stress, such as a pull or twist, on the supply cord or output cord from being transmitted to terminals, splices, or interior wiring. Compliance shall be determined by subjecting the cord to the Strain Relief Test, Section 34.

11.2.2 A metal strain-relief clamp or band is acceptable without supplementary protection on Type SJ or heavier cord.

11.2.3 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 35, Push-Back Relief Test.

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11.3 Bushings

11.3.1 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, reliably secured in place, and shall have a smooth, rounded surface against which the cord may bear.

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

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

11.3.3 Vulcanized fiber may be employed if the bushing is not less than 3/64 inch (1.2 mm) thick, and if formed and secured in place so that it will not be adversely affected by conditions of ordinary moisture.

11.3.4 A separate soft-rubber, neoprene, or polyvinyl chloride bushing may be used in the frame of a motor or in the enclosure of a capacitor attached to a motor provided the bushing is:

a) At least 3/64 inch (1.2 mm) thick; and

b) Located so that it will not be exposed to oil, grease, oily vapor, or other substances having a deleterious effect on the compound.

11.3.5 A bushing of a material mentioned in 11.3.4 may be used at any point in a product if used in conjunction with a type of cord for which an insulating bushing is not required.

11.3.6 If a bushing of a material mentioned in 11.3.4 is used, the hole in which the bushing is mounted shall be smooth and free from sharp edges.

11.3.7 An insulating bushing molded integrally with the supply cord is acceptable provided the built-up section is not less than 1/16 inch (1.6 mm) thick where the cord passes through the enclosure.

11.3.8 An insulating 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.

12 External Connections and Wiring

12.1 A connector for the output circuit shall have a voltage rating equal to the output rating of the charger and shall comply with the requirements in UL 1977. A connector shall:

a) Have a nonstandard pin configuration; and

b) Be polarized.

12.2 Output wiring shall be attached to or provided with the product. It shall be of a size and rating acceptable for the application and shall be either:

a) A flexible cord of Type S, SE, SO, ST, STO, SJ, SJE, SJO, SJT, SJTO, EV, EVJ, EVE, EVJE, EVT, or EVJT; or

b) Individual conductors that comply with the requirements in 12.3.

12.3 With reference to 12.2(b), the individual conductors shall be insulated with neoprene or other equivalent insulation. Equivalent insulation shall withstand flexing, handling, and impact in the temperature range of minus 29 to plus 54 °C (minus 20 to plus 130 °F). The minimum average insulation thickness

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shall not be less than 0.060 inch (1.52 mm) for 8 – 2 AWG (8.4 – 33.6 mm^2) wire and 0.080 inch (2.03 mm) for 1 – 4/0 AWG (42.4 – 107 mm^2) wire.

12.4 Live parts shall be recessed from the face of the connector to reduce the possibility of a short circuit.

12.5 A metal enclosure of a product shall not be connected to an electrical circuit of the charger.

Exception: A secondary circuit rated 50 volts or less may be connected to the enclosure provided it is marked in accordance with 49.7.

13 Current-Carrying Parts

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

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

a) If acceptable in accordance with 4.1; or

b) Within a motor.

14 Internal Wiring

14.1 General

14.1.1 The internal wiring of a product shall be of a type and size specified in this Section. Other types of wiring may be accepted based on:

a) Exposure to oil, grease, or other substances that may have a deleterious effect on the insulation;

b) The temperature and voltage; and

c) Other conditions of service to which the wiring may be subjected.

Exception: Internal wiring in a secondary circuit of 50 volts open circuit or less, if it is acceptable when judged as bare wire with respect to intermingling with the primary circuit wiring and separation from other uninsulated live parts and grounded metal need not comply with this Section.

14.1.2 The minimum average thickness of insulation on wiring shall not be less than 3/64 inch (1.2 mm) for unbraided neoprene-insulated wire, 1/32 inch (0.8 mm) for thermoplastic-insulated wire, 1/32 inch for rubber-insulated wire with an impregnated braid, and 1/64 inch (0.4 mm) for cross-linked synthetic polymer.

Exception: Internal wiring as defined in the Exception to 14.1.1 need not comply.

14.1.3 The length of the power-supply cord inside a product shall not be more than that needed for the electrical connections.

14.1.4 The jacket of a flexible cord 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 14.1.2;

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b) The individual conductors are supported in a manner that maintains separation from live parts and dead metal parts; or

c) Supplementary insulation equivalent to that required by 14.1.2 is reliably secured on each individual conductor.

14.2 Tubing

14.2.1 Insulation on internal wiring consisting of coated fabric, thermoplastic, or other types of tubing is to be considered with respect to the electrical, mechanical, and flammability properties of the material.

14.3 Protection of wiring

14.3.1 Internal wiring shall be protected if, when judged in accordance with 7.2, 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.

14.3.2 Wires within an enclosure, compartment, raceway, or the like, shall be located or protected so that they cannot contact any sharp edge, burr, fin, screw threads, moving part, or the like, that may damage the conductor insulation.

14.3.3 A hole in a sheet metal wall within the overall enclosure of a product through which insulated wires pass shall be provided with a bushing.

14.4 Electrical connections

14.4.1 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 points of connection.

14.4.2 With reference to 14.4.1, a wire-binding screw, a stud-and-nut terminal, or a pressure wire connector used as a terminating device shall be evaluated by conducting heat cycling tests in accordance with UL 486A-486B.

14.4.3 All splices and connections shall be mechanically secure and shall make reliable electrical contact.

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

14.4.5 A splice shall be provided with insulation equivalent to that of the wires involved.

Exception: Insulation is not required when the splice is supported in a manner that maintains spacings from live parts and dead metal parts in accordance with Spacings, Section 24.

14.4.6 If the voltage involved is less than 250 volts, insulation consisting of two layers of acceptable thermoplastic tape or one layer of friction tape and one layer of rubber tape, which has been investigated and found acceptable for the purpose, is acceptable on a splice. An insulated splicing device is acceptable within the limits of voltage and temperature ratings of the device.

14.4.7 In determining if splice insulation consisting of coated fabric, thermoplastic, or other tubing is acceptable, consideration is to be given to such factors as dielectric properties, heat-resistant and

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moisture-resistant characteristics, and the like. Thermoplastic tape wrapped over a sharp edge is not acceptable.

14.4.8 The means of connecting stranded internal wiring to a wire-binding screw shall be such that loose strands of wire cannot contact other live parts not always of the same polarity as the wire or contact 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 reliable means.

14.4.9 A nominal 0.110, 0.125, 0.187, 0.205, or 0.250 inch (2.8, 3.2, 4.8, 5.2, or 6.4 mm) wide quick-connect terminal shall comply with the requirements in UL 310. Other sizes of quick-connect terminals shall be investigated with respect to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rises. All tests are to be conducted in accordance with the requirements in UL 310.

14.5 Separation of circuits

14.5.1 For the purpose of the requirements in 14.6.1 and 14.7.1, 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; and

e) AC input power and DC power circuits.

14.6 Factory wiring

14.6.1 A factory-installed conductor shall be separated by a barrier as specified in 14.8 or segregated as specified in 14.6.2 from:

a) A factory-installed conductor of a different circuit unless both conductors are insulated for the maximum voltage of either circuit; and

b) An uninsulated live part of a different circuit.

14.6.2 Segregation of a factory-installed conductor from another factory-installed conductor or an uninsulated live part of a different circuit as required by 14.6.1 is capable of being accomplished by clamping, routing, or an equivalent means that maintains a permanent separation.

14.7 Field wiring

14.7.1 The equipment shall be constructed so that a field-installed conductor shall be separated by a barrier as specified in 14.8.1 and 14.8.2, or segregated as specified in 14.7.2 from:

a) A factory-installed conductor of a different circuit, unless the conductors of both circuits are insulated for the maximum voltage of either circuit;

b) A field-installed conductor of a different circuit unless:

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

2) Both circuits are insulated for the maximum voltage of either circuit;

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c) An uninsulated live part of a different circuit; and

Exception: A field-installed conductor is not required to be separated or segregated 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 or both circuits are other than Class 2 or Class 3.

d) An uninsulated live part of the same circuit when short circuit with it results in a risk of fire, electric shock, electrical energy – high current levels, or injury to persons.

14.7.2 Segregation of a field-installed conductor from a factory- or field-installed conductor or from an uninsulated live part of a different circuit as required by 14.7.1 may 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 field-installed conductor and factory- or field-installed conductors or live parts of a different circuit are separated by a minimum of 1/4 inch (6.4 mm). In determining whether a device having such openings complies with this requirement, it is to be wired as in service including 6 inches (152 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.

14.8 Separation barriers

14.8.1 A barrier used to provide separation between conductors of different circuits and between a conductor and an uninsulated live part of different circuits as required by 14.6.1 and 14.7.1 shall be supported so that it cannot be readily deformed to defeat its purpose and shall be:

a) Grounded metal; or

b) Insulating material no less than 0.028 inch (0.71 mm) thick.

14.8.2 A barrier used to provide separation between field-installed conductors and field- or factory-installed conductors or uninsulated live parts as required by 14.6.1 and 14.7.1 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.

15 Insulating Materials

15.1 An insulating washer, a bushing, or the like, and a base or a support for mounting a live part shall be moisture-resistant material that is not affected adversely by the temperatures and stresses to which it is subjected under conditions of use.

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

a) Its mechanical strength, resistance to ignition, dielectric strength, insulation resistance, and heat-resistance 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 shall be considered with respect to conditions of service.

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16 Motors

16.1 A fan motor used in a product shall be provided with protection consisting of one of the following:

a) Thermal or impedance protection complying with the requirements in UL 1004-2, or UL 1004-3; or

b) Other protection that is shown by testing to be equivalent to the protection mentioned in (a).

Exception: A fan motor with the air-propelling component coupled directly to the motor shaft complying with the requirements in 6.15(b) and with 39.4.1 need not have the protection indicated in (a) or (b).

17 Transformers

17.1 General

17.1.1 A transformer shall have its primary winding electrically isolated from its secondary winding and shall be constructed as specified in this Section so that there is no electrical connection – under normal and overload conditions – between the primary and secondary windings, between the primary winding and the core, or between separate adjacent secondary windings if such connection might result in a risk of fire or electric shock.

Exception: The requirements in this Section do not apply to control-circuit transformers used only for controlling internal loads within the battery charger, such as pilot lights, fans, contactor coils, relays, and timers.

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

17.2 Coil insulation

17.2.1 A transformer winding including the start, all taps, finish, and crossover leads up to the point where insulated leads are provided shall be constructed to provide insulation required for the transformer temperature class as specified in Table 17.1.

Exception: Insulation may be reduced or waived between the primary and core when all of the following conditions are met:

a) The core is of a low electrical conductance material, for example ferrite used in switch-mode product;

b) The core is treated as a live and electrically conductive part when judging insulation and spacings between the core and;

1) Accessible metal parts;

2) The secondary windings; and

3) Any other output circuitry.

c) In applying (b), the core shall be considered to be at the maximum potential of the primary winding; and

d) Insulation of Type D, E, F, and G per Table 17.1 between secondary windings and core.

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17.2.2 Insulating material, such as outer-wrap and crossover-lead insulation, employed to prevent live parts from becoming accessible through openings in the outer enclosure in accordance with 7.1, shall not be less than 0.028 inch (0.71 mm) thick.

Exception: Insulation need not be provided if the transformer is inaccessible.

Table 17.1
Transformer Insulation

Insulation required	Types 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 H
2. Insulation between the primary and any secondary winding	A, B, C, D, or H
3. Insulation between any winding or lead connections and dead metal parts	D, E, F, or G
4. Insulation between the crossover leads and:	A, D, E, G, H, or I
a) The turns of a different winding;	
b) The metal product enclosure; or	
c) The core	

INSULATION TYPES:

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 (0.71 mm) thick.

C. A material having a thickness less than 0.028 inch may be used provided that it is mechanically, electrically, and thermally equivalent to Type A or B and the material has a dielectric breakdown strength of 5000 volts for the thickness used.

D. Spacings specified in Table 17.2 may be used in place of the specified insulation.

E. Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.013 inch (0.33 mm) if used in conjunction with an air spacing of 1/2 that specified for Type D.

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

G. A material having a thickness less than that specified for Type E or F may be used, provided that it is mechanically and thermally equivalent to E and F and the material has a dielectric breakdown strength of 5000 volts for the thickness used for E and 2500 volts for F.

H. Winding wire complying with UL 2353.

I. Insulation between a crossover lead and the winding to which it is connected is not specified if:

a) The coil withstands the dielectric voltage-withstand test described in 32.1.1 (a) and (c) with the potential applied between the coil leads, with the inner coil lead cut at the point where it enters the layer; or

b) For a molded-bobbin transformer, the coil withstands the induced-potential tests described in 32.2.

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Table 17.2
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 – 125	1/16	(1.6)
Greater than 125 – 250	3/32	(2.4)
Greater than 250 – 600	1/4	(6.4)

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.

17.2.3 A flanged bobbin-wound transformer shall be constructed to maintain physical separation between the primary and secondary windings. Physical separation may be accomplished by employing a three-flange bobbin for winding the primary and secondary windings adjacent to each other. As an alternative, a telescoping bobbin construction, each section containing an individual winding, may be used where the primary winding is wound over the secondary winding or the secondary winding over the primary winding. The bobbin insulation material shall comply with Type A, B, C, or D of Table 17.1.

Exception: A two-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation is considered acceptable if:

a) The tape insulation complies with Type A or C of Table 17.1;

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

c) The Abnormal Tests, Section 41, are continued for 15 days; and

d) The induced potential tests described in 32.2 are conducted.

18 Resistors

18.1 A power resistor secured by a clamp, a bolt, or both shall be reliably supported and the assembly shall be prevented from loosening or rotating.

18.2 The use of a lockwasher is considered to comply with the requirement in 18.1.

19 Switches and Controllers

19.1 A switch or other control device shall be acceptable for the application and shall have current and voltage ratings not less than those of the circuit that it controls when the battery charger is operated normally.

Exception: A switch or other control device, other than a protective device, having an acceptable alternating-current rating may be connected in a direct-current secondary circuit if the results of the overload test described in 36.2 are acceptable.

19.2 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.

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

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

19.4 A switch provided as part of a product intended to be connected to a power-supply circuit having a potential to ground of more than 150 volts shall be acceptable for the maximum potential to ground of the circuit. A nominal 208 volt, single-or three-phase, or a 120/240 volt, single-phase product is considered to involve a potential to ground of less than 150 volts. A two-wire, single-phase or three-wire, three-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: This requirement does not apply to a product marked in accordance with 49.6.

19.5 If a unit "off" switch or circuit breaker is mounted such that movement of the operating handle between the "on" and "off" positions results in one position being above the other position, the upper position shall be the "on" position.

Exception: This requirement does not apply to:

a) A timer;

b) A switching device having two "on" positions (such as a double throw switch);

c) A rotationally-operated switch; or

d) A rocker switch.

20 Overcurrent Protection

20.1 A protective device, the normal functioning of which requires renewal, replacement, or resetting, shall be in a readily accessible location.

Exception: This requirement does not apply to a protective device that would ordinarily be unknown to the user because of its location and omission of reference to the device in the operating instructions, circuit diagrams, and other instruction materials provided with a battery charger.

20.2 The input circuit of a product shall be provided with overcurrent protection. The overcurrent protection shall consist of one or more circuit breakers, cartridge fuses, or Type S plug fuses of a type and rating acceptable for branch circuit protection for the circuit involved in accordance with the requirements in NFPA 70.

Exception: Input circuit overcurrent protection is not required if a statement in accordance with 49.8 is provided in the operating manual or in a marking provided on the enclosure.

20.3 A circuit breaker provided to comply with the requirement in 20.2 shall be a common trip type that automatically opens all ungrounded conductors of the input circuit under fault or overload conditions within the battery charger.

Exception: If the battery charger 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.

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20.4 A thermal cutoff or other device employed to reduce a risk of fire or electric shock due to overheating of a transformer during normal 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 UL 60691.

20.5 An acceptably rated direct-current circuit breaker or fuse or fuses shall be provided in the output circuit of the battery charger for overcurrent protection against short-circuiting of the terminals and reverse polarity connection. See 39.1 – 39.3.

Exception: A protective circuit may be used in lieu of a circuit breaker or fuse provided the charger complies with the output short circuit and reverse polarity tests under any condition of a single component open or short fault in the protective circuit.

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

20.7 If a fuseholder is accessible to the user, the fuse size shall be marked in accordance with 48.5.

20.8 An uninsulated live part of a fuseholder, other than the screw shell or clips, that may increase the risk of an electric shock shall not be exposed to contact by a person removing or replacing the fuse.

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

21 Lampholders

21.1 The screw shell of an Edison-base lampholder in a product shall be connected to a conductor that is intended to be connected to the grounded conductor of the power-supply circuit.

21.2 A lampholder shall be designed or installed so that uninsulated live parts, other than a screw shell, that present a risk of electric shock are not exposed to contact by persons removing or replacing the lamp in normal service.

22 Capacitors

22.1 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 a malfunction or breakdown of the capacitor.

22.2 The container of a capacitor shall be of metal providing strength and protection not less than that of uncoated steel having a minimum 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 the capacitor is mounted inside a product having an enclosure that complies with the requirements in 6.1 – 6.5.

22.3 A capacitor employing a dielectric medium more combustible than askarel shall be protected against expulsion of the dielectric medium under both normal and abnormal conditions of use.

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23 Printed Wiring

23.1 A printed-circuit board shall comply with the requirements in UL 796, and shall be classed V-1 or V-2 in accordance with the requirements in 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.

Exception: A printed-wiring board that contains only Class 2 circuits need not comply with UL 796, provided deterioration or breakage of the bond between the conductor and the base material would not result in a risk of fire or electric shock.

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

23.3 Consideration is to be given to a barrier or partition that is part of the product assembly and that provides mechanical protection and electrical insulation for a component connected to a printed-circuit board.

24 Spacings

24.1 General

24.1.1 The spacings for a unit shall not be less than the applicable values specified in Table 24.1 or as provided in 24.3.

Exception No. 1: This requirement does not apply when liners and barriers are used as specified in 24.2.1.

Exception No. 2: The spacing requirement does not apply between adjacent foils on printed-wiring boards provided with a conformal coating complying with the requirements in UL 746C. See 24.1.2.

Exception No. 3: On printed-wiring boards having a flammability classification of V-0 and constructed from a base material having a minimum Comparative Tracking Index (CTI) rating of 175 volts, spacings (other than spacings to ground, between primary and secondary circuits, between the battery supply circuit and other circuits, and at field wiring terminals) are not specified between traces of different potential connected in the same circuit where:

a) The spacings comply with the requirements in 39.6; or

b) An analysis of the circuit indicates that no more than 12.5 milliamperes of current flows 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 shall be 1/32 inch (0.8 mm). When these foils are in circuits described in 24.1.12 or 24.1.13, no spacing is specified.

Exception No. 5: The spacing requirements in Table 24.1 do not apply to inherent spacings of a component such as a switch, lampholder, power switching semiconductor, or a motor. See 24.1.7.

Exception No. 6: Spacings within a transformer shall be provided in accordance with Table 17.2 at locations that are not insulated, including those with film-coated magnet wire.

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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.

Table 24.1
Spacings

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]	
		Through air		Over surface		Shortest distance	
0 – 50	(0 – 70.7)	1/16[c,d]	(1.6)[c,d]	1/16[c,d]	(1.6)[c,d]	1/16[c]	(1.6)[c]
Greater than 50 to 150	(70.7 to 212.1)	1/8[c,d]	(3.2)[c,d]	1/4[d]	(6.4)[d]	1/4	(6.4)
Greater than 150 to 300	(212.1 to 424.2)	1/4	(6.4)	3/8	(9.5)	1/2	(12.7)
Greater than 300 to 600	(424.2 to 848.4)	3/8	(9.5)	1/2	(12.7)	1/2	(12.7)
Greater than 600 to 1000	(848.4 to 1414)	3/4[e]	(19.1)[e]	3/4[e]	(19.1)[e]	3/4	(19.1)

[a] For printed-wiring boards, see Exception Nos. 2 – 4 in 24.1.1.

[b] For the purpose of this requirement, a metal piece attached to the enclosure is a 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 (6.4 mm).

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

[e] Between uninsulated high-voltage parts and (1) uninsulated high-voltage parts of opposite polarity or different potentials, (2) earth-grounded metal parts, (3) uninsulated primary-circuit parts, (4) insulated primary-circuit parts, (5) insulated high-voltage parts of opposite polarity, or of different potentials.

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24.1.2 With reference to Exception No. 2 to 24.1.1 concerning conformal coatings, minimum spacings between adjacent foils are based on voltage transient and dielectric voltage-withstand tests in accordance with UL 746C. A conformal coating on a printed-wiring board shall not be used as insulation in lieu of spacings between a foil on a printed-wiring board and uninsulated live metal parts of opposite polarity or to dead metal parts.

24.1.3 Where an uninsulated live part is not rigidly secured in position by means other than friction between surfaces or where 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 shall be maintained.

24.1.4 With reference to 24.1.3, a lock washer applied as intended is a method of rigidly securing a part.

24.1.5 Inherent spacings of the components specified in Exception No. 5 of 24.1.1 shall comply with the requirements for the component in question where 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 applicable spacings specified in this Standard.

24.1.6 With respect to judging spacings, an uninsulated live part is determined to be at opposite polarity to uninsulated live parts in another circuit. Spacings shall be based on the highest of the circuit voltages.

24.1.7 Film-coated wire is an uninsulated live part when judging spacings.

24.1.8 Spacings at field-wiring terminals shall be measured with conductors installed in the terminals. The gauge of these conductors shall be based on the rating of the circuit containing the terminals.

24.1.9 Spacings between uninsulated live parts of different potential and between such parts and dead metal that are capable of being grounded in service are not specified for parts of LVLE circuits in accordance with 5.6.

24.1.10 Spacings between uninsulated live parts of different potential, and between such parts and dead metal that are capable of being grounded in service, are not specified for parts of limited-energy circuits in accordance with 5.5. Spacings in these circuits exceeding 30 volts rms (42.4 volts peak) or 60 volts, dc are judged by the applicable test described in Dielectric Voltage-Withstand Test, Section 32. Also see Section 38, Volt-Ampere Capacity Tests.

24.1.11 Spacings within the circuits described in (a) and (b) that are not safety circuits are not specified. The spacings in these circuits shall be judged on the basis of the Dielectric Voltage-Withstand Test, Section 32. Also see Section 38, Volt-Ampere Capacity Tests. Spacings between these circuits and the enclosure, grounded dead metal, and other circuits shall comply with the applicable spacing requirements.

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

b) Battery circuits at a potential of 100 volts or less. See 24.1.12.

24.1.12 With reference to 24.1.11(b), spacings within a circuit derived from a battery supply rated over 100 volts are not specified when the voltage within the circuit is limited to 100 volts or less by a regulating network complying with the requirement in 24.4.10.

24.1.13 The spacings between live and dead metal parts within an instrument shall be determined by conducting the applicable dielectric voltage-withstand test described in Dielectric Voltage-Withstand Test, Section 32.

Exception: A meter complying with the requirements in UL 1437, is not required to be subjected to a dielectric voltage-withstand test.

24.1.14 Epoxy may be used to reduce spacings only when the following conditions are met:

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

b) There are no significant voids in the epoxy;

c) The epoxy is minimum 1/32 inch (0.8 mm) thick;

d) The area of reduced spacing, with epoxy applied, withstands the applicable potential specified in the Dielectric Voltage-Withstand Test, Section 32; and

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

e) The epoxy temperature during the Temperature Test does not exceed 117 °F (65 °C) rise [based on an assumed operating ambient rating of 77 °F (25 °C)] or 194 °F (90 °C) limit (when tested at an ambient rating of greater than 25 °C).

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Exception: When the epoxy has been investigated and determined to have a higher operating temperature rating, the temperatures may be exceeded when temperatures do not exceed the material temperature rating.

24.2 Insulation barriers

24.2.1 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 24.1.1 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 UL 746C.

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

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

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

Exception No. 2: Mica equal to or more than 0.006 inch (0.165 mm) may be used as insulation between a heat sink and a live case of a semiconductor device.

24.2.2 Insulating tubing complying with the requirements in UL 224, may be used as insulation of a conductor including bus bars in lieu of the minimum spacings and capacitor case in lieu of bonding the case for grounding, only when the following conditions are met:

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

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

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

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

24.2.3 A wrap of thermoplastic tape, complying with the requirements in UL 510, meets the intent of the requirements when all of the following conditions are met:

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

b) The wrap is equal to or more than 0.028 inch (0.72 mm) thick when used in conjunction with less than one-half the required through air spacing;

c) Its temperature rating is no less than the maximum temperature observed during the temperature test.

d) The tape is not subject to compression; and

e) The tape is not wrapped over a sharp edge.

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24.3 Alternate spacings – clearances and creepage distances

24.3.1 As an alternative to the spacing requirements of 24.1, the spacing requirements in UL 840, may be used. The spacing requirements of UL 840 shall not be used for field wiring terminals and spacings to a dead metal enclosure. In determining the pollution degree and overvoltage category, the end-use application is to be taken into account and is capable of modifying those characteristics given in 24.3.2 and 24.3.3.

24.3.2 The level of pollution for indoor use equipment shall be pollution degree 2. Hermetically sealed or encapsulated enclosures, or coated printing-wiring boards in compliance with the Printed-Wiring Board Coating Performance Test in UL 840, are pollution degree 1.

24.3.3 The equipment shall be rated overvoltage category III, II, and I as defined in UL 840.

24.3.4 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.

24.3.5 All printed-wiring boards are considered to have a minimum comparative tracking index of 100 without further investigation.

24.4 Control circuits

24.4.1 A LVLE circuit as described in 5.6 or a limited-energy circuit as described in 5.5 is not prohibited from being connected to a single-point reference ground.

24.4.2 Except as indicated in 24.4.3, a LVLE circuit (see 5.6) 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 14.1 and Section 23, Printed Wiring.

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

24.4.4 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 24.4.5. Printed-wiring boards, insulated wires, and motors used in such circuits shall be types that are required for the application. See 14.1, 16.1, and 23.1.

24.4.5 Eight amperes for 0 – 42.4 volts peak ac, or 0 – 30 volts dc, or amperes equal to 150 divided by the maximum voltage for 30 – 60 volts dc. See 24.4.6.

Exception: The current values specified in 24.4.5 do not apply when the circuit includes an overcurrent protection device as described in 24.4.9.

24.4.6 With reference to the current specified in 24.4.5, the maximum current is to be measured under any condition of loading including short circuit using a resistor that is to be continuously readjusted during the 1-minute period to maintain maximum load current, and not exceeding the value indicated in 24.4.5.

24.4.7 With reference to the voltage limit specified in 24.4.5, measurement is to be made with the unit connected to the voltage specified in 27.1 and with all loading circuits disconnected. Where a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement is to be made from either end of the winding to the tap.

24.4.8 When the control circuit mentioned in 24.4.4 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

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nonadjustable manual-reset protective device, or a regulating network (see 24.4.11), the circuits in which the current is limited in accordance with 24.4.9 or 24.4.10 are not required to be investigated.

24.4.9 A fuse or circuit-protective device provided in the control circuit used to limit the current in accordance with 24.4.8 shall be rated or set at not more than the values specified in Table 24.2.

Table 24.2
Rating for Secondary Fuse or Circuit Protector

Circuit voltage (Volts, rms)	Maximum overcurrent protection (Amperes)
20 or less	5
More than 20 but not greater than 60	100/V[a]
[a] V is the maximum output voltage, regardless of load, with the primary energized.	

24.4.10 One or more resistors or a regulating network used to limit the current in accordance with 24.4.8 shall be such that the current under any condition of load including short circuit does not exceed the values indicated in 24.4.5.

24.4.11 Where a regulating network is used to limit the voltage or current in accordance with 24.4.4 – 24.4.10, the performance shall not be affected by malfunction, either short circuit or open circuit, of any single component – excluding a resistor.

24.4.12 In a circuit of the type described in 24.4.8, 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 investigated in accordance with the applicable requirements in this Standard.

25 Grounding

25.1 A product intended to be connected to the power supply by a metal-enclosed wiring system such as rigid metal conduit or armored cable, or intended to be connected by a means other than a metal-enclosed wiring system, such as non-metallic-sheathed cable shall have a terminal or lead for connecting the metal enclosure and enclosure parts to the equipment-grounding conductor.

25.2 The surface of the insulation on a lead intended for the connection of a grounding conductor shall be green with or without one or more yellow stripes, and no other lead shall be so identified.

25.3 A wire-binding screw intended for the connection of a field-installed equipment grounding conductor shall have a green colored head that is hexagonal, slotted, or both. A pressure wire connector or a stud-and-nut-type terminal intended for connection of such a conductor shall be plainly identified by:

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

b) A wiring diagram attached to the product; or

c) The grounding symbol illustrated in Figure 25.1, on or adjacent to the terminal, or on a wiring diagram provided on the product.

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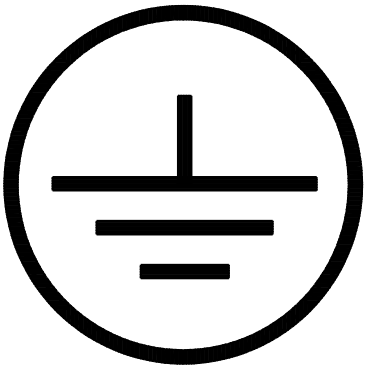
Figure 25.1

Grounding Symbol



IEC417, Symbol 5019

25.4 The grounding connection shall be located so that it is unlikely to be removed during normal servicing of the product.

25.5 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.

25.6 A terminal solely for connection of an equipment-grounding conductor shall secure a conductor of the size acceptable for the application, in accordance with NFPA 70.

25.7 The grounding conductor of a power-supply cord shall be connected to the grounding blade of a grounding attachment plug and shall be connected to dead metal parts within the frame or enclosure by means of a screw or by an equivalent means that is not likely to be removed during any servicing operation not involving the power-supply cord. Solder alone shall not be used for securing the grounding conductor.

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

26 Bonding of Internal Parts

26.1 With reference to 25.3, in a product all exposed dead metal parts and all dead metal parts inside the enclosure shall be conductively connected to the field-equipment grounding means if the parts are exposed to contact:

a) During normal operation or adjustment of the charger; or

b) During any servicing operation including maintenance and repair that are likely to become energized through electrical fault.

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26.2 Uninsulated metal parts of the enclosure, motor frames and mounting brackets, component mounting brackets, capacitors, and other electrical components shall be bonded for grounding if they may be contacted by the user or serviceman.

Exception: This requirement does not apply to the following metal parts:

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

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

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

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

26.3 Metal-to-metal hinge bearing members may be considered as a means for bonding the door for grounding.

26.4 If the continuity of the grounding system relies on the dimensional integrity of a nonmetallic material, the material shall be acceptable for the purpose when investigated for dimensional stability.

26.5 Other than as noted in 26.6, the circuitry shall be arranged so that the equipment-grounding connection or conductor, the enclosure, the frame, the component mounting panel, and the earth ground do not carry current except during an electrical fault.

26.6 A single-point reference ground may be employed in a low-voltage or isolated-limited-secondary circuit. The enclosure, frame, or panel, including bolted joints, may carry the current of a low-voltage circuit. In neither of these instances is such current to be carried through the field-equipment grounding means, the metallic raceway or other power-supply grounding means, or the earth ground. See 24.4.1.

26.7 A separate component bonding conductor shall be of copper, a copper alloy, or other materials acceptable for use as an electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by enameling, galvanizing, plating, or equivalent means. A separate bonding conductor or strap shall:

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

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

26.8 The bonding shall be by a positive means, such as by clamps, rivets, bolted, or screwed connections, or by welding, soldering, or brazing with materials having a softening or melting point greater than 455 °C (850 °F). The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material, other than as indicated in 26.9.

26.9 A connection that depends upon the clamping action exerted by rubber or similar material may be acceptable if it complies with Section 44, Bonding Conductor Test, for bonding conductors under any normal degree of compression permitted by a variable clamping device and if the results are still

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acceptable after exposure to the effects of oil, grease, moisture, and thermal degradation that are likely to occur in service. Also, the effect of assembling and disassembling, for maintenance purposes, such a clamping device is to be considered with particular emphasis on the likelihood of it being reassembled in its intended position.

26.10 On a permanently connected or cord-connected product, the size of a conductor or a strap employed to bond an electrical enclosure or motor frame shall be based on the rating of the branch-circuit overcurrent device to which the product will be connected. The size of the conductor or strap shall be in accordance with Table 26.1.

Exception: A smaller conductor or strap may be used if it complies with the Grounding Impedance Test, Section 37.

Table 26.1
Bonding Wire Conductor Size

Rating of overcurrent device, amperes	Size of bonding conductor[a]			
	Copper wire		Aluminum wire	
	AWG	(mm^2)	AWG	(mm^2)
15	14	(2.1)	12	(3.3)
20	12	(3.3)	10	(5.3)
30	10	(5.3)	8	(8.3)
40	10	(5.3)	8	(8.3)
60	10	(5.3)	8	(8.3)
100	8	(8.3)	6	(13.3)

[a] Or equivalent cross-sectional area.

26.11 The resistance between two parts connected by a bonding conductor shall not be more than 0.1 ohm.

26.12 A bonding conductor to a component, device, or electrical enclosure is not required to be larger than the size of the conductors supplying power to the component or components within the enclosure.

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

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PERFORMANCE

27 General

27.1 A representative sample of a product shall be subjected to the tests described in Sections 27 – 44. Unless otherwise specified, all tests are to be conducted at the voltage specified in Table 27.1. A product rated 50 – 60 hertz is to be tested at 60 hertz.

Table 27.1
Values of Test Voltages

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

28 Leakage Current Test

28.1 The leakage current of a cord-connected power unit when tested in accordance with 28.2 – 28.6 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 having primary-circuit filtering shall have higher leakage current levels at accessible parts, only when 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 25, Grounding; or

b) Leakage current does not exceed 5 percent of the input current determined in accordance with Section 29, Power Input Test, and all of the following conditions are met:

1) The unit complies with the grounding requirements in Section 25, Grounding;

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

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

28.2 All exposed conductive surfaces are to be tested for leakage currents. The leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one surface to another if simultaneously accessible. Parts are considered to be exposed surfaces unless guarded by an enclosure considered acceptable as defined in 7.2 to reduce the risk of an electric shock. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply between output terminals operating at voltage less than 30 volts rms – 42.4 volts peak.

28.3 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 by 20 centimeters in contact with the surface. If the surface has an area less than 10 by 20 centimeters, the metal foil is to be the same size

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as the surface. The metal foil is not to remain in place long enough to affect the temperature of the product.

28.4 The circuit for the leakage-current measurement is to be as illustrated in Figure 28.1. The measurement instrument is defined in (a) – (c). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument. The meter used need not have all the attributes of the defined instrument.

a) The meter is to have an input impedance of 1500 ohms resistance 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 to have an error of not more than 5 percent at 60 hertz.

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

28.6 A sample of the product is to be tested for leakage current starting with the as-received condition – the as-received condition is without prior energizing, 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 voltage specified in Table 27.1. The test sequence, with reference to the measuring circuit, Figure 28.1, is to be as follows:

a) With switch S1 open, the product 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 product switching devices in all their normal operating positions.

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

c) The leakage current is to be monitored, using both positions of switch S2, until thermal stabilization is attained by operating the product as in the temperature test.

28.7 Normally the complete leakage current test program as described in 28.6 is to be conducted without interruption for other tests. With the concurrence of those concerned, the leakage current test may be interrupted to conduct other nondestructive tests.

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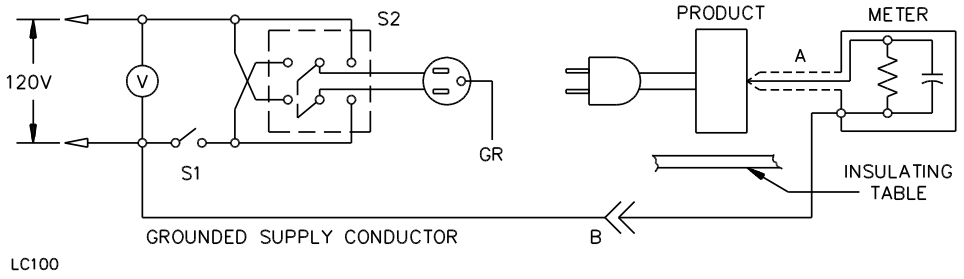
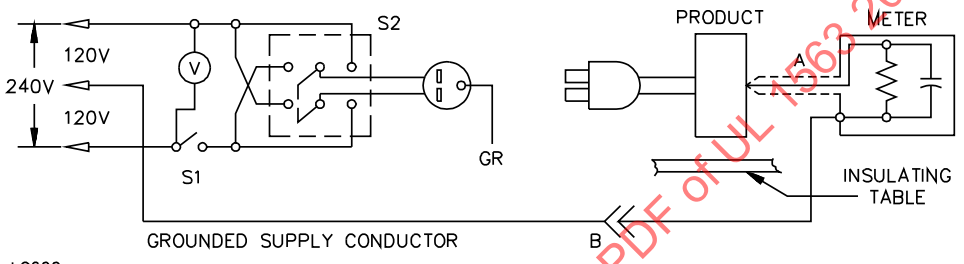
Figure 28.1

Leakage-Current Measurement Circuits



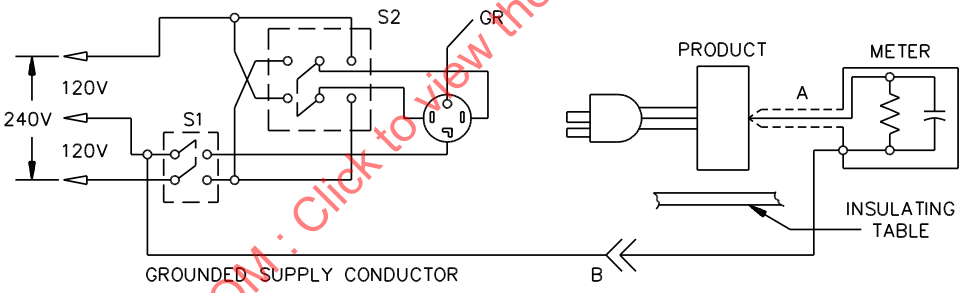
LC100

Product intended for connection to a 120 volt power supply.



LC200

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



LC300

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

NOTE:

a – Probe with shielded lead.

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

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29 Power Input Test

29.1 The input current and power factor to a product is to be measured with the charger operating while connected to the maximum rated load. The current input shall not be more than 110 percent of the rated value.

29.2 A product having an output rating of more than 20 amperes and intended to charge lead-acid storage batteries is to be tested with:

a) A resistive-capacitive (rc) load having capacitance of 100,000 microfarads;

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

c) An acceptable battery if requested by the manufacturer.

29.3 With reference to 29.2(c), if a product is to be tested using a battery or batteries as the load, the size of the battery is to be of the size indicated by the 8 hour rating marked on the product's nameplate. The battery is to be connected to the proper load and then discharged to 1.70 volts per cell at a rate not exceeding the discharge rate assigned by the battery manufacturer, and not exceeding one-sixth of the ampere-hour capacity of the battery.

29.4 Output current measurements of either half-wave or full-wave rectified circuits are to be based on the average current.

30 Temperature Test

30.1 A product, tested as described in 30.2 – 30.11, using a load adjusted to the rated maximum load current as described in 30.2 and 30.3, shall not reach a temperature at any point high enough to cause a risk of fire, damage to any material used, or exceed the temperature rises specified in Table 30.1.

Table 30.1
Maximum Acceptable Temperature Rises

Materials and components	°C	(°F)
1. A surface upon which a permanently connected product may be mounted in service, and surfaces that may be adjacent to the product when so mounted	65	(117)
2. Any point on or within a terminal box or compartment of a permanently connected product on which field-installed conductors to be connected may rest	35	(63)
3. Class 105 coil insulation systems of a relay, a solenoid, or the like:		
Thermocouple method	65[a]	(117[a])
Resistance method	85	(153)
4. Class 130 coil insulation systems of a relay, a solenoid, or the like:		
Thermocouple method	85[a]	(153[a])
Resistance method	100	(180)
5. Class 105 transformer insulation systems:		
Thermocouple method	65[a]	(117[a])
Resistance method	70	(126)
6. Class 130 transformer insulation systems:		
Thermocouple method	85[a]	(153[a])

Table 30.1 Continued on Next Page

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Table 30.1 Continued

Materials and components	°C	(°F)
Resistance method	95	(171)
7. Class 155 transformer insulation systems:		
Thermocouple method	110	(198)
Resistance method	115	(207)
8. Class 180 transformer insulation systems:		
Thermocouple method	125	(225)
Resistance method	135	(243)
9. Class A motor coil insulation systems:		
a) In an open motor:		
Thermocouple method	65[a]	(117[a])
Resistance method	75	(135)
b) In a totally enclosed motor:		
Thermocouple method	70[a]	(126[a])
Resistance method	80	(144)
10. Class B motor coil insulation systems:		
a) In an open motor:		
Thermocouple method	85[a]	(153[a])
Resistance method	95	(171)
b) In a totally enclosed motor:		
Thermocouple method	85[a]	(153[a])
Resistance method	100	(180)
11. Varnished-cloth insulation	60	(108)
12. Fiber employed as electrical insulation	65	(117)
13. Phenolic composition employed as electrical insulation or as a part the deterioration of which would result in a risk of fire or electric shock	125[b]	(225[b])
14. Wood and other combustible material	65	(117)
15. Rubber- or thermoplastic-insulated wire and cord	35[b,c,d]	(63[b,c,d])
16. Fuse	65[e]	(117[e])
17. Capacitor:		
Electrolytic	40[f]	(72[f])
Other than electrolytic	65[g]	(117[g])
18. Sealing compound	h	(h)
19. Selenium rectifier	50[i,j]	(90[i,j])
20. Silicon rectifier	75[j]	(135[j])

[a] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature rise measured by means of a thermocouple may be 5 °C (9 °F) higher than that specified, if the temperature rise of the coil as measured by the resistance method is not more than that specified.

[b] 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.

[c] The temperature rise of rubber-insulated conductors within a Class A insulated motor and rubber-insulated motor leads, and a rubber-insulated flexible cord entering a motor may be more than 35 °C (63 °F), provided that an acceptable braid is employed on the conductors of other than a flexible cord. This does not apply to thermoplastic-insulated wires or cords.

Table 30.1 Continued on Next Page

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Table 30.1 Continued

Materials and components	°C	(°F)
[d] A short length of rubber- or thermoplastic-insulated flexible cord inside the product may be exposed to a temperature of more than 60 °C (140 °F) if supplementary insulation acceptable for the measured temperature and of acceptable dielectric properties is employed on each individual conductor. *Exception: A flexible cord having a temperature rating greater than 60 °C may be exposed to a corresponding higher temperature.*		
[e] A fuse that has been investigated and found acceptable for use at a higher temperature may be used at that temperature.		
[f] For an electrolytic capacitor that is integral with or attached to a motor, the temperature rise on insulating material integral with the capacitor enclosure may be not more than 65 °C (117 °F).		
[g] A capacitor that operates at a temperature rise of more than 65 °C (117 °F) may be judged on the basis of its marked temperature limit.		
[h] Except for a thermosetting compound, the maximum sealing compound temperature, when corrected to a 25 °C (77 °F) ambient temperature, is 15 °C (27 °F) less than the softening point of the compound as determined in accordance with ASTM E28.		
[i] A temperature rise of 60 °C (108 °F) is acceptable if the stack assembly is insulated with phenolic composition or other insulating material acceptable for a temperature of 150 °C (302 °F).		
[j] The limitation does not apply to a material that has been investigated and found acceptable for a higher temperature.		

30.2 With reference to 29.1, if the load is comprised of a battery supplemented with a resistive load in accordance with 29.2(b), the manufacturer shall provide the characteristic charge curve for the product. The resistor is to be adjusted throughout the charging period so that the current follows the characteristic charge curve during the temperature test.

30.3 With reference to 30.2, in the temperature test of a product using a battery load, the battery shall be discharged as indicated in 29.3 then charged until temperatures on the product reach a maximum and begin to decrease. The temperature test is then to be continued using a second battery, also discharged as indicated in 29.3, until maximum temperatures are attained. A product provided with a timer and a marked charging time based on the ampere-hour capacity of the battery is to be tested for the marked time period.

Exception: A second battery is not used for products which provide a constant charging current or have a marked charging time such that only one battery can be charged during an 8-hour period.

30.4 An automatic protector or other recycling device is not to operate during the normal temperature test.

30.5 A product designed for mounting or support in more than one position, or in a confined location, is to be tested in a manner representing the most severe conditions. An adjacent mounting or supporting surface is to consist of 1-inch thick, soft-pine boards.

30.6 All values of temperature rise in Table 30.1 are based on an assumed ambient temperature of 25 °C (77 °F). However, tests may be conducted at any ambient temperature within the range of 10 – 40 °C (50 – 104 °F).

30.7 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.

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

30.8 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, 225.0 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.

30.9 Thermocouples are to consist of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). 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 specified in the "Tolerances on Initial Values of EMF versus Temperature" tables in ASTM E230.

30.10 A thermocouple junction and adjacent thermocouple lead wires are to be securely held in thermal contact with the surface of the material being measured. In most cases, adequate thermal contact results from securely taping or cementing the thermocouple in place, but if a metal surface is involved, brazing or soldering of the thermocouple to the metal may be necessary.

30.11 For a test that is to be continued until constant temperatures are attained, thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 5 minutes, indicate no further increase.

31 Intermediate Abnormal Test

31.1 A product tested using a battery as a load as described in 30.3 shall be subjected to an intermediate abnormal test described in 31.2 immediately following the temperature test. The product shall not emit flame or molten metal or result in a risk of fire or electric shock during the test. The test is to be followed by a dielectric voltage-withstand test, as required by 32.1.1(a), applied between the primary and secondary windings of the transformer.

Exception: A product that is current limited during normal charging is not required to be subjected to a continuous load test.

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31.2 The rated output current of the product is to be continuously maintained by an adjustable resistor connected in parallel with the battery. The test is to be continued:

a) Until ultimate conditions are observed;

b) For 7 hours if cycling of an automatically reset protector occurs; or

c) For 50 cycles of resetting a manually reset protector.

32 Dielectric Voltage-Withstand Test

32.1 General

32.1.1 A product shall withstand for 1 minute without breakdown the application of a 40 to 70 hertz essentially sinusoidal potential with the product at the maximum operating temperature:

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

1) The primary circuit and dead metal parts;

2) The primary and secondary circuits; and

3) All secondary windings, including any ferro-resonant windings.

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

c) Five hundred volts between a secondary circuit operating at 50 volts or less and dead metal parts; 1000 volts plus twice the maximum rated secondary circuit voltage between a secondary circuit, including any ferro-resonant windings, operating at more than 50 volts and dead metal parts.

d) One thousand volts plus the rated voltage of a capacitor between the terminals of a capacitor used for radio-interference elimination or arc suppression.

As an alternative, testing may be conducted using a direct current potential equal to the peak of the specified sinusoidal potential (1.414 times the sinusoidal rms value).

32.1.2 To determine whether a product complies with the requirements in 32.1.1, it is to be tested using a source of 500-volt-ampere capacity or larger, having an output voltage that 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 and as rapid as is consistent with correct indication of its value by a voltmeter.

32.2 Induced potential

32.2.1 If a bobbin-wound transformer is required to be tested as provided in note (l) of Table 17.1 and item (d) of Exception to 17.2.3, after constant temperatures have been reached as the result of operation under the conditions specified in Temperature Test, Section 30, each of three separate samples of the transformer shall withstand without breakdown an induced potential test in accordance with 32.2.2 and 32.2.3.

32.2.2 While still heated, the primary winding is to be subjected to an alternating potential of twice the rated voltage at any acceptable frequency – typically 120 hertz or higher – for 7200 electrical cycles or for 60 seconds, whichever is less. The required test voltage is to be obtained by starting at one-quarter or less of the full value and increasing to the full value in not more than 15 seconds. After being held for the time

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specified, the voltage is to be reduced within 5 seconds to one-quarter or less of the maximum value, and the primary-winding circuit is to be opened.

32.2.3 An oven may be used to condition the samples to the temperature attained under the conditions specified in 32.2.1 and 32.2.2 before conducting the test described in those paragraphs.

33 Humidity Conditioning

33.1 A product shall be conditioned for 24 hours in moist air having a relative humidity of 85 ±5 percent at a temperature of 32.0 ±2.0 °C (89.6 ±3.6 °F). After the conditioning:

a) A cord-connected product rated for a nominal 120-volt supply shall comply with Leakage-Current Test, Section 28. The circuit illustrated in Figure 33.1 shall be used in this tests, which may be discontinued when the leakage current stabilizes.

b) A product other than as mentioned in (a) shall have an insulation resistance of 50,000 ohms or more between live parts and interconnected dead metal parts.

c) All products shall withstand without breakdown for 1 minute the application of a 40 to 70 hertz essentially sinusoidal potential of 1000 volts, or a direct current potential of 1414 volts, between live parts and interconnected dead metal parts.

33.2 Before conducting the leakage-current measurements described in 33.1 using the circuit illustrated in Figure 33.1, the product is to be disconnected from the receptacle and it is to be determined that stray currents are negligible by closing switch S1, utilizing both positions of switch S2, and observing the stray leakage on the meter.

33.3 The isolation transformer in this circuit is provided to reduce the risk of electric shock to personnel conducting the test.

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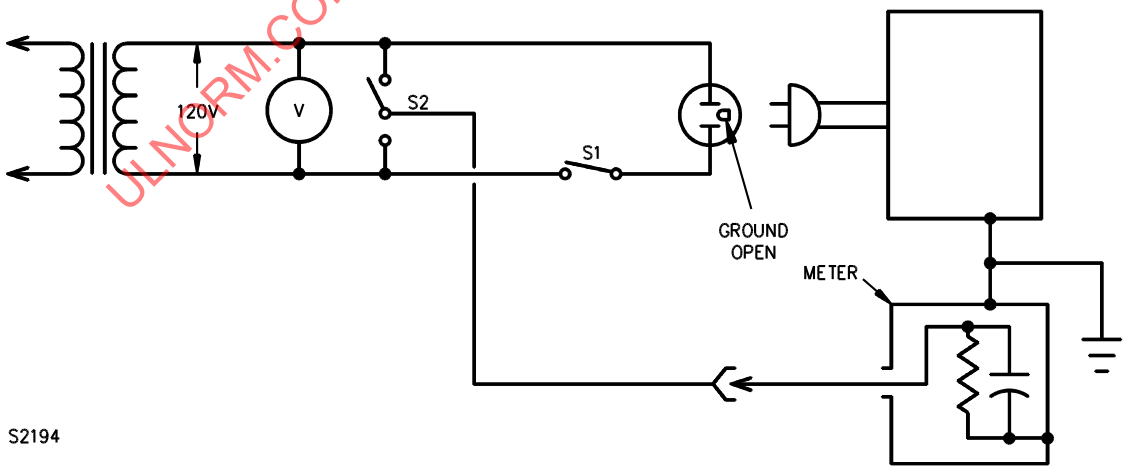
Figure 33.1

Circuit for Measuring Leakage Current After Humidity Conditioning



34 Strain Relief Test

34.1 The strain relief means specified in 11.2.1 shall withstand for 1 minute without displacement a direct pull of 35 pounds (156 N) applied to the cord, as described in 34.2, with the connections in the product

disconnected. The strain relief is not acceptable if, at the point of disconnection of the conductors, there is such movement of the cord or lead as to indicate that stress on the connections have resulted.

34.2 A 35-pound (16 kg) weight is to be suspended from the cord and supported by the product so that the strain relief means is stressed from any angle the construction of the product permits.

35 Push-Back Relief Test

35.1 To determine compliance with 11.2.3, a product shall be tested in accordance with 35.2 without occurrence of any of the conditions specified in or 11.2.3 (a) – (d).

35.2 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 11.2.3.

36 Overload Test

36.1 If tests are required, a switch or other control device shall be subjected to the overload test without electrical or mechanical malfunction or breakdown. The performance is unacceptable if:

a) The fuse in the grounding connection opens during the test;

b) There is welding of contacts or mechanism breakdown; or

c) The device is otherwise incapable of completing the test.

36.2 To determine if a primary-circuit device performs acceptably while controlling its load, the product is to be connected to a grounded supply with the rotor of a motor locked in position and with the output load adjusted to 150 percent of the rated value. During the test, exposed dead metal parts of the product 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 connected in the ungrounded conductor of the supply circuit. The device is to be operated for 50 cycles 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.

36.3 To determine if a secondary-circuit switch or other control device mentioned in the Exception to 19.1 complies with the requirements in the overload test, the product is to be connected to a supply circuit of rated frequency and maximum test voltage – see Table 27.1. The device is to be caused to make and break 150 percent of the rated secondary-load current. During the test, exposed dead metal parts of the product are to be connected to the polarity opposite to the switching devices through a 3-ampere plug fuse. The test is to be conducted as described in 36.2.

37 Grounding Impedance Test

37.1 The impedance at 60 hertz between the point of connection of the equipment-grounding means and any other metal part that is required to be grounded (see Section 25, Grounding) shall not be more than 0.1 ohm when measured in accordance with 37.2.

37.2 Compliance with 37.1 is to be determined by measuring the voltage when a current of 25 amperes derived from a 60 hertz source with a no-load voltage not exceeding 6 volts is passed between the grounding connection and the metal part in question.

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38 Volt-Ampere Capacity Tests

38.1 Isolated-limited-power circuit

38.1.1 The continuous-use capacity of an isolated-limited-power circuit shall not exceed 100 volt-amperes when energized from a circuit of rated frequency at the normal test voltage specified in Table 27.1.

38.2 Single-wound secondary transformer

38.2.1 The temperature rise of the enclosure, core, or coil of a single-wound secondary transformer shall be at least 50 °C (90 °F) when the secondary is loaded to the maximum output obtainable or 100 volt-amperes, whichever is less.

38.3 Multisecondary transformer

38.3.1 Each secondary winding of a multisecondary transformer is to be loaded in turn with a variable resistor. Starting with a cold transformer for each part of the test, the load resistance is to be decreased from open-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 outputs obtained by this method shall not exceed:

a) 350 volt-amperes for 0 – 15 volts;

b) 250 volt-amperes for 15.1 – 30 volts; and

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

39 Abnormal Operation Tests

39.1 General

39.1.1 A product shall not emit flame or molten metal or result in a risk of fire or electric shock when subjected to the tests described in 39.2 – 39.6. After each test the product shall comply with the dielectric voltage-withstand test as required by 32.1.1(a), applied between the transformer primary and secondary windings and between the primary winding and accessible dead metal parts.

39.1.2 During each test:

a) The enclosure of the product is to be connected directly to ground;

b) The product is to rest on a soft-pine surface covered with white tissue paper; and

c) A double layer of cheesecloth is to be draped over the product.

Exception: A product with a nonmetallic enclosure without exposed dead metal parts need not be grounded.

39.1.3 For a product having multitap positions for adjustment of the output-charging rate, the tests required by 39.1.1 are to be conducted at more than one setting of output-voltage or -current rating or both, to represent the most severe operating condition.

Exception No. 1: Test may be conducted at only one position if that position represents the most severe condition.

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Exception No. 2: A product having fixed tap positions that are used for alternate input-voltage ratings need only be tested at the position indicated.

39.1.4 A separate sample is to be used for each test unless the manufacturer requests that a single sample be subjected to more than one test.

39.1.5 An abnormal operation test may be concluded by the opening of branch-circuit overcurrent protection if the product is marked in accordance with 49.8.

39.2 Output short-circuit

39.2.1 The product is to be tested as described in 39.2.2. The product shall comply with the requirement in 39.1.1 and upon completion of the test the protector contacts shall be operative.

39.2.2 With reference to 39.2.1, fuses and other protective devices provided as part of the product are to remain in the circuit, except that a polarity-protection circuit that prevents output-current flow until a battery is correctly connected to the output is to be made inoperative to permit the required output-current flow. The output connections of the product are to be short-circuited and the charger connected to a source of supply adjusted to its highest test voltage – see Table 27.1. The test is to be continued until the internal protection opens, constant temperatures are attained, or the transformer winding opens. If an automatically reset protector is provided, the test is to be continued for 7 hours. If a manually reset protector is provided the test is to be continued until the protector operates for 50 cycles.

39.3 Reverse polarity

39.3.1 The external output leads are to be connected in reverse polarity to an acceptable fully-charged, lead-acid battery. The product is then to be connected to its maximum test voltage – see Table 27.1 – and operated until the ultimate condition is observed, or 4 hours if cycling of an automatically reset protector occurs. Fuses and other protective devices provided as part of the product are to remain in the circuit.

39.4 Blocked rotor fan

39.4.1 A product having a fan motor is to be operated as in the normal temperature test for 7 hours except the rotor of the fan motor is to be blocked.

39.5 High voltage

39.5.1 A product that is intended for operation with two or more supply-voltage levels or with a varying number of battery cells or both, shall be connected in such a way as to produce the most adverse conditions when connected to the highest alternating-current input voltage specified for the charger. For example, 440 volts plus 10 percent on a 220-volt tap with the product connected for 12-cell charging to a six-cell battery. The product is to be connected to a discharged battery, all normally supplied protective devices are to be left in the circuit, and the product is then to be energized. The test is to be continued until the internal protection opens, constant temperatures are attained, or the circuitry opens. If an automatically reset protector is provided, the test is to be continued for 7 hours. A manually reset protector is to be operated for 50 cycles.

39.6 Evaluation of reduced spacings on printed-wiring boards

39.6.1 In accordance with (a) in Exception No. 3 to 24.1.1, printed-wiring board traces of different potential having reduced spacings shall be judged by conducting a shorted trace test described in 39.6.2.

39.6.2 Printed-wiring board traces mentioned in 39.6.1 are to be short-circuited, one location at a time, and the test is to be conducted as described in 39.1.1 – 39.1.4. As a result of this test:

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a) The overcurrent protection associated with the branch circuit to the unit shall not open; and

b) A wire or a printed-wiring board trace shall not open.

When the circuit is interrupted by opening of a component, the test is to be repeated twice using new components, as required.

Exception: Opening of an internal overcurrent protective device is a test result that eliminates the need for the test being repeated.

40 Burnout Test

40.1 General

40.1.1 A product shall not emit flame or molten metal or result in a risk of fire or electric shock while operating as described in the temperature test, except under the burnout conditions described in 40.2.1. With reference to 40.3.1, the burnout test of the transformer shall be followed by a dielectric voltage-withstand test, as required by 32.1.1(a), applied between the primary and secondary windings of the transformer and between the primary winding and accessible dead metal parts of the transformer.

40.1.2 For a product having multitap positions, the tests described in 40.1.1 shall be conducted at more than one setting of output-voltage or current rating or both, to represent the most severe operating condition.

Exception: Tests may be conducted at only one position if that position represents the most severe condition.

40.1.3 A burnout test may be concluded by the opening of branch-circuit overcurrent protection if the product is marked in accordance with 49.8.

40.2 Relay and solenoid burnout

40.2.1 An electromagnetic relay or a solenoid having an open-coil construction is to be tested by blocking the armature or the plunger in the de-energized position. The product is then to be operated until burnout of the coil occurs or the temperatures become constant. During the test, the product enclosure is to be connected directly to ground.

40.3 Transformer burnout

40.3.1 A resistive load that causes the primary to draw three times the alternating current obtained during normal operation – see 29.1 and Table 27.1 – is to be connected directly to the transformer secondary winding with the product connected to a supply circuit at 100 percent of the maximum test voltage – see Table 27.1. For a transformer having a center tap secondary, a single load is to be connected across the legs of the winding that result in the greatest potential. During the test, the product enclosure is to be connected directly to ground. The transformer is to be operated continuously:

a) Until the ultimate conditions are observed;

b) For 7 hours if cycling of an automatically reset protector occurs; or

c) For 50 cycles of resetting a manually reset protector.

Exception No. 1: The test need not be conducted if over-current protection rated at least 125 percent, but not exceeding 150 percent, of the rated input current is provided by:

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a) Internal input-circuit protection; or

b) Branch-circuit protection as marked on the product in accordance with 49.8.

Exception No. 2: A transformer employed in a switch-mode inverter or converter circuit may be subjected to the transformer overload test described in 40.3.5 in lieu of the transformer burnout test.

40.3.2 The overcurrent protection specified in the Exception to 40.3.1 shall not trip the three successive on-off operations of the product at intervals of not more than 5 seconds under full-load conditions.

40.3.3 A ferro-resonant transformer is to be tested as described in 40.3.1, except that a resistive load that draws the maximum power input – see Power Input Test, Section 29 – is to be connected directly to the transformer secondary winding, with the product connected to a supply circuit at 106 percent of the maximum test voltage specified in Table 27.1.

40.3.4 A transformer supplying a low-voltage circuit as described in 24.4.1 is to be tested in the same manner as a Class 2 transformer, with low-voltage wiring terminals short-circuited, and wiring not conforming to 14.1 short-circuited. A transformer supplying an isolated-limited-power circuit as described in 24.4.1 is to be tested with all secondary windings directly short-circuited. If a portion of an isolated-limited-power circuit is connected to low-voltage, field-wiring terminals, separate samples are to be subjected to the Class 2 transformer test and the shorted-secondary test.

40.3.5 In reference to Exception No. 2 to 40.3.1, 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.

41 Fifteen-Day Abnormal Tests

41.1 If a transformer is required to be tested as specified in (c) of the Exception to 17.2.3, the transformer shall comply with the 15-day abnormal-operation tests described in this Section. The abnormal tests may be conducted with:

a) A protective device built into the transformer;

b) Input-circuit overcurrent protection if connected in series with the transformer winding;

c) Output-circuit overcurrent protection if connected directly to the transformer winding; or

d) Branch-circuit over-current protection if the product is marked in accordance with 49.8.

41.2 For the purposes of these requirements, each secondary winding tap other than a center tap and each primary winding tap designed to supply power to a load are considered to be the equivalent of a secondary winding.

41.3 For the sequence of tests described in 41.5, if an abnormal-operation test continues for 15 days without a winding or a protective device opening, the remaining tests need not be conducted. For example, if the test described in 41.5(a) continues for 15 days, the tests described in items (b) and (c) are not required to be conducted.

41.4 A transformer shall operate for 15 days with the secondary winding loaded to rated current.

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41.5 A risk of fire or electric shock shall not result from:

a) Short circuiting the secondary winding;

b) Loading the secondary winding to a current equal to the rated current plus X percent of the difference between the short-circuit current and the rated current – Where X equals 75, 50, 25, 20, 15, 10, and 5 respectively; and

c) Loading the secondary winding to the rated current.

41.6 To determine whether a transformer complies with the requirement in 41.5, one separate sample is to be subjected to each condition described in 41.5 (a) – (c). For a transformer that employs more than one secondary winding, each of the secondary windings is to be loaded for each condition specified in 41.5 with the other windings loaded to rated current. The test conditions are to be as specified in 41.7 – 41.15.

41.7 To determine the short-circuit current value for conducting the tests described in 41.5 (b) and (c), the transformer is to be at room temperature at the beginning of the measurement, and the short-circuit current is to be measured approximately 1 minute after the voltage is applied to the primary winding. A protective device outside the transformer, if provided by the manufacturer, is to be short-circuited during the measurement of the short-circuit current. If the line fuse or transformer winding opens within 1 minute after the application of the primary voltage, the short-circuit current is considered to be that value recorded just before the line fuse or winding opens. The short-circuit current of any one winding is to be measured with the other secondary windings open-circuited.

41.8 For the loading conditions, a variable resistor is to be connected across the secondary winding. The tests described in 41.5 (a) – (c) are to be continued for 15 days unless a winding of the transformer or a protective device opens in a shorter time. In conducting the tests described in 41.5 (b) and (c), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, if necessary, 1 minute after voltage is applied to the primary winding.

41.9 If short-circuiting the secondary winding causes one of the windings to open before 15 days, then the next test in the sequence described in 41.5 (b) and (c) that continues for 15 days is to have a variable load resistor reduced to zero impedance at the end of the 15 days. This is to cause the transformer to burn out if this condition can occur as a result of a secondary-winding short circuit.

41.10 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 41.5 (a) – (c) is to be discontinued if the protective device opens the circuit and the next test in the sequence is to be started. This procedure is to be continued until a condition specified in 41.5 (a) – (c) is reached that allows the circuit to hold for 15 days. An automatically reset protective device is to be tested in the same manner.

41.11 If a protective device opens the circuit or a winding on any sample opens during the 15-day abnormal-operation tests while the samples are unattended, the variable resistor load on the other samples is to be increased, by reducing the resistance, until the protective device opens the circuit or the winding opens, so that the samples may be subjected to the dielectric voltage-withstand test described in 41.15 while in a heated condition.

41.12 Samples for the 15-day abnormal operation tests are to be prepared as follows:

a) The transformer is to be mounted in the product enclosure as intended and the enclosure is to be placed on a softwood surface covered with white tissue paper or cheesecloth.

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b) Exposed dead metal parts and one end of each secondary winding are to be connected to ground through a 1-ampere nontime-delay fuse, unless such a connection may create a condition that is not likely under single-fault conditions.

c) A single layer of cheesecloth is to be draped loosely over the product enclosure.

d) The product is to be connected to a supply circuit, as specified in 27.1, that is fused in accordance with 17.1.1.

e) All secondary windings are to be loaded to rated current before the abnormal condition is introduced; and the loads, other than that connected to the winding to be overloaded, are not to be readjusted thereafter.

41.13 Each 15-day abnormal-operation test is to be continued until a risk of fire develops, the circuit under test burns open, or 15 days have passed.

41.14 The results of the test are not acceptable if the cheesecloth or tissue paper glows or flames, the 1-ampere fuse opens, or a breakdown occurs when the test described in 41.15 is conducted.

41.15 While still in a heated condition from the tests described in 41.5, a transformer shall withstand the Dielectric Voltage-Withstand Test described in 32.1.1 (a) and (c). The dielectric voltage-withstand test potential is to be applied to the transformer approximately 1 minute after completion of the abnormal operation test.

42 Strength and Rigidity Tests

42.1 General

42.1.1 There shall not be a reduction of spacings beyond the minimum acceptable level or exposure of a live part that presents a risk of electric shock when a product is subjected to the tests described in 42.2 – 42.4. The tests described in 42.3 and 42.4 apply only to single-circuit industrial truck battery chargers, and the tests are to be on a completely assembled and packaged charger. The rod described in 7.2 is to be used to determine whether a live part that presents a risk of electric shock is exposed.

42.2 Impact test

42.2.1 A sheet-metal enclosure having a thickness less than that required by 6.3 – 6.8 is to be subjected to an impact of 5 foot-pounds (6.78 J) using a 2-inch (50.8-mm) diameter steel ball.

42.3 Drop test

42.3.1 A product shall be placed on a concrete surface, and the longest edge shall be raised 6 inches (152.4 mm) as the product is tilted. The product shall then be allowed to fall freely onto the concrete surface. The entire product shall then be raised 2 inches (50.8 mm) in an upright position and allowed to fall freely onto the concrete surface.

42.4 Tip-over test

42.4.1 A product shall be placed on a concrete surface and the front bottom edge raised until the product tips over. The product shall be allowed to fall freely onto the concrete surface.

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43 Permanence of Marking

43.1 A marking that is required to be permanent shall be molded, die-stamped, paint-stenciled, stamped, etched on metal, or another method that is permanently secured; or be a pressure-sensitive label secured by adhesive that complies with the requirements in UL 969.

44 Bonding Conductor Test

44.1 A bonding conductor that does not comply with the requirement in 26.9 is acceptable if:

a) The bonding conductor does not open when carrying for the time specified in Table 44.1 a current that equals twice the branch-circuit overcurrent-device rating – see 44.3 – but not less than 40 amperes; and

b) None of three samples of the bonding conductor, selected at random, opens during a limited short-circuit test with a current as specified in Table 44.2 when in series with a fuse as described in 44.2 and 44.3.

Table 44.1
Duration of Current Flow

Rating of overcurrent device, amperes	Minimum duration of current flow, minutes
30 or less	2
31 – 60	4
61 – 100	6

44.2 The circuit for the test described in 44.1(b) is to have a power factor of 0.9 – 1.0 and is to be limited to the current specified in Table 44.2 at the voltage specified in Table 27.1. The open-circuit voltage of the test circuit is to be 100 – 105 percent of the specified voltage. The circuit is to be connected through a non-renewable fuse described in 44.3. One test is to be performed on each of the three samples of the bonding conductor subject to the test.

Table 44.2
Bonding Conductor Short-Circuit Test

Combined rating of device				Circuit capacity, amperes	
				Volts	
Volt-amperes, single-phase	Volt-amperes, 3-phase	Volt-amperes, direct-current	Horsepower (W output)	0 – 250	251 – 600
0 – 1176	0 – 832	0 – 624	1/2 maximum (373)	200	1000
1177 – 1920	833 – 1496	625 – 1128	Over 1/2 (373) to 1 (746) maximum	1000	1000
1921 – 4080	1497 – 3990	1129 – 3000	1 (746) to 3 (2200)	2000	5000
4081 – 9600	3991 – 9145	3001 – 6960	3 (2200) to 7-1/2 (5600)	3500	5000
9601 or more	9146 or more	6961 or more	Over 7-1/2 (5600)	5000	5000

44.3 The fuse used for connection of the circuit described in 44.1 and 44.2 shall have a current rating equal to that of the branch circuit overcurrent device to which the equipment is connected, but not less than 20 amperes. Characteristics of the fuse are such that the fuse will not open in less than 12 seconds when carrying twice its rated current.

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MANUFACTURING AND PRODUCTION TESTS

45 Dielectric Voltage-Withstand Test

45.1 Each product shall withstand without electrical breakdown, as a routine production-line test, the application of a 40 – 70 hertz potential, in accordance with either Condition A or Condition B of , between:

a) The primary wiring, including connected components, and accessible dead metal parts that are likely to become energized;

b) Primary wiring and secondary wiring, including terminals;

c) The secondary wiring and accessible dead metal parts;

d) A resonant winding and accessible dead metal parts; and

e) A resonant winding and the secondary winding.

Table 45.1
Production-Line Test Conditions

Product or motor rating	Condition A		Condition B	
	Potential, volts	Time, seconds	Potential, volts	Time, seconds
250 volts or less with no motor rated more than 1/2 horsepower (375 W)	1000	60	1200	1
More than 250 volts or with a motor rated more than 1/2 horsepower	1000 + 2V[a]	60	1200 + 2.4V[a]	1
Note - As an alternative, testing may be conducted using a direct current potential equal to the peak of the specified sinusoidal potential (1.414 times the sinusoidal rms value). [a] V = Maximum marked voltage.				

45.2 The product may be in a heated or unheated condition for the test.

45.3 The test shall be conducted when the battery charger is complete (fully assembled). The product shall not be unwired, modified, or disassembled for the test.

Exception No. 1: A part, such as a snap cover or a friction-fit knob that would interfere 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 product.

45.4 A product employing a solid-state component that is not relied upon to reduce a risk of electric 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 45.1. The circuitry may be rearranged for the purpose of the test to reduce the likelihood of solid-state-component damage while retaining representative dielectric stress of the circuit.

45.5 The test equipment shall include a transformer having an essentially sinusoidal output, 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 product.

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