UL 469

STANDARD FOR SAFETY

Musical Instruments and Accessories

UL Standard for Safety for Musical Instruments and Accessories, UL 469

Fourth Edition, Dated November 3, 2006

Summary of Topics

This revision to UL 469 is being issued to remove the reference to the withdrawal date of UL 873 and to address universal upkeep of UL Standards for Safety. These revisions are considered to be non-substantive and not subject to UL's STP process.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

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UL 469

Standard for Musical Instruments and Accessories

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Fourth Edition

November 3, 2006

This UL Standard for Safety consists of the Fourth Edition including revisions through October 3, 2013.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover power-operated musical instruments and accessories rated 300 volts or less, intended for household and commercial use on supply circuits in accordance with the National Electrical Code, NFPA 70.

1.2 Musical instruments include organs, electronic pianos, music synthesizers, and other such products that produce music under the direct control of the player.

1.3 These requirements also cover accessories for use with musical instruments, such as rhythm generators and similar equipment having self-contained tone generators, tone cabinets, music tuners, and the like.

1.4 These requirements do not cover commercial audio equipment, such as amplifiers, mixers, and signal processors for general use; or special effects units, amplifier-speakers, and the like, that are intended for use by professional and semiprofessional musicians.

1.5 These requirements do not cover musical instruments that are categorized as electrically operated toys and are covered by the Standard for Electric Toys, UL 696.

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

2 General

2.1 Components

2.1.1 Except as indicated in 2.1.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

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

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

b) Is superseded by a requirement in this standard.

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

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

2.2 Units of measurement

2.2.1 When a value for measurement is followed by a value in other units in parentheses, the first stated value is the requirement.

2.2.2 All applicable alternating-current electrical measurements are in root-mean-square (rms) units unless otherwise stated.

2.3 Undated references

2.3.1 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.

3 Glossary

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

3.2 FIBER – Where the term fiber is used, vulcanized fiber is meant.

3.3 HAZARDOUS CIRCUITRY – Circuitry involving a risk of electric shock as described in the Leakage-Current and Shock-Current Tests, Section 36, or a risk of fire as described in Risk of Fire, Section 26.

3.4 INSULATION, BASIC – The insulation necessary for the proper functioning of the product and for basic protection against electric shock.

3.5 INSULATION, REINFORCED – An improved basic insulation with such mechanical and electrical qualities that it, in itself, provides the same degree of protection against electric shock as an insulation system comprising both basic insulation and supplementary insulation.

3.6 INSULATION, SUPPLEMENTARY – An independent insulation provided in addition to the basic insulation to protect against electric shock in case of electrical breakdown of the basic insulation.

3.7 LOW-VOLTAGE CIRCUIT – A circuit involving a peak open-circuit potential of not more than:

a) The applicable values specified in Table 36.1, where wet contact is not likely to occur or

b) 21.2 volts peak where wet contact is likely to occur.

3.8 ORDINARY TOOL – A flat-bladed or cross-recessed screwdriver or pliers.

3.9 PRODUCT, COMMERCIAL – A product intended for use in commercial establishments, hotels, motels, houses of worship, schools, studios, and businesses.

3.10 PRODUCT, HOUSEHOLD – A product intended for use in the home.

3.11 PRODUCT, PORTABLE – A product that is intended to be moved or that can easily be moved from one place to another in normal use.

3.12 PRODUCT, STATIONARY – A product for which there is a dedicated location or that is not easily moved from one place to another in normal use.

3.13 UNRELIABLE COMPONENT – The following are considered to be unreliable components: electrolytic capacitors, transistors, diodes, vacuum tubes, and the like.

3.14 USER SERVICING – User servicing includes:

a) Battery – Replacement of a battery other than one intended to be soldered in place.

b) Fuse – Replacement of a fuse other than:

1) A fuse intended to be soldered in place.

2) A fuse not readily perceptible to the user. A fuse is not readily perceptible if it is located within a chassis, compartment, or enclosure within the overall product that makes the fuse invisible to the user. If the enclosure has a cover, it is to be one that does not need to be opened or removed in normal operation or user servicing, can be opened or removed only with a tool, and is prevented from being discarded. A fuse is readily perceptible if it is recognizable during normal operation or user servicing, either visually or by touch; or if the fuse is indicated, either on the product or on literature packed with it.

c) Vacuum Tube – Replacement of a vacuum tube other than a tube intended to be soldered in place.

d) User Adjustment – Adjustment of a marked adjustable control or an adjustable component if the adjustment can be accomplished using an ordinary tool, with the product in operation, and without defeating an interlock.

e) Unmarked Adjustment – Adjustment of an unmarked adjustable control if the adjustment can be accomplished without a tool, with the product in operation, and without defeating an interlock.

f) Terminals, Jacks, Connectors – Interconnection to terminals, jacks, and connectors that are readily perceptible to the user and are intended for connection of other accessories and equipment, such as microphones, speakers, tone cabinets, tape recorders, amplifiers, and preamplifiers.

1) A terminal, jack, or connector is readily perceptible if recognizable during normal operation or user servicing, either visually or by touch; or if it is indicated on the product or on literature packed with it.

2) A terminal, jack, or connector is not readily perceptible if located within a chassis, compartment, or enclosure within the overall product so that it is not visible to the user. If the enclosure has a cover, it is to be one that does not need to be opened or removed in normal operation or user servicing, can be opened or removed only with a tool, and is prevented from being discarded.

g) Piano Strings – Tuning of piano strings, but not replacement of piano strings or other servicing operations intended to be performed by a qualified piano service technician.

h) Lamp – Replacement of an incandescent lamp, whether it be a single lamp or one of a series or parallel string, intended for connection directly across the supply circuit – nominal 120 or 220 volts – or a fluorescent lamp, for example, a low-pressure mercury electric-discharge lamp with a fluorescing coating.

Exception No. 1: A lamp that is intended to be soldered in place and is soldered in place in the product.

Exception No. 2: A neon lamp, for example an electric-discharge lamp with neon as the filling gas.

Exception No. 3: Low-voltage – less than 30 volts – vacuum-fluorescent display device.

CONSTRUCTION

4 General

4.1 The construction of a product shall be such that:

a) Normal use and user servicing does not result in a risk of fire, electric shock, or injury to persons;

b) Materials and components are used within their electrical, mechanical, and temperature limits; and

c) The assembly protects components and wiring from being displaced or damaged.

4.2 The materials and components referred to in 4.1 and elsewhere in the requirements are those involving a risk of fire, electric shock, or injury to persons and are so considered unless specifically indicated otherwise.

4.3 A product shall be formed and assembled so that it has the strength and rigidity necessary to resist the abuses to which it might be subjected, without increasing the risk of fire, electric shock, or injury to persons due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other serious defects.

5 Enclosure

5.1 A product shall be provided with an enclosure that houses all vacuum tubes, motor-driven parts, and live parts, other than cords and cables, that involve a risk of fire, electric shock, or injury to persons. The enclosure shall be constructed so that it will protect the various parts of the product against mechanical damage.

5.2 The bottom shall be complete so as to protect all electrical parts. In judging the bottom of a portable product, consideration shall be given to the possibility of the product being placed on objects that may damage wiring or other electrical components.

5.3 The thickness of a sheet-metal enclosure shall not be less than the applicable value specified in Table 5.1.

Exception: The thickness may be less than that specified in Table 5.1 if investigated and found to provide equivalent strength.

Table 5.1
Thickness of sheet metal

Maximum dimensions of enclosure				Minimum thickness											
				Steel								Copper, brass, or aluminum			
				Without supporting frame				With supporting frame or equivalent reinforcing				Without supporting frame,		With supporting frame or equivalent reinforcing,	
Length or width,		Area,		Zinc coated,		Uncoated,		Zinc coated,		Uncoated,					
inches	(m)	in^2	(m^2)	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
12	0.30	90	0.06	0.036	0.91	0.032	0.81	0.025[a]	0.64	0.021[a]	0.53	0.045	1.14	0.029	0.74
18	0.46	135	0.09	0.046	1.17	0.043	1.09	0.036	0.91	0.032	0.81	0.058	1.47	0.045	1.14
24	0.61	360	0.23	0.057	1.45	0.054	1.37	0.046	1.17	0.043	1.09	0.075	1.91	0.058	1.47
48	1.22	1200	0.77	0.071	1.80	0.067	1.70	0.057	1.45	0.054	1.37	0.095	2.41	0.075	1.91
60	1.52	1500	0.97	0.098	2.49	0.095	2.41	0.057	1.45	0.054	1.37	0.122	3.10	0.075	1.91
Over 60		Over 1500		0.127	3.23	0.124	3.15	0.057	1.45	0.054	1.37	0.153	3.89	0.075	1.91

[a] Sheet steel for an enclosure intended for outdoor use (raintight) shall not be less than 0.036 inch thick if zinc coated and not less than 0.032 inch thick if uncoated.

5.4 The thickness of a cast-metal enclosure shall not be less than the applicable value specified in Table 5.2.

Table 5.2
Thickness of cast metal

Metal	Minimum thickness			
	At base of threads, at small, flat unreinforced surfaces and at surfaces that are reinforced by curving, ribbing, or the like or are otherwise of a shape or size to provide mechanical strength,		At relatively large, unreinforced, flat surfaces,	
	inch	(mm)	inch	(mm)
Die-cast metal	3/64	1.2	5/64	2.0
Cast malleable iron or permanent mold cast aluminum	1/16	1.6	3/32	2.4
Other cast metal	3/32	2.4	1/8	3.2

5.5 A wooden enclosure shall not be less than 1/2 inch (12.7 mm) thick at portions of the enclosure that serve as a supporting frame for a product that weighs 10 pounds (4.54 kg) or more. Portions of the enclosure that do not serve to support parts or as structural members of the frame shall not be less than 1/8 inch (3.2 mm) thick.

Exception: A wooden enclosure may be less than 1/2 inch thick if investigated and found to provide equivalent strength.

5.6 A polymeric enclosure or polymeric part of an enclosure shall comply with the applicable requirements in Table 7.1.

6 Mechanical Assembly

6.1 A switch, lampholder, attachment plug, or similar component shall be mounted securely and shall be prevented from turning.

Exception No. 1: The requirement that a switch be prevented from turning may be waived if all four of the following conditions are met:

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

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

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

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

Exception No. 2: A lampholder of a type in which the lamp cannot be replaced, such as a neon pilot or indicator light where the lamp is sealed in by a nonremovable jewel, need not be prevented from turning if rotation will not reduce spacings below the minimum acceptable values.

6.2 The means for preventing the turning mentioned in 6.1 is to consist of more than friction between surfaces; for example, a lock washer is acceptable as a means for preventing a small stem-mounted switch or other device that has a single-hole mounting means from turning.

6.3 An uninsulated live part shall be secured to the base or mounting surface so that it will be prevented from turning or shifting in position if such displacement may result in a reduction of spacings below the minimum acceptable values. Friction between surfaces is not acceptable as a means to prevent shifting or turning of a live part; but a properly applied lock washer is acceptable.

7 Materials

7.1 General

7.1.1 Cellulose nitrate or any comparably flammable material shall not be used.

7.1.2 A material shall comply with applicable requirements in Table 7.1.

Exception No. 1: The requirements do not apply to the internal insulating systems of components or where component requirements exist.

Exception No. 2: An external or internal part located in nonhazardous circuitry or used in nonelectrical applications and not specifically described in Table 7.1 need not comply with the flammability requirements in Table 7.1; however, the part shall comply with the requirement in 7.1.1.

Exception No. 3: The requirements do not apply to fiber and similar material that is 0.01 inch (0.25 mm) thick or less.

Exception No. 4: The requirements do not comply to small parts as indicated in Table 7.1.

Table 7.1
Material requirements for various applications

Table 7.1 revised March 18, 2010

Application	Material	Minimum flammability classification[a]	Resistance to ignition		Dielectric strength and volume resistivity[b]	Small parts exception[c]
			Hot wire[b]	High current[b]		
Enclosure	Polymeric	V-2[d]	Required	Not required	Not required	Not applicable
Dust cover, key, music rack, pedal, stop, and tab not part of a required enclosure	Polymeric	HB	Not required	Not required	Not required	Yes

Table 7.1 Continued on Next Page

Table 7.1 Continued

Application			Material	Minimum flammability classification[a]	Resistance to ignition		Dielectric strength and volume resistivity[b]	Small parts exception[c]
					Hot wire[b]	High current[b]		
Material in contact with current-carrying part connected in	Hazardous circuitry	Polarity only on material[e]	Polymeric	HB	Required	Required	Required	No – electrical Yes – flammability and resistance to ignition
				V-2	Not required	Not required	Required	
		Opposite polarity on material[e,f]		V-1	Not required	Not required	Required	No
	LVLE[g] circuitry			HB	Not required	Not required	Not required	Yes
	Hazardous circuitry	Polarity only on material[e]	Low density polymeric foam[h]	HBF	Required	Required	Required	No – electrical Yes – flammability and resistance to ignition
				HF-2	Not required	Not required	Required	
		Opposite polarity on material[e]		HF-1	Not required	Not required	Required	No
	LVLE[g] circuitry			HBF	Not required	Not required	Not required	Yes
Speaker or decorative grille, not part of required enclosure			Foam[h]	HBF	Not required	Not required	Not required	Yes
			Molded	HB	Not required	Not required	Not required	Yes
			Woven (cloth)	See Section 57	See Section 57			Yes
Printed-wiring board	Hazardous circuitry		All	V-1	Not required	Not required	Required	No
	LVLE[g] circuitry			HB	Not required	Not required	Not required	No
	Nonhazardous circuitry			HB[i]	Not required	Not required	Not required	Yes

[a] The flammability classifications V-0, V-1, V-2, HB, HF-1, HF-2, and HBF are to be determined as described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. A material classified using 1/16-inch (1.6-mm) thick bar specimens is acceptable in lesser thicknesses in the end product.

[b] These columns refer to the following requirements:

1) The part shall have a minimum resistance to hot-wire ignition of 7 seconds, or a minimum resistance to high-current-arc ignition of 60 arcs, or both, as stated. See 7.1.3 and 7.1.4.

2) The dielectric strength of the part shall be at least 175 volts per mil (7000 V/mm) and the volume resistivity shall be at least 50 megohm-centimeters. See 7.1.6 and 7.1.7.

[c] In order for the small part exception to apply, the part shall comply with the following:

1) The maximum volume shall not exceed 4000 mm^3,

2) The maximum dimension shall not exceed 60 mm, and

3) The part shall be located so it cannot propagate flame from one area to another or act as a bridge between a possible source of ignition and other ignitable parts.

Table 7.1 Continued on Next Page

Table 7.1 Continued

Application	Material	Minimum flammability classification[a]	Resistance to ignition		Dielectric strength and volume resistivity[b]	Small parts exception[c]
			Hot wire[b]	High current[b]		

[d] A polymeric enclosure material having a flammability classification of HB may be used if the material is not employed to render live parts involving a risk of electric shock inaccessible.

[e] Polarity is defined as the condition of being electrically energized positive or negative with respect to some electrical reference point. For the purpose of the table:

1) Opposite polarity across material means that the positive or negative and the reference point are both in contact with the material in question, such as illustrated in parts (A) and (B) in Figure 7.1 where the absolute value of V_1 is greater than the absolute value of V_2.

2) Polarity only on material means that the positive or negative only is located on the material and the reference point is not in contact with the same material, such as part (C) in Figure 7.1 where the absolute value of V_1 is greater than the absolute value of V_2.

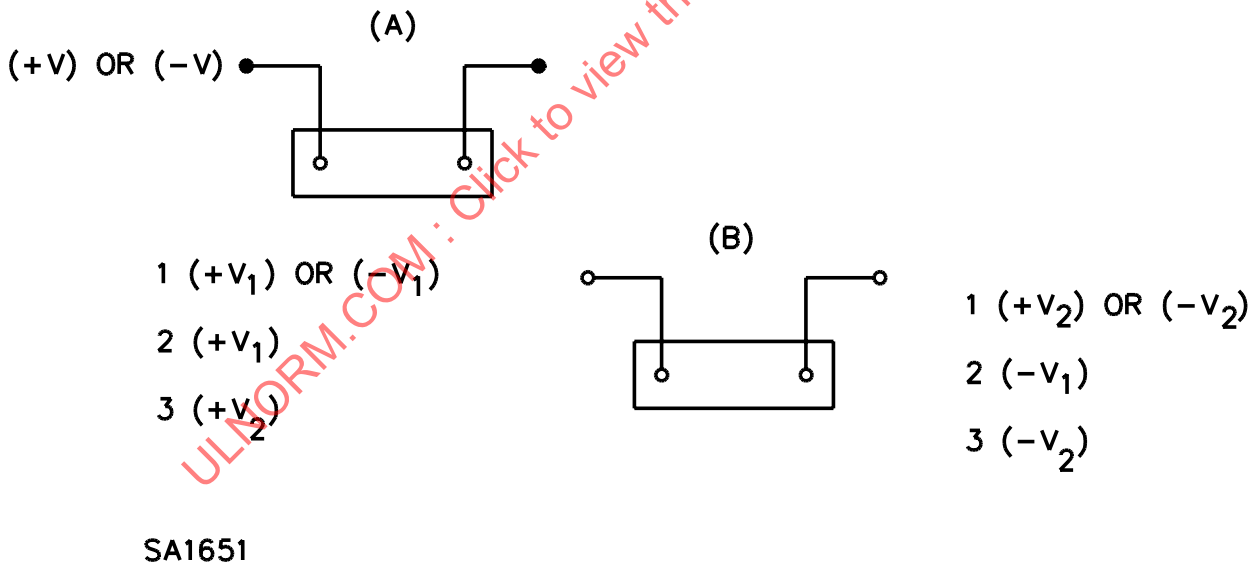
[f] Insulating material having a flammability classification of V-2 or HB may be used as direct support of live parts provided the material complies with the direct-support requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

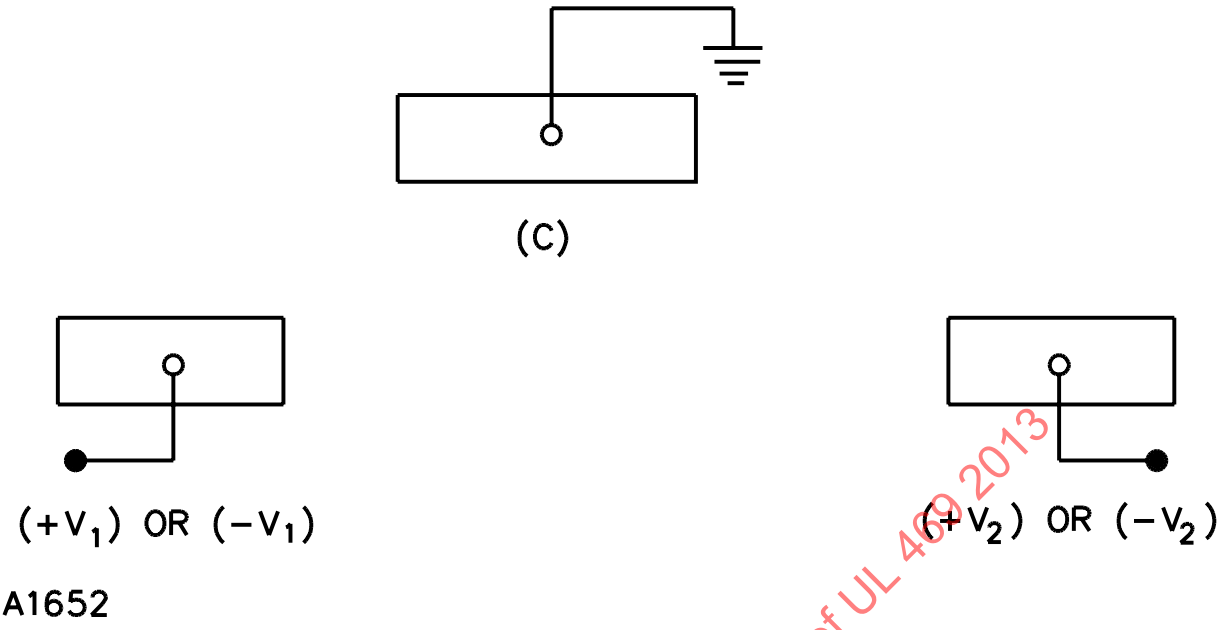
[g] LVLE signifies low-voltage, limited-energy. See 27.1.2.

[h] Foam having a specific gravity of less than 0.6 is considered to be low-density foam. Material having a specific gravity of 0.6 or greater is considered to be polymeric and is to be judged accordingly.

[i] Applies to base material only.

Figure 7.1
Polarity on material





7.1.3 Resistance to hot-wire ignition, as mentioned in note (b)(1) of Table 7.1, is the number of seconds needed to ignite a sample that is wrapped with resistance wire that dissipates a specified level of electrical energy. See 7.1.5.

7.1.4 High-ampere arc resistance to ignition, as mentioned in note (b)(1) of Table 7.1, is expressed as the number of arc-rupture exposures – standardized as to electrode type and shape and electrical circuit – that are necessary to ignite a material when they are applied as a specified rate on the surface of the material. See 7.1.5.

7.1.5 With reference to 7.1.3 and 7.1.4, bar samples are to be used for the tests. A material classified using 1/16-inch (1.6-mm) thick bar specimens is acceptable in lesser thicknesses in the end product. The tests are to be conducted in accordance with the requirements in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

7.1.6 A material for which the requirement in note (b)(2) of Table 7.1 applies shall have a dielectric strength of at least 175 volts per mil (7000 V/mm) as determined after conditioning for 40 hours at 23.0 ±1.0°C (73.4 ±1.8°F) and 90 ±5 percent relative humidity, conducted in accordance with the Standard Method of Tests for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies, ASTM D149-1975. These are minimum values usually characteristic of the majority of materials classed as insulators.

7.1.7 A material for which the requirement in note (b)(2) of Table 7.1 applies shall have a volume resistivity of at least 50 megohm-centimeters as measured after conditioning for 40 hours at 23.0 ±1.0°C (73.4 ±1.8°F) and 50 ±5 percent relative humidity as indicated in Procedure A of the Standard Method of Tests for Conditioning Plastics and Electrical Insulating Materials for Testing, ASTM D618-1971, and 10 megohm-centimeters after being conditioned for 96 hours at 35.0 ±1.0°C (96.8 ±1.8°F) and 90 ±5 percent relative humidity as indicated in Procedure C, conducted in accordance with the Standard Methods of Tests for D-C Resistance or Conductance of Insulating Materials, ASTM D257-1976. These are minimum values usually characteristic of the majority of materials classed as insulators.

7.1.8 A molded part shall have the necessary mechanical strength and rigidity to withstand the stresses of actual service.

7.2 Guard and barrier insulating material for rendering live parts inaccessible

7.2.1 A guard or barrier of insulating material employed to render live parts inaccessible shall:

a) Not be less than 0.028 inch (0.71 mm) thick.

Exception No. 1: Fiber, or the equivalent, that is not less than 0.013 inch (0.33 mm) thick may be used to cover a splice within the overall enclosure.

Exception No. 2: A covering of paper that is not less than 0.028 inch (0.71 mm) thick may be used on an electrolytic capacitor or similar part.

Exception No. 3: A fiber shell of a metal-jacketed pilot lampholder covering all live parts may be not less than 0.020 inch (0.51 mm) thick.

b) Comply with the requirement in 7.1.2.

8 Protection Against Corrosion

8.1 An iron or steel part shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means, if corrosion of the unprotected part would result in a risk of fire, electric shock, or injury to persons.

Exception No. 1: This requirement does not apply to surfaces of a sheet steel or cast-iron part within an enclosure if the oxidation of the iron or steel due to the exposure of the metal to air or moisture is not likely to be appreciable – the thickness of metal and temperature also being factors.

Exception No. 2: This requirement does not apply to a bearing, laminations, or a minor part, such as a washer, screw, and the like.

9 Current-Carrying Parts

9.1 A current-carrying part shall be of silver, copper, a copper-base alloy, stainless steel, aluminum, or other material acceptable for the intended use.

Exception No. 1: Plated steel may be used for secondary-circuit parts, and for some primary-circuit parts, such as for capacitor terminals where a glass-to-metal seal is necessary and for leads or threaded studs of semiconductor devices.

Exception No. 2: Blued steel or steel with an equivalent corrosion resistance is acceptable for the current-carrying arms of a mechanically or magnetically operated leaf switch, but not elsewhere.

9.2 A contact of a socket, separable connector, and the like, connected in a circuit involving a risk of fire shall be made of nonferrous spring metal acceptable for the intended use.

10 Accessibility of Live Parts

10.1 General

10.1.1 A live part, including an audio output or speaker terminal, that involves a risk of electric shock shall not be accessible to the extent that it can be touched during normal operation or user servicing.

10.1.2 The accessibility of a live part is to be determined in accordance with Table 10.1.

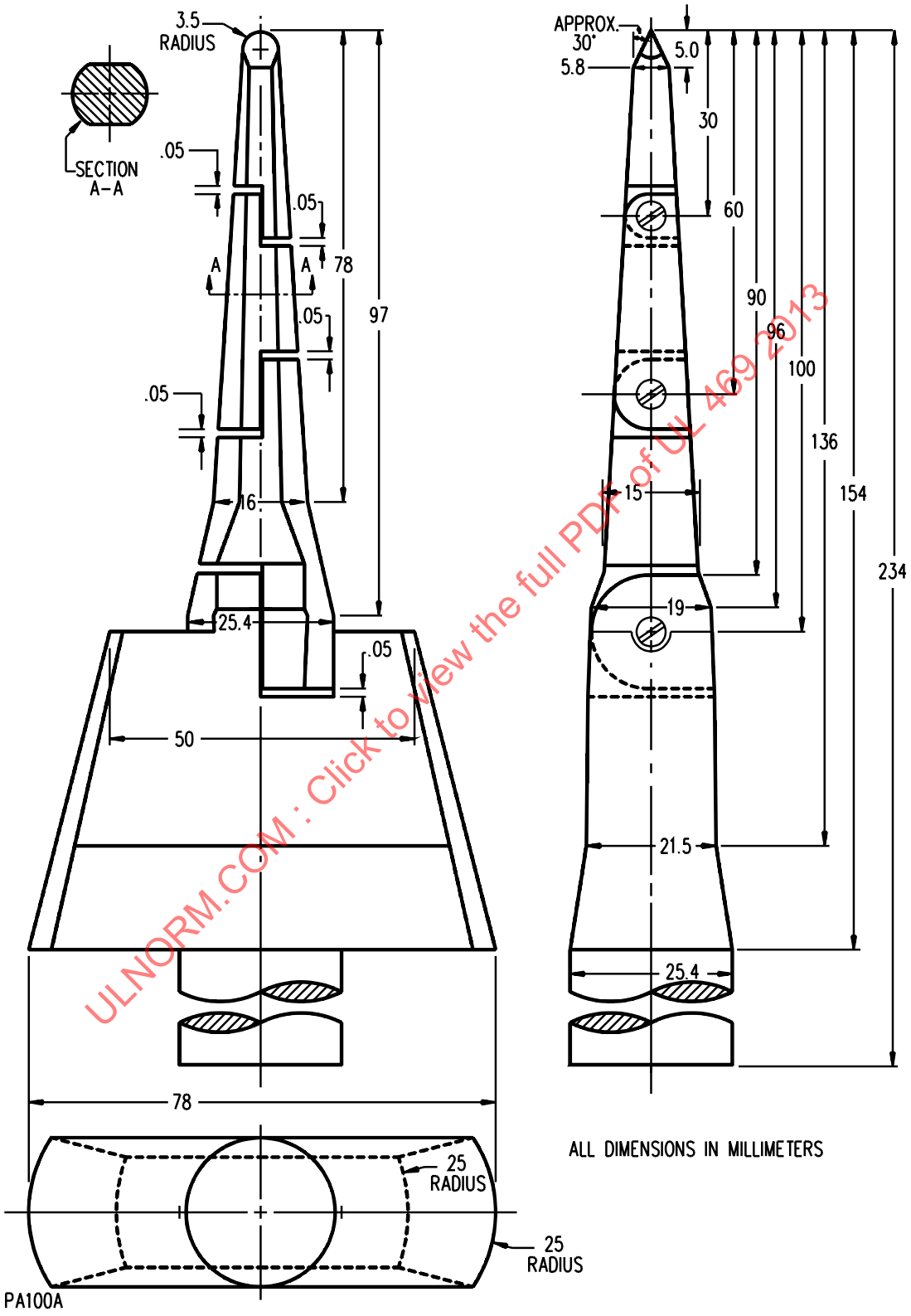
Table 10.1
Recessing of live parts

Maximum width of slots – inches (mm)	Diameter of round holes – inches (mm)	Minimum distance between opening and live part[a]
Less than 1 (25.4)	Less than 1 (25.4)	Probe[b]
	1 but not more than 2 (50.8)	5D
1 (25.4) but not more than 2 (50.8)	More than 2 (50.8) but not more than 3 (76.2)	6D
More than 2 (50.8) but not more than 3 (76.2)		7D

[a] D is the diameter of the largest sphere that can pass through the opening.
[b] See 10.1.3.

10.1.3 An opening that will not permit the entrance of a 1-inch (25.4-mm) diameter rod is acceptable, if the probe illustrated in Figure 10.1 cannot be made to touch any uninsulated live part or film-coated wire when inserted into the opening. The probe may be articulated into any configuration and may be rotated or angled to any position before, during, or after insertion into the opening, and the penetration may be to any depth allowed by the opening size, including minimal depth combined with maximum articulation. No force is to be applied to the probe.

Figure 10.1
Probe for determining accessibility of live parts

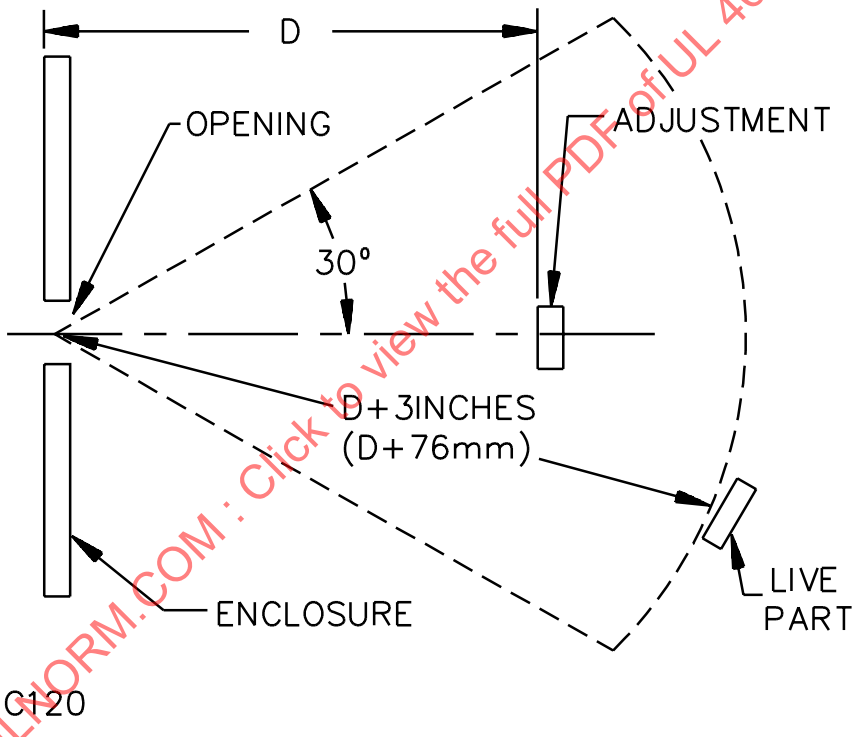


10.1.4 A friction-fit knob, snap cover, or similar loose part may be removed or opened when evaluating accessibility.

10.2 Adjustment opening

10.2.1 A part beyond an opening that may be used in making an adjustment considered to be a function of user servicing is not considered to be accessible if a 1/8-inch (3.2-mm) diameter straight rod is prevented from touching the part when the rod is inserted through the opening and moved to all positions possible without producing an angle of more than 30 degrees between the rod and a line drawn between the center of the opening and the center of the face of the adjusting mechanism. As illustrated in Figure 10.2, the length of the rod inside the opening is not to exceed the distance between the opening and the face of the adjusting mechanism by more than 3 inches (76.2 mm).

Figure 10.2
Accessibility of live part through adjustment opening



10.3 Screens, barriers, and other openings

10.3.1 Each protective screen or barrier, opening larger than covered by Table 10.1, irregular opening, or opening in flexible material is to be given consideration with respect to the intent of the requirements.

10.4 Control shaft

10.4.1 A control shaft that involves a possible source of electrical shock shall be rendered inaccessible by means of an interlocked compartment or by means of an insulating knob that is not removable from the exterior of the enclosure.

10.4.2 A setscrew, sealing compound, or a device that depends upon friction to prevent removal of a knob from the exterior of the enclosure is not an acceptable means of rendering a control shaft inaccessible.

10.5 Captive part

10.5.1 A part of the product:

a) That is subject to removal during user servicing,

b) That is not essential for the functioning of the product,

c) That is not exposed to view during normal use, and

d) The omission of which may result in a risk of electric shock

shall be made captive or otherwise arranged to prevent it from being omitted.

11 Exposure to Rain or Moisture

11.1 A product that may be subjected to casual or incidental exposure to rain or moisture out-of-doors shall withstand the wetting test described in the Exposure to Rain Test, Section 57.

Exception: This requirement does not apply to a product marked in accordance with 64.12.1.

11.2 A product is considered to be subject to casual or incidental exposure to rain or moisture if it is cord-connected and at least one of the following applies:

a) It is provided with a handle, wheels, rollers, or the like, so as to make it portable.

b) It can be operated from a battery.

12 Supply Connections

12.1 General

12.1.1 A product shall be provided with a length of flexible cord and an attachment plug for connection to the supply circuit.

12.2 Power-supply cord

12.2.1 The ampacity of the cord shall not be less than the sum of the marked rating of the product and the marked rating of all conventional parallel-slot receptacles used to supply power to another product or accessory.

12.2.2 A power-supply cord shall be one of the types specified in Table 12.1. A cord of another type may be used if its properties are such that it will be equally serviceable for the application. For example, an appliance wiring material construction that has been determined to be equivalent to Non-Integral Type SPT-2 cord may be used in applications where Non-Integral Type SPT-2 cord is specified.

Table 12.1
Cords for products

Products	Type of cord	Maximum length, feet	(m)
Commercial	SJ, SJT, SJE	25	7.62
Household	Non-Integral SPT-2, SV, SVT, SVE,	10	3.05
	SJ, SJT, SJE	25	7.62

12.2.3 20 AWG conductors may be employed in appliance wiring material constructions as referenced in 12.2.2 provided that:

a) The appliance is rated 2.0 A or less,

b) The appliance does not employ a convenience receptacle, and

c) Overcurrent protection rated 2.0 A or less is provided in the attachment plug and connected so as to interrupt the ungrounded side of the supply circuit.

12.2.3 revised March 18, 2010

12.2.4 The length of the cord shall not be more than the value specified in Table 12.1 and not less than 5 feet (1.52 m).

Exception: A product intended for use in a location where a power receptacle will be available adjacent to the product may be provided with cord that is less than 5 feet long.

12.2.5 The length of a power-supply cord is to be measured from the face of the attachment plug to the point where the cord emerges from the product.

12.3 Cord-connector body

12.3.1 A cord-connector body employed as part of a separable cord set shall be constructed so that the cord-connector body cannot readily be used to defeat the conventional interlock device.

12.3.2 The conventional interlock device referred to in 12.3.1 has nominal 3/32-inch diameter pins, spaced 5/16 inch (7.9 mm) apart, measured between pin centers.

12.4 Cord strain relief

12.4.1 The power-supply cord shall be attached to the product so that a mechanical stress on the cord leaving the overall enclosure cannot:

a) Be transmitted to terminals, splices, or interior wiring;

b) Separate an interlock connector from the part of the product to which it is attached; or

c) Damage an interlock such that it does not perform its intended function.

To determine compliance with the foregoing, the product is to be subjected to the Strain-Relief Test, Section 51.

12.4.2 If a knot in a power-supply cord serves as strain relief, any surface the knot contacts shall be free from projections, sharp edges, burrs, fins, and the like, that cause abrasion of the insulation on the cord.

12.5 Cord push-back relief

12.5.1 A power-supply cord shall be provided with a means that prevents the cord from being deliberately pushed inside the enclosure if, when pushed inside, any of the following will occur:

a) The insulation on the cord is subjected to temperatures or voltages that exceed those for which it is rated,

b) The cord can come in contact with a sharp edge or moving part that could damage insulation,

c) The cord displaces a part resulting in reduction of spacings in hazardous circuitry or stress on internal connections, or

d) The cord remains inside the product enclosure and cannot be retrieved if there are no user serviceable parts.

Exception: This consideration does not apply if a separate cord-storage compartment is provided.

12.6 Bushings

12.6.1 An opening in a wall, barrier, or overall enclosure through which a supply cord passes shall be provided with a bushing or the equivalent that is substantial, reliably secured in place, and that has a smooth, rounded surface against which the cord may bear. If a cord other than Type S, SO, ST, STO, SJ, SJO, SJT, SV, or SVT is employed and the wall or barrier is of metal, an insulating bushing shall be provided.

Exception: If the exit for the cord is in wood, wood composition, or an insulating material, a surface free of fins, burrs, and the like, is considered equivalent to a bushing.

12.6.2 Ceramic, porcelain, phenolic, and some molded compositions are acceptable for insulating bushings. Except as indicated in 12.6.3, a separate bushing shall not be made of wood or rubber.

12.6.3 A soft rubber bushing may be employed in the frame of a motor if the bushing is not less than 3/64 inch (1.2 mm) thick and if the bushing is located so that it will not be exposed to oil, grease, oily vapor, or other substance having a harmful effect on rubber. If a soft rubber bushing is employed in a hole in a metal motor frame, the hole shall be free from sharp edges, burrs, projections, and the like that would be likely to cut into the rubber.

12.6.4 Fiber may be employed if the finished bushing is not less than 3/64 inch (1.2 mm) thick and is formed and secured in place so that it will not be adversely affected by ordinary moisture. Sheet fiber not less than 0.028 inch (0.71 mm) thick may be used under the same conditions.

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

12.6.6 An insulated metal grommet may be used in place of an insulating bushing if the insulating material used is not less than 1/32 inch (0.8 mm) thick and completely fills the space between the grommet and the metal in which the grommet is mounted.

12.7 Cord routing

12.7.1 A separate flexible cord or wire that is not connected in the supply circuit or that does not involve a risk of fire or electric shock shall not be routed through a bushing or opening with the power-supply cord at a point of flexure.

12.8 Attachment plug

12.8.1 The supply cord of a product shall terminate in a polarized 2-wire parallel-blade or 3-wire grounding type attachment plug. The attachment plug shall have an American Standard configuration of pins and American Standard ratings. It shall be of a type acceptable for use:

a) With a current not less than the rated current of the product and

b) At a voltage equal to the rated voltage of the product.

If the product can be adapted for use on two or more different supply voltages by means of an input voltage selector, the attachment plug provided with the product shall be acceptable for one of the voltages for which the product is intended to be connected.

Exception No. 1: If the product is intended to be connected to a supply circuit not defined in the National Electrical Code, ANSI/NFPA 70, the configuration of the attachment plug is to conform to the applicable standards of the country into which the product is intended to be shipped. This exception applies only when the product is set for use on the foreign supply circuit when leaving the factory.

Exception No. 2: Direct plug-in transformer units shall comply with the polarization requirements in the Standard for Class 2 Power Units, UL 1310.

12.8.2 If a polarized attachment plug is used, a fuseholder, an overcurrent-protective device other than an automatic control without a marked off position, the center contact of an Edison-base lampholder, an interlock, and a manual on-off switch with a marked off position shall not be connected to the grounded supply circuit of the attachment plug.

13 Grounding

13.1 General

13.1.1 A power-supply cord of a product intended for use on a circuit operating at a potential of more than 150 volts to ground shall include an equipment-grounding conductor.

13.1.2 If a means for grounding is provided on a product, whether or not such a means is required, it shall comply with the requirements in 13.1.3 – 13.2.1.

Exception: A 2-wire product with a performance ground, such as a chassis ground terminal, need not comply with the requirements in 13.1.6 – 13.2.1.

13.1.3 An equipment-grounding conductor of a flexible cord shall be:

a) Finished to show a green color or green with one or more yellow stripes;

b) Connected to the grounding member of an attachment plug having a fixed grounding contact; and

c) Connected to the frame or enclosure of the product by a screw or other means not likely to be removed during servicing that does not involve the power-supply cord. Solder alone shall not be used for securing a grounding conductor.

13.1.4 The screw mentioned in 13.1.3(c) shall be of corrosion-resistant metal, or shall be protected against corrosion in a manner that will not inhibit electrical conductivity between the screw and any other conductor. A lock washer shall be employed to prevent the screw from becoming loosened by vibration.

13.1.5 If two or more products are intended to be electrically or mechanically interconnected and one of them is grounded, each unit of the system that has a separate power-supply cord shall have a grounding conductor in the power-supply cord. If the products are interconnected electrically and one of them is grounded, they shall be bonded together; for example, by means of a discrete conductor included in an interconnecting cable.

13.1.6 If a grounding means is provided on a product, all exposed dead metal parts and all dead metal parts within the enclosure that are exposed to contact during any user- or service personnel-servicing operation and are likely to become energized shall be connected to the grounding means.

13.1.7 With reference to the requirement in 13.1.6, the following dead metal parts are not considered likely to become energized:

a) A small metal part such as an adhesive-attached foil marking, a screw, or a handle that is:

1) On the exterior of the enclosure and separated from all electrical components by grounded metal or

2) Electrically isolated from all electrical components.

b) A panel or cover that is isolated from all electrical components by a barrier of vulcanized fiber, varnished cloth, phenolic composition, or other moisture-resistant insulating material not less than 1/32 inch (0.8 mm) thick and secured in place.

c) A panel or cover that does not enclose uninsulated live parts and is electrically isolated from other electrical components.

d) Cores and assembly screws of a relay, a solenoid, and the like.

13.1.8 It may not be practical to connect certain conductive parts – control shafts, mounting screws, and the like – to the grounding means. Such parts are not considered likely to become energized if supplementary insulation is employed in addition to the basic insulation provided. Where it is impractical to provide separate basic insulation and supplementary insulation, reinforced insulation may be used.

13.1.9 Basic insulation shall have a dielectric voltage-withstand capability of 1000 volts for 1 minute and a minimum through-air or over-surface spacing of 1/16 inch (1.6 mm).

13.1.10 The insulation qualities and the resistance of deterioration with aging of material employed as supplementary insulation shall be not less than that which would be required for the same material employed as basic insulation. The minimum spacing through supplementary insulation used in circuits involving 125 volts or less shall be 1/32 inch (0.8 mm) and this insulation shall have a dielectric voltage-withstand capability of at least 2500 volts for 1 minute. The minimum through-air or over-surface spacing between conductive parts separated by supplementary insulation shall be 1/16 inch (1.6 mm).

13.1.11 The insulation qualities and resistance to deterioration with aging of materials employed as reinforced insulation shall not be less than the total of that which would be required for the combination of basic and supplementary insulation. The minimum spacing through reinforced insulation used in circuits involving 125 volts or less shall be 5/64 inch (2.0 mm) and this insulation shall have a dielectric voltage-withstand capability of at least 3500 volts for 1 minute. The minimum through-air or over-surface spacing between a live part and an accessible conductive part shall be 1/8 inch (3.2 mm).

13.2 Grounding-type cord-connector body

13.2.1 If a product:

a) Is provided with a power-supply cord or cord set incorporating a separable cord-connector body and

b) Has conductive parts that are connected to the grounding conductor that may be contacted during the connection or disconnection of the cord-connector body at the product end of the cord,

the construction shall be such that the grounding connection is made first and broken last with respect to the power-supply conductors.

13.3 Grounding adapters

13.3.1 A grounding adapter packaged with a product equipped with a grounding-type supply cord shall not be attached to the attachment plug before reaching the user. Also, see 64.13.1.

13.4 Grounded-product receptacle

13.4.1 A convenience receptacle provided on a product that is intended to be grounded shall be of a grounding type. The grounding contact of the receptacle shall be electrically connected to the grounding means of the product.

14 Supply-Circuit-Voltage Selector

14.1 A supply-circuit-voltage selector shall be constructed so that the setting cannot be unintentionally changed.

14.2 A supply-circuit-voltage selector on a cord-connected product shall be set at the factory to a voltage value corresponding to the type of attachment plug provided.

14.3 If a product is constructed so that the setting of the supply-circuit-voltage selector can be changed by the user, the action of changing the voltage-selector setting shall also change the supply-circuit-voltage indication.

14.4 The voltage-selector setting mentioned in 14.3 shall be externally visible.

Exception: The voltage-selector setting need not be externally visible if the product is marked in accordance with 64.11.2.

15 Capacitors

15.1 The voltage rating of a capacitor shall equal or exceed the maximum steady-state potential to which the capacitor is subjected during normal operation of the product.

15.2 A capacitor shall employ materials and shall be constructed so that it will not constitute a risk of fire or injury to persons. A paper capacitor shall be impregnated or otherwise enclosed to exclude moisture. A paper cover for a capacitor shall not be less than 0.028 inch (0.71 mm) thick if a risk of electric shock is involved.

15.3 A capacitor employing a liquid dielectric medium more combustible than askarel shall not expel the dielectric medium when tested in accordance with the applicable performance requirements in this standard, including faulted overcurrent conditions based on the branch circuit in which it is used.

15.4 A capacitor connected across the supply circuit, or used in primary supply circuits for line-bypass or metal-enclosure isolation; or between live parts and exposed metal parts shall comply with the applicable requirements in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414.

15.4 revised March 18, 2010

15.5 A capacitor is considered to be connected across the supply circuit when used in any of the following applications:

a) With the capacitor in a shorted condition and with the product in a heated condition, a primary-circuit current of more than 1 ampere passes through the capacitor. The current through the capacitor can be limited to 1 ampere or less by a fixed impedance or a protective device rated 1 ampere or less; or

b) A capacitor used for line-bypass in a product provided with a terminal or connector intended to be grounded.

16 Lampholders

16.1 The terminals of a lampholder shall be securely riveted or otherwise secured in place. The center contact and its mounting shall be secured so that it will be held within the shell when the lamp is removed. The lampholder terminals and other live parts, including the lamp base, shall be protected so that grounding or a risk of electric shock during use or user servicing is unlikely. Soft rubber shall not be used for the insulation of a lampholder shell.

17 Receptacles

17.1 An unused receptacle that involves hazardous energy, such as one provided for the attachment of an accessory, shall not be of the type employed as a receptacle for a single-prong, shielded-type phonograph plug, and if of the conventional parallel-slot type shall involve line power only. See 13.4.1.

17.2 If the face of a receptacle is less than 5/8 inch (15.9 mm) wide or less than 7/8 inch (22.2 mm) long, the face of the receptacle shall project not more than 3/16 inch (4.8 mm) from the part of the mounting surface that is within a rectangle 5/8 inch wide and 7/8 inch long symmetrically located about the receptacle contacts; and if the mounting surface is conductive, the face of the receptacle shall project not less than 3/32 inch (2.4 mm) from that part of the mounting surface.

17.3 The area surrounding an unused attachment-plug receptacle shall be free of any projections that would prevent full insertion of the blades of a circular attachment plug having a face diameter of 1-3/16 inches (30.2 mm).

Exception: Projections that prevent the blades of the attachment plug from being inserted to make electrical contact with the contacts of the receptacle are acceptable.

18 Overload Protection

18.1 General

18.1.1 A protective device, such as a fuse or a manually reset overcurrent device, shall be designed for the purpose of overload protection.

18.1.2 A protective device or component relied upon to reduce a risk of fire or electric shock shall comply with the requirements for that component.

18.2 Fuses

18.2.1 A user-serviceable fuse (see 3.14) shall be mounted or guarded to prevent live parts from being exposed to unintentional contact. The arrangement shall be such that the fuse cannot be positively gripped or held by any part of the fuseholder while live parts are exposed at any time during replacement.

18.2.2 A clip for a cartridge fuse shall be provided with end stops. The clip shall be mounted securely and prevented from turning.

19 Internal Wiring

19.1 Types of wire

19.1.1 The internal wiring of a product shall be of a type capable of withstanding the temperature, voltage, and other conditions of service to which the wiring may be subjected; for example, exposure to oil or grease.

19.1.2 The insulation on thermoplastic insulated wire shall not be less than 0.007 inch (0.18 mm) thick if the maximum potential involved is not more than 300 volts peak; 1/64 inch (0.4 mm) if the maximum potential involved is more than 300 but not more than 600 volts peak; and 1/32 inch (0.8 mm) if the maximum potential involved is more than 600 but not more than 1000 volts peak.

19.1.3 The primary wiring of a power-transformer-operated product, including the transformer primary-winding leads but not the primary winding, having a power-supply input of more than 300 watts shall not be smaller than 18 AWG (0.82 mm^2).

Exception: This requirement does not apply if an investigation shows that overloading of the primary wiring due to a fault in the circuits connected to the secondary of the transformer, or in the transformer itself, does not result in a risk of fire.

19.1.3 revised March 18, 2010

19.2 Sleeving, tape, tubing, and wire insulation

19.2.1 Sleeving, tape, tubing, and wire insulation shall be rated for the voltage involved and the temperature attained under any condition of actual use. Tape shall be flame retardant. Sleeving, tubing, and wire insulation shall have a flame-retardant rating of VW-1.

Exception: This requirement does not apply to sleeving, tape, tubing, and wire insulation located in a nonhazardous secondary circuit if the wires are reliably segregated – for example, by routing, clamping, or partitioning– from wiring located in hazardous-energy circuits or in low-voltage, limited-energy circuits.

19.3 Mechanical protection

19.3.1 The wiring and connections between parts within a product shall be protected or enclosed.

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

19.3.3 All wiring that involves a risk of fire or electric shock shall be located and secured so that contact with the wiring by the objects is not likely during a user-servicing operation that involves removal and replacement of objects.

19.3.4 Wires within an enclosure, compartment, raceway, or the like, shall be routed or protected so that no damage to conductor insulation can result from contact with any rough, sharp, or moving part.

19.3.5 A metal clamp or guide used for routing stationary internal wiring shall be provided with smooth, rounded edges. Auxiliary nonconducting mechanical protection shall be provided under a clamp where pressure is exerted on a conductor having thermoplastic insulation less than 1/32 inch (0.8 mm) thick and no overall braid.

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

19.3.7 A hook-up wire involving hazardous circuitry and employing thermoplastic insulation with wall thickness less than 1/32 inch (0.8 mm) shall be located entirely within a chassis or be protected against mechanical damage and not subject to flexing during normal operation or handling during user servicing.

19.3.8 Wire smaller than 24 AWG (0.21 mm^2) shall be protected against mechanical damage, taking into consideration the effects of vibration, impact, and handling during user servicing.

19.3.8 revised March 18, 2010

19.3.9 Low-energy-circuit wiring – such as an audio-signal lead – that is not housed entirely within the enclosure and that may contact a part involving a risk of fire or electric shock shall be insulated within the enclosure. Such wiring shall be provided with strain and push-back relief that complies with the requirements in 12.4.1 and 12.5.1.

19.4 Splices and connections

19.4.1 A splice and connection shall be mechanically secure and shall provide electrical contact. A soldered connection shall be made mechanically secure before being soldered if breaking or loosening of the connection may result in contact with either dead metal or other live parts so as to create a risk of fire or electric shock, or a reduction of spacings below the minimum required for the application. Consideration shall be given to vibration, temperature, and the like, when judging the acceptability of electrical connections.

19.4.2 With respect to the requirement in 19.4.1, a lead is considered to be mechanically secure if the lead is:

a) Wrapped at least three quarters of the way around a terminal,

b) Inserted through an eyelet or opening of a terminal block or printed wiring board prior to soldering,

c) Twisted with other conductors, or

d) Inserted into a U- or V-shaped slot in the terminal prior to soldering.

19.4.3 The insulation on a splice shall be equivalent to that of the wires involved if permanence of spacing between the splice and other metal parts may not be maintained.

19.4.4 Threaded pressure cable wire connectors used for splicing internal wiring shall be located within the overall enclosure so that they will not be subject to handling by the user.

Exception: This requirement does not apply if the connectors are taped to the conductors.

19.5 Wire-wrapped connections

19.5.1 A wire-wrapped connection shall comply with the requirements in 19.5.2 – 19.5.5 and in the Solderless Wire-Wrap Connections Tests, Section 54.

19.5.2 A wire-wrapped connection is acceptable if it is not subject to movement or flexure on the wires during conditions of normal operation or user servicing.

19.5.3 Solid copper wire used for wire-wrapped connections shall be 24, 22, or 20 AWG (0.21, 0.32, or 0.52 mm^2). Other sizes and types of wire may be used if investigated and found to be acceptable for the application.

19.5.3 revised March 18, 2010

19.5.4 A terminal shall be of copper or brass and have at least two sharp edges. A terminal of other materials may be used if investigated and found to be acceptable for the application.

19.5.5 A wrap shall have at least 20 points on the corners of the terminal in contact with the wire with at least 16 points closely wrapped with no overlapping. Closely wrapped means that there are no gaps between adjacent turns greater than one-half the diameter of the wire, not including gaps on the first and last turns. See Table 19.1 for typical number of wraps. A lesser number of wraps may be used if investigated and found to be equivalent to one of the wraps covered in Table 19.1.

Table 19.1
Typical number of wraps

Number of sharp corners on the terminal	Number of closely wrapped turns	Total number of turns
4	4	5
2	8	10

19.6 Aluminum terminations

19.6.1 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for interconnection between current carrying parts or as motor windings, shall be terminated at each end by a method acceptable for the combination of metals involved at the connection point.

19.6.2 With reference to 19.6.1 a wire-binding screw or a pressure wire connector used as a terminating device shall be a type intended for use with aluminum under the conditions involved – for example, temperature, heat cycling, and vibration.

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19.7 Quick-connect terminals

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

20 Remote-Control and Interconnecting Cables

20.1 A cable used as an interconnecting cable or for the connection of a remote control, or the like, shall be Type SJ, SJT, or SJE flexible cord or other cord that has been determined to be the equivalent.

Exception No. 1: A cable used solely for external interconnection between units of a system and not likely to be handled during normal operation may be of a type that is at least as serviceable as the supply cord.

Exception No. 2: Integral Type SPT-1 flexible-cord or a type that has been determined to be equivalent may be used for connection of a remote control, or a similar construction, if:

a) The remote-control circuit is supplied from a bell-ringing, or Class 2 transformer; or

b) The following conditions are met:

1) The potential between the conductors of the cord, and between any conductor and earth or other accessible part is not more than 30 volts AC or 60 volts DC where wet contact is not likely to occur and 21.2 volts peak where wet contact is likely to occur if the current between these points is more than 0.5 milliampere when tested in accordance with 36.1.2 – 36.1.8, and

2) The product does not involve a risk of fire or electric shock when it is subjected to the short-circuit test described in 50.1.1.

Exception No. 3: A cord or cable other than Type SJ, SJT, SJE, Non-Integral Type SPT-2, an appliance wiring material construction that has been determined to be equivalent to Non-Integral Type SPT-2 cord, or the equivalent, may be used for the connection of a remote control, or the like, under the conditions stated in Exception No. 2(b) if the arcing test described in 50.2.1 and 50.2.2 does not result in a risk of fire.

Exception No. 4: A cord or cable other than Type SJ, SJT, SJE, Non-Integral Type SPT-2, an appliance wiring material construction that has been determined to be equivalent to Non-Integral Type SPT-2 cord, or the equivalent, may be used for the connection of a remote control, or the like, if the cord or cable is located in a nonhazardous secondary circuit as described in 27.2.1 and 27.2.2.

20.2 A cable used as an interconnecting cable or for connection of a remote control shall have an ampacity not less than the current rating of the product, accessory, or product section it supplies. If the cable is permanently attached to the product, it shall be provided with a cord exit, strain relief, and push-back relief that comply with the requirements in 12.4.1 – 12.6.6.

20.3 Cord and wire used to interconnect units within the overall enclosure and involving a risk of fire or electric shock shall be provided with strain-relief means.

Exception: This requirement does not apply to cord or wire that is:

a) Securely fastened to the enclosure walls by means of clamps, staples, or the equivalent; or

b) Located so that it will not be subject to handling during user servicing.

20.4 Interchassis cables and wiring within an overall enclosure shall be arranged and routed by means of clamps, string ties, or the equivalent, in spaces that afford protection against damage during user servicing.

21 Integrated Circuits

21.1 An integrated circuit involving hazardous energy shall be constructed of materials and subjected to the tests specified in Table 21.1.

Table 21.1
Requirements for integrated circuits

Table 21.1 revised March 18, 2010

Alternative	Type of construction[a]	Minimum flammability classification[b]		External pin arcing test[c]	Other tests[d]
		Enclosure	Terminal support		
I	Hybrid	HB	V-1[e]	Not required	1 and 2
II	Hybrid	5V (or metal)	5V	Not required	1
III	Hybrid	5V (or metal)	V-1	Required on terminal material	1
IV	Hybrid	V-2	5V	Required on enclosure material	1
V	Hybrid	V-2	V-1	Required on enclosure and terminal material	1
VI	Nonhybrid	V-2	Not applicable	Not required	1

[a] A hybrid construction typically consists of an aluminum or ceramic substrate printed-wiring board, with chips of discrete transistors and diodes, and discrete capacitors attached to the foils. Deposited carbon usually serves as resistive elements. Terminal pins are attached to the foils on the substrate and supported in a terminal block. The typical hybrid assembly usually has a thermoplastic enclosure covering the top and three sides, and the fourth side filled with the terminal block. A nonhybrid or true integrated circuit is generally smaller than the hybrid type, is completely encapsulated, and contains only layered elements. In such a case, the enclosure of the integrated circuit, which is generally also the encapsulant, is to have a minimum flammability classification of V-2.

[b] See footnote a to Table 7.1.

[c] Tests are to be conducted in accordance with 50.2.1 and 50.2.2, except arcing is to be across the terminal-support material rather than across cotton.

[d] The numbers in this column refer to the following tests, the results of which are to be evaluated by the conditions described in 46.1.8.

1) Short-circuit tests at external IC pins, and unreliable component short-circuit tests at external IC pins.

2) Short-circuit tests at an IC assembly, and unreliable component short-circuit tests inside assembly.

[e] Includes printed-wiring board.

22 Motors, Coil Windings, and Transformers

22.1 A coil winding shall be impregnated or otherwise treated to resist the absorption of moisture.

22.2 With regard to the requirement in 22.1, film-coated wire is not required to be additionally treated to resist the absorption of moisture, but fiber, cloth, and similar moisture-absorptive materials shall be provided with impregnation or otherwise treated to resist the absorption of moisture.

22.3 A transformer or a motor transformer that is normally connected across the supply circuit shall comply with one of the following construction requirements for transformers or motor transformers as specified in:

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

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

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

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

Exception: This requirement does not apply to switching transformers.

22.3 revised November 3, 2009

22.4 A motor provided as a part of a product shall be of a type that can handle the maximum normal load of the product without introducing a risk of fire, electric shock, or injury to persons.

22.5 A brush-holder assembly shall be constructed so that when a brush is worn out – no longer capable of performing its function – the brush, spring, and other parts of the assembly will be retained to the degree necessary to reduce the likelihood of:

a) Accessible dead metal parts becoming energized and

b) Live parts becoming accessible.

23 Field-Installed Accessories

23.1 For the purpose of these requirements, accessory equipment is defined as equipment that is:

a) Intended to be attached or added to a product by the user and

b) Of such size that it may be marked for identification by a catalog number or its equivalent.

Accessory equipment is usually dependent upon the basic product for mechanical or electrical support or input and may or may not, by itself, perform a complete function.

23.2 Accessory equipment shall be constructed so that it can be added to a product without introducing a risk of fire, electric shock, or injury to persons.

23.3 The installation of accessory equipment shall be restricted to an arrangement that can be accomplished mechanically by means of ordinary tools and electrically by means of a plug-in connection to a receptacle available on the product or as a part of the building wiring.

24 Switches and Interlocks

24.1 Switches

24.1.1 A switch connected to wiring involving a risk of fire or electric shock shall be of a type acceptable for the intended use and shall have an electrical rating not less than that of the load it controls.

24.1.2 With respect to the requirements in 24.1.1, the ampere rating of a supply circuit control switch shall be equal to or greater than the maximum steady state [root-mean-square (rms)] current it controls as determined during the input test. For a power amplifier supply circuit control switch, the ampere rating shall be equal to or greater than the maximum steady state (rms) current it controls as determined during the input test specified in 38.3, at one-eighth maximum undistorted power output or one-eighth of the manufacturer's rated output power, whichever is greater.

24.2 Interlocks

24.2.1 An interlock provided to reduce a risk of electric shock or injury to persons shall be located so that unintentional operation is unlikely and constructed and installed so that it complies with either 24.2.1 (a) or (b):

a) The interlock device shall be such that it cannot be readily defeated without:

1) Damaging the product;

2) Making wiring connections or alterations;

3) Using other than ordinary tools; or

4) Using materials other than those readily available. Adhesive tape, string, or conventional extension cord sets are considered readily available.

b) The product is marked as required by 64.6.1 and during normal operation and user servicing:

1) The interlock is not likely to be defeated by improper disassembly, for example, removal of the wrong screws during removal of the cover.

2) The cover in which the interlock is mounted will not be rotated by its own weight about the interlock axis perpendicular to the cover during any stage of its removal or replacement, if such rotation gives access to a live part or damages the interlock or the cover.

3) The act of removal or replacement of the interlocked cover will not subject the user to unintentional contact with a live part. See 24.2.3.

4) The interlocked cover cannot be readily misapplied to result in a risk of electric shock, unless such misapplication is obvious during and after replacement of the cover.

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24.2.2 If two momentary contact switches must be operated to energize the product, the arrangement shall comply with 24.2.1(a)(4); and the operating means shall be spaced from each other and from live parts so that if they are operated simultaneously by one individual, contact with a live part will be unlikely.

24.2.3 A part that is recessed more than 2-1/2 inches (63.5 mm) from the edge of the cabinet opening, normal to the plane of the cover, is excluded when determining that the act of removal or replacement of a cover subjects the user to unintentional contact with a live part.

24.2.4 If it is necessary to remove a chassis from the cabinet for user servicing, the arrangement of the interlock assembly shall not be readily defeatable with the chassis out of the cabinet.

25 Spacings

25.1 General

25.1.1 In primary circuits, there shall be a spacing through air or over surface between uninsulated live parts of opposite polarity, and between an uninsulated live part and a dead metal part of not less than 1/16 inch (1.6 mm) for a circuit potential of 150 volts or less, and 3/32 inch (2.4 mm) for a circuit potential of more than 150 volts. If a part is not rigidly fixed in position by means other than friction between surfaces, the construction shall be such that at least the minimum acceptable spacing is maintained with the movable part in any position.

Exception No. 1: This requirement does not apply to the inherent spacings of a component of the product, such as a snap switch. The acceptability of the spacings on a component is judged according to the requirements for that component.

Exception No. 2: This requirement does not apply to the spacings between terminal-lead solder pads on a printed-wiring board for semiconductors, connectors, and similar miniature components having inherent spacings that provide permanent separation of the terminal leads. Such spacings are to be judged by the results of the dielectric voltage-withstand tests described in 41.2.1 – 41.4.1 and 41.7.1 – 41.8.1, as appropriate.

25.1.2 Secondary-circuit spacings shall be judged by the results of the Dielectric Voltage-Withstand Tests, Section 41.

Exception: Low-voltage, limited-energy, and nonhazardous secondary circuits as described in Low-Energy Circuits, Section 27, need not comply with this requirement.

25.1.3 The spacings in a motor shall comply with the spacing requirements in the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1.

25.1.3 revised October 3, 2013

25.2 Barriers and liners

25.2.1 A barrier or liner of fiber or similar material, employed where spacings would otherwise be unacceptable between uninsulated live parts of opposite polarity involving a potential source of fire or electric shock or between such parts and exposed dead metal parts, shall not be less than 0.028 inch (0.71 mm) thick and shall comply with the requirements in 7.1.2.

Exception No. 1: Insulation built into a component need not comply with this requirement.

Exception No. 2: If the barrier or liner is used in conjunction with an air spacing not less than one-half the required spacing through air, the thickness may be not less than 0.013 inch (0.33 mm) provided the barrier or liner is:

a) Mechanically strong if exposed or otherwise likely to be subjected to mechanical damage,

b) Held in place, and

c) Located so that it will not be adversely affected by the operation of the product in service.

26 Risk of Fire

26.1 A risk of fire is considered to exist at any component connected to a source of power either under normal conditions or when all exposed parts and all user connections are grounded while the power-supply rectifier and any two elements of one other vacuum tube, transistor, or similar solid-state device are short circuited.

Exception: A risk of fire is not considered to exist if one or more of the following conditions exist:

a) There is additional series impedance of not less than 10,000 ohms in a circuit where the voltage is 125 volts or less.

b) There is additional series impedance of not less than 20,000 ohms in a circuit where the voltage is more than 125 volts but not more than 250 volts.

c) Material, such as cotton, is not ignited under any service conditions of breakdown or malfunction of the part itself. The arcing test for cables is described in 50.2.1 and 50.2.2.

d) A component is connected in a low-voltage, limited-energy circuit as described in 27.1.2 and 27.1.4.

e) A component is connected in a nonhazardous circuit as described in 27.2.1 and 27.2.2.

27 Low-Energy Circuits

27.1 Low-voltage, limited-energy circuits

27.1.1 Spacings in a low-voltage, limited-energy circuit are not specified, other than as may be required to prevent contact with an uninsulated live part of another circuit.

27.1.2 A low-voltage, limited-energy circuit is a circuit that is supplied from an isolated secondary winding of a transformer and that complies with the applicable values specified in Table 27.1. Power limitations of a low-voltage, limited-energy circuit may be obtained by the use of any of the following configurations:

a) An inherently-limited transformer;

b) A non-inherently-limited transformer coupled with an overcurrent protective device in the output circuit;

c) A combination transformer and fixed impedance; or

d) An arrangement determined to be equivalent to (a), (b), or (c).

Table 27.1
Low-voltage, limited-energy circuits

Inherently limited transformer (overcurrent protection not required)				Not-inherently-limited transformer (overcurrent protection required)			
Circuit voltage (volts)[a]	0 – 20 volts AC or DC[b]	Over 20 volts but not more than 30 volts AC or DC[b]	Over 30 volts but not more than 60 volts DC[b]	0 – 15 volts AC or DC[b]	Over 15 volts but not more than 20 volts AC or DC[b]	Over 20 volts but not more than 30 volts AC or DC[b]	Over 30 volts but not more than 60 volts DC[b]
Power limitation (volt-amperes)[b]	–	–	–	350	250	250	250
Current limitation (amperes)[d]	8	8	150/V[a]	1000/V[a]	1000/V[a]	1000/V[a]	1000/V[a]
Maximum overcurrent protection (amperes)	–	–	–	5	5	100/V[a]	100/V[a]

NOTE – In all cases the applied primary voltage shall be as indicated in Table 33.1.

[a] Maximum output voltage, regardless of load, with applied voltage as specified in Table 33.1.

[b] The waveform shall comply with the requirements in Table 36.1.

[c] Maximum volt-ampere output regardless of load, and overcurrent protection (if provided) bypassed.

[d] Maximum output after 1 minute of operation under any noncapacitive load, including short circuit, and with overcurrent protection (if provided) bypassed.

27.1.3 The secondary winding of the transformer and the fixed series impedance or regulator specified in 27.1.2 (b) and (c) are to be evaluated as part of the hazardous energy circuit.

27.1.4 The overcurrent-protective device mentioned in 27.1.2 shall:

a) Not be of an automatically-reset type and

b) Be trip-free from the reclosing mechanism if of the manually-reset type.

27.2 Nonhazardous secondary circuits

27.2.1 A nonhazardous secondary circuit is considered to exist if the source of power to the circuit is not capable of:

a) Producing an open-circuit voltage exceeding:

1) 30 volts AC or 60 volts DC where wet contact is not likely to occur and

2) 21.1 volts peak where wet contact is likely to occur (see 11.2); and

b) Delivering a power of more than 15 watts into an external resistor connected singly between each of these points and any return to the power supply.

27.2.2 An overcurrent-protective device may be used to limit the available power in a circuit to 15 watts or less in order to comply with 27.2.1(b).

27.2.3 A printed-wiring board shall comply with the applicable requirements in Table 7.1, and wiring not segregated or routed away from wiring located in hazardous energy circuits or low-voltage, limited-energy circuits shall be rated VW-1.

27.2.4 There are no additional specifications for insulating material, spacings, and components in a nonhazardous secondary circuit other than as may be required to prevent contact with an uninsulated live part of another circuit.

PROTECTION AGAINST INJURY TO PERSONS

28 Scope

28.1 The requirements in Protection Against Injury to Persons, General, Section 29; Power-Operated Moving Parts, Section 30; Enclosures and Guards, Section 31; and Sharp Edges, Section 32; are applicable to products covered by this standard that may involve a risk of injury to persons in normal operation.

28.2 There are risks of injury to persons inherent in some products that, if completely eliminated, would defeat the utility of the product. The requirements in Sections 29 – 32 are intended to reduce such risks, while retaining the normal function of such a product.

29 General

29.1 If operation, maintenance, or reasonably foreseeable misuse of a product by the user involves a risk of injury to persons, protection shall be provided for the reduction of such risk.

29.2 Among the factors to be considered in evaluating the acceptability of an exposed moving part are:

a) Degree of exposure necessary to perform its intended function,

b) Sharpness of the moving part,

c) Risk of unintentional contact therewith,

d) Speed of the moving part, and

e) Risk that a part of the body would be endangered or that clothing would be entangled by the moving part.

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

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

29.4 A product shall be subjected to the tests described in this section and the Strength of Enclosure Tests, Section 55, to determine compliance with the requirement in 29.1.

30 Power-Operated Moving Parts

30.1 The accessibility of a power-operated moving part, such as a gear or linkage, is to be judged by the applicable accessibility requirements in 10.1.1 – 10.3.1. The accessibility requirements are to be applied after the installation or assembly of parts provided by the manufacturer has been completed in accordance with the instructions provided by the manufacturer.

Exception: The requirement does not apply to a tape reel, a tape-drive mechanism or a piano-roll-drive mechanism that must be exposed for intended use. However, a gear or linkage is to be judged for accessibility if the construction permits that part to move with a tape reel, cartridge, cassette, or piano roll removed from its operating position.

31 Enclosures and Guards

31.1 An opening in a guard or enclosure around a part that is capable of causing injury shall have a minor dimension less than 1 inch (25.4 mm), and shall not permit the probe illustrated in Figure 10.1 to contact the part when inserted as described in 10.1.3.

31.2 A guard or portion of an enclosure acting as a guard for parts capable of causing injury shall be:

a) Mounted to the assembly so that such parts cannot be operated with a guard removed,

b) Secured to the assembly using fasteners requiring a tool for removal, or

c) Provided with an interlock to protect against access to the source of injury.

32 Sharp Edges

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

Exception: This requirement does not apply to a part or portion of a part needed to perform a working function.

PERFORMANCE

33 General

33.1 Voltmeters

33.1.1 Unless otherwise indicated, voltage measurements are to be made with a voltmeter having a resistance of 2000 ohms per volt minimum for potentials of 1000 volts or less.

33.1.2 The open-circuit-voltage measurement used in conjunction with a leakage or shock-current determination is to be made with a measuring instrument that has an input impedance that does not significantly affect the circuit being measured. In general, a measuring instrument with a minimum input impedance of 1 megohm is to be used.

33.2 Cheesecloth indicators

33.2.1 The cloth used for tests is to be bleached cheesecloth running 14 – 15 square yards per pound (26 – 28 m^2/kg) and having what is known in the trade as a count of 32 by 28, that is, for any square inch, 32 threads in one direction and 28 threads in the other direction (for any cm^2, 13 threads in one direction and 11 threads in the other direction).

33.2.2 Tests involving cheesecloth are to be conducted in a room free of drafts.

33.3 Supply circuit

33.3.1 All operational tests are to be conducted with the product connected to a supply circuit of rated frequency and the voltage specified in Table 33.1. A product with a dual-frequency rating is to be tested at 60 hertz if 60 hertz is included in the rating and may also be tested at the second frequency if such testing is warranted.

Table 33.1
Operation test voltages

Marked voltage rating between[a]	Test voltage for normal-operation tests	Tests voltage for abnormal-operation tests
105 – 130	Maximum marked voltage, but not less than 120	130[b]
210 – 260	Maximum marked voltage, but not less than 240	110 percent of maximum marked voltage, but not less than 240 or more than 260[b]

[a] Primary circuit adjustments, if any, are to be set for the minimum voltage that is in the 105 – 120 volt range, or in the 210 – 240 volt range, and the potential of the supply circuit is to be as prescribed for the applicable voltage range.

[b] The test voltage may be reduced to a lower value, but not less than 105 volts or 210 volts, as applicable, if the lower value will represent a more severe condition or if a higher voltage would cause a protective device to open the circuit.

33.3.2 A product having both alternating-current and direct-current ratings is to be tested with the product connected to an alternating-current supply and again to a direct-current supply.

Exception: If it can be established that one test results in the most severe operating conditions, only that test need be conducted.

34 Normal-Operation Tests

34.1 Operation of a product as described in 34.2 shall not increase the risk of fire, electric shock, or injury to persons.

34.2 A sample of the product in the as-received condition is to be set up or installed and operated in accordance with the manufacturer's instructions with respect to the intended use of the product, including normal maintenance and cleaning, with all accessories supplied by the manufacturer for use with the product in place. The product is to be manipulated as it would be in actual use, including manipulation of all controls, and operated under the various loading conditions that can be expected. Operation is to be for a sufficient length of time or through a sufficient number of cycles that all reasonably foreseeable complications are revealed.

35 Connector- and Component-Displacement and -Substitution Tests

35.1 General

35.1.1 The disconnection and displacement of a part resulting from shipping or moving of the product shall not result in a risk of fire, electric shock, or injury to persons.

35.1.2 Any handling, disconnection, or displacement either intentional or unintentional, of a component of a printed-wiring assembly, a connector, lead, tube shield, cover, or other similar part that may occur during normal operation or user servicing shall not result in a risk of fire, electric shock, or injury to persons.

35.1.3 A barrier, mechanical restraint, and the effect of gravity are to be given consideration as means of fastening a connector, but a fastening means that relies solely on friction between parts is to be investigated with respect to its effectiveness. A fastening means is not to be removed if it cannot be removed unintentionally and need not be removed during user servicing. A flexible fastening means is to be constructed so that it returns to its original position and shape after flexing.

35.1.4 Inserting a male connector in a female connector other than the one intended to receive it, misalignment of male and female connectors, and other manipulations of parts that are accessible to the user shall not result in a risk of fire, electric shock, or injury to persons.

35.1.5 A disconnecting part, such as an electrical connector, secured by friction fit only, is to be investigated with respect to risks of fire or electric shock while in its most extreme disconnected position.

Exception: The part need not be so investigated if it complies with one or more of the following:

a) The part withstands a separation force of 1.1 pounds (500 grams) after five insertions and withdrawals;

b) The part is soldered together and need not be removed for user servicing;

c) The part is of such dimensions or is permanently routed or secured that no risk of fire, electric shock, or injury to persons can result if the part becomes disconnected; or

d) A 1/32-inch (0.8-mm) thick aluminum insulating sleeve having at least a 1/16-inch (1.6-mm) overlap is provided over the connector part.

35.2 Vacuum-tube substitution

35.2.1 The insertion in any socket of any vacuum tube or its glass or metal equivalent of like designation used in the product shall not result in a risk of electric shock.

36 Leakage-Current and Shock-Current Tests

36.1 Leakage-current test

36.1.1 Leakage current refers to all currents, including capacitively coupled currents, that may be conveyed between exposed conductive surfaces of the equipment and ground, or other exposed conductive surfaces of the equipment.

36.1.2 If the open circuit potential between the accessible part and earth ground or any other accessible part is more than the applicable value specified in Table 36.1, a product shall be tested for leakage current in accordance with 36.1.3 – 36.1.9. The leakage current at any accessible part shall not be more than:

a) 0.5 milliampere for ungrounded 2-wire portable, stationary, or fixed equipment;

b) 0.5 milliampere for grounded 3-wire portable equipment; and

c) 0.75 milliampere for grounded 3-wire stationary or fixed equipment.

Table 36.1
Maximum voltages

Wave form		Fundamental frequency, hz		Maximum volts peak[a]
Alternating current, direct current, and combinations of both	**Polarity reversal**	**Greater than**	**But not greater than**	**Wet contact not likely to occur[b]**
Where the change in instantaneous voltage for any duration equal to 5 percent of the period of the fundamental frequency of the wave form is not more than 20 volts.[c]	Where the instantaneous voltage does not reverse in polarity	Any		60
	Where the instantaneous voltage does reverse in polarity	Any		60 volts peak and 84.4 volts peak-to-peak[d]

Table 36.1 Continued on Next Page

Table 36.1 Continued

Wave form		Fundamental frequency, hz		Maximum volts peak[a]
Alternating current, direct current, and combinations of both	**Polarity reversal**	**Greater than**	**But not greater than**	**Wet contact not likely to occur[b]**
Where the change in instantaneous voltage for any duration equal to 5 percent of the period of the fundamental frequency of the wave form is greater than 20 volts.[c]	Where the instantaneous voltage does not reverse in polarity	0	3	60
		3	4	55
		4	5	50
		5	6	45
		6	7	40
		7	8	35
		8	9	30
		9	10	25
		10	200	24.8
		200	300	26
		300	400	28
		400	500	31
		500	600	34
		600	700	37
		700	800	41
		800	900	46
		900	1000	51
		1000	1400	56
		1400		60
	Where the instantaneous voltage does reverse in polarity	Values to be determined by an investigation to determine equivalent protection level		

[a] The maximum output voltage regardless of load shall be measured with the input voltage applied per Table 33.1.

[b] "Wet contact not likely to occur" generally refers to indoor or sheltered locations that are not normally associated with water or other liquids.

[c] The change in instantaneous voltage at any 5 percent of the period of the fundamental frequency of the wave form is to be determined by taking any 18-degree segment along with the wave form and determining the change in instantaneous voltage in that segment.

[d] For a sinusoidal wave, 84.8 volts peak-to-peak equals 30 volts rms.

36.1.3 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 where simultaneously accessible, and from one surface to another where simultaneously accessible. A part is considered to be an exposed surface unless guarded by an enclosure considered to reduce the risk of electric shock.

36.1.4 Parts are considered to be simultaneously accessible if they can be contacted by one or both hands of a person at the same time. For the purpose of this measurement, one hand is considered to be able to simultaneously contact parts that are within a 4 by 8 inch (100 by 200 mm) rectangle; and two hands of a person are considered to be able to simultaneously contact parts that are not more than 6 feet (1.8 m) apart.

36.1.5 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 is less than 10 by 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the equipment.

36.1.6 The measurement circuit for the leakage-current test is to be as illustrated in Figure 36.1. 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 the particular measurement as would the defined instrument; it need not have all of the attributes of the defined instrument:

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

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

c) Over a frequency range of 0 – 100 kilohertz, the measurement circuitry 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 milliampere, the measurement is to have an error of not more than 5 percent at 60 hertz.

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

36.1.8 A sample of the product is to be tested for leakage current starting with the as-received condition with all switches closed, but with its grounding conductor, if any, open at the attachment plug. A product that has not been energized for a minimum of 48 hours prior to the test and that is at room temperature is considered to be in the as-received condition. The supply voltage is to be the maximum voltage marked on the equipment, but not less than 120 or 240 volts. The test sequence, with reference to the measuring circuit – Figure 36.1 – is to be as follows:

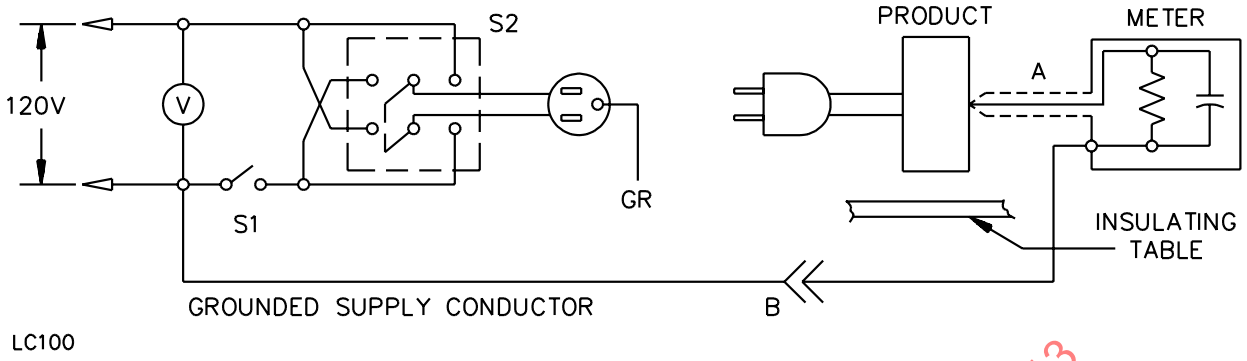
a) With switch S1 open, the product is to be connected to the measuring circuit. Leakage current is to be measured using both positions of switch S2, and with the product switching devices in all of their normal-operating positions.

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, and with the product switching devices in all their normal-operating positions.

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

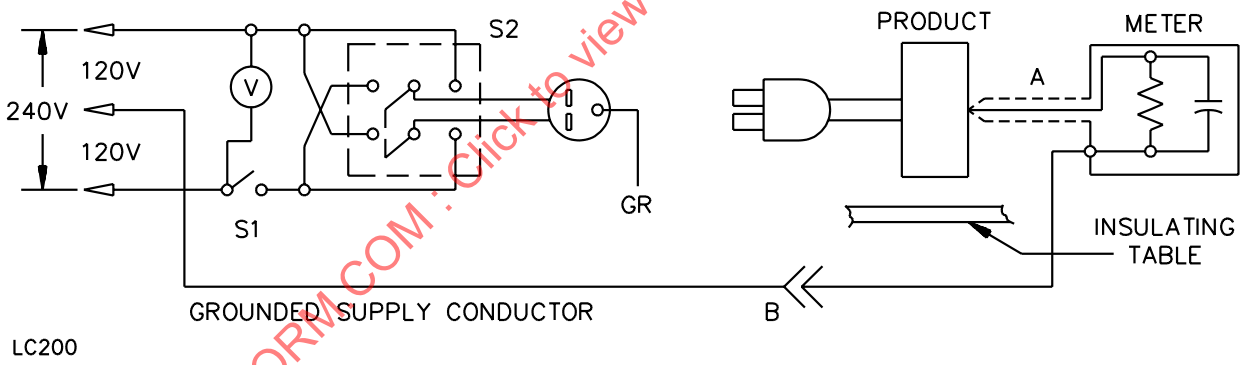
36.1.9 Normally, the complete leakage current test described in 36.1.8 is to be conducted without interruption for other tests. With the concurrence of those concerned, the leakage current test may be interrupted for the purpose of conducting other nondestructive tests.

Figure 36.1
Leakage current measurement circuits



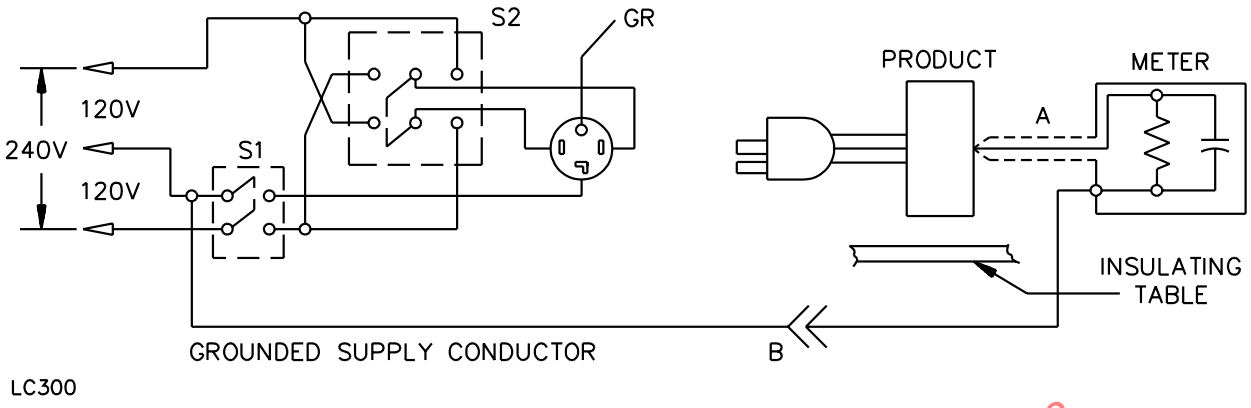
LC100

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.



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

A – Probe with shielded lead.

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

36.2 Shock-current test

36.2.1 General

36.2.1.1 If the open-circuit potential between any part exposed only during user servicing and earth ground or any other simultaneously accessible part exceeds the values specified in Table 36.1:

a) The continuous current flow through a 500-ohm resistor shall not exceed the limits specified in Table 36.2,

b) The peak current shall not exceed 809 milliamperes regardless of duration,

c) The combination of magnitude and duration of peak current flow shall not exceed the limits specified in 36.2.3.1, or

d) The combination of capacitance and voltage shall not exceed the limits specified in 36.2.2.1.

Table 36.2
Current during user servicing

Frequency, hertz[a]	Maximum current through a 500-ohm resistor, milliamperes peak
0 – 100	7.1
500	9.4
1,000	11.0
2,000	14.1
3,000	17.3
4,000	19.6
5,000	22.0
6,000	25.1
7,000 or more	27.5

[a] Linear interpolation between adjacent values may be used to determine the maximum current corresponding to frequencies not shown. The table applies to repetitive nonsinusoidal or sinusoidal waveforms.

36.2.1.2 If the product has a direct-current rating, measurements are made with the product connected in turn to each side of a 3-wire, direct-current supply circuit.

36.2.1.3 Unreliable insulation, such as that usually used between the voice coil and the frame of a speaker, between live parts and the metal frame of a phonograph pickup cartridge, between the two channels of a stereophonic-phonographic pickup cartridge, and between the plates of an adjustable or variable air-dielectric capacitor, may be short-circuited during this test.

36.2.1.4 An unreliable component, such as a rectifier, vacuum tube, electrolytic capacitor, transistor, or other solid-state device that affects the shock current shall be open-circuited or short-circuited one at a time during the tests.

36.2.1.5 Current measurements are made:

a) With any operating control, or adjustable control that is subject to user operation, in all operating positions; and

b) Either with or without a tube, separable connector, or similar device in place.

36.2.2 Stored voltage

36.2.2.1 The maximum capacitance between capacitor terminals that are accessible during user servicing shall satisfy the following equations:

$$C = \frac{88{,}400}{E^{1.43}(L_n E^{-1.26})} \quad for \quad 21.2 \leq E \leq 400$$

$$C = 35{,}288 E^{-1.5364} \quad for \quad 400 \leq E \leq 1000$$

in which:

C is the maximum capacitance of the capacitor in microfarads,

E is the potential in volts across the capacitor prior to discharge, and

ln is the natural logarithm (base e).

36.2.2.2 To determine whether a capacitor complies with the requirement in 36.2.2.1, the potential E is to be measured 5 seconds after the capacitor terminals are accessible by the removal or opening of an interlocked cover, or the like. Typical calculated values are given in Table 36.3.

Table 36.3
Stored voltage

Potential across capacitance prior to discharge, volts	Maximum acceptable capacitance, microfarads
1000	0.868
900	1.02
800	1.22
700	1.50
600	1.90
500	2.52
400	3.55
380	3.86
360	4.22
340	4.64
320	5.13
300	5.71
280	6.40
260	7.24
240	8.27
220	9.56

Table 36.3 Continued on Next Page

Table 36.3 Continued

Potential across capacitance prior to discharge, volts	Maximum acceptable capacitance, microfarads
200	11.2
180	13.4
160	16.3
140	20.5
120	26.6
100	36.5
90	43.8
80	53.8
70	68.0
60	89.4
50	124.00
45	150.00
42.4	169.00
40	186.00[a]
30	319.00[a]
25	452.00[a]
21.2	625.00[a]

[a] Where wet contact is likely to occur only.

36.2.3 Transient current

36.2.3.1 The duration of a transient current – direct or alternating – through a 500-ohm resistor connected between any part exposed only during servicing and earth ground or any other accessible part shall satisfy the following equation:

$$T \leq \left(\frac{20\sqrt{2}}{I}\right)^{1.43}$$

in which:

T is the duration, measured in seconds, from the time that the instantaneous value of the current first exceeds 7.1 milliamperes until the time that the current falls below 7.1 milliamperes for the last time, and

I is the peak current in milliamperes.

The interval between occurrences shall be equal to or greater than 60 seconds if the current is repetitive. The peak current shall not exceed 809 milliamperes regardless of duration. Typical calculated values are given in Table 36.4.

Table 36.4
Transient current

Maximum peak current (I) through 500-ohm resistor, milliamperes	Maximum acceptable duration (T) of waveform containing excursions greater than 7.1 milliamperes peak, seconds
7.1	7.26
8.5	5.58
10.0	4.42
12.5	3.21
15.0	2.48
17.5	1.99
20.0	1.64
22.5	1.39
25.0	1.19
30.0	0.919
40.0	0.609
50.0	0.443
60.0	0.341
70.0	0.274
80.0	0.226
90.0	0.191
100.0	0.164
150.0	0.092
200.0	0.061
250.0	0.044
300.0	0.034
350.0	0.027
400.0	0.023
450.0	0.019
500.0	0.016
600.0	0.012
700.0	0.010
809.0	0.0083

37 Resistance of Grounding Circuit Test

37.1 The resistance between the point of connection of the equipment-grounding means, at or within the product, and any other point in the grounding circuit shall not be more than 0.1 ohm.

37.2 Any appropriate instrument may be used to determine whether a product complies with the requirement in 37.1, but if unacceptable results are obtained, an alternating current of at least 25 amperes from a power supply of not more than 12 volts is to be passed from the point of connection of the equipment-grounding means to any point in the grounding circuit. The current and the resulting drop in potential are to be measured between the two points. The resistance in ohms is to be determined by dividing the drop in potential in volts by the current in amperes passing between the two points. The grounding conductor of a power-supply cord is not to be tested by the latter method.

38 Power-Input Test

38.1 The current or wattage consumption of a product shall not exceed the marked input rating by more than 5 percent when the product is operated under normal conditions as specified in 38.2 – 38.10 while connected to a supply circuit of rated frequency and voltage as specified for normal operation in Table 33.1.

38.2 An organ or similar musical instrument having a tone generator shall be operated with any ten keys and two foot-pedals, if provided, depressed. Those stops and tabs causing the organ to operate under conditions of maximum load are to be activated. A matched resistive load is to be connected across the output of the product, and speakers, if provided, are to be disconnected and replaced by matched resistive loads. Input power (or current) is then to be determined according to the following equation:

$$P_{in} = P_o + \frac{1}{3}(P_{max} - P_o)$$

in which:

P_{in} is the calculated normal input power,

P_o is the measured input power under no signal conditions, and

P_{max} is the measured input power with the volume control adjusted to deliver maximum output and with ten keys and two foot-pedals depressed.

Exception: At the manufacturer's request, a 1-kHz or geometric mean frequency sine wave may be used as the input signal for a product employing a power amplifier. The input signal is to be applied to the first stage of the amplifier circuit. Input power or current is to be determined with the amplifier delivering one-eighth of the maximum undistorted output power into internal speakers or matched resistive loads when operated as specified in 38.5 – 38.9.

38.3 The input power or current of a product incorporating an amplifier and provided with auxiliary input jacks, with or without tone generators, is to be determined with the amplifier delivering one-eighth of the measured maximum undistorted output power or one-eighth of the manufacturer's marked output power, whichever is greater, into matched resistive loads when operated as specified in 38.5 – 38.9. The test is to be repeated for each audio-load-impedance tap provided, and in each test the resistive load is to closely match the rated-output load of the amplifier taps.

38.4 Each input and corresponding output of a biamplifier, multichannel amplifier, or other product that has an effect on the total power consumption of the product is to be operated simultaneously under the conditions specified in 38.3.

38.5 The audio-input connections of the product to be tested are to be connected to a sinewave oscillator. The frequency of the oscillator is to be adjusted to 1000 hertz.

Exception: The geometric-mean-frequency of each channel is to be applied as the input signal for each channel of a product intended to cover only a limited portion of the audio-frequency range, such as a bass amplifier, biamplifier, and the like.

38.6 The geometric-mean-frequency is equal to the square root of the product of the low-frequency limit and the high-frequency limit. The low-frequency limit is to be 20 hertz or the manufacturer's rated value, whichever is higher; the upper frequency limit is to be 20 kilohertz or the manufacturer's rated value, whichever is lower.

38.7 Tone controls, filters, and wave-shaping controls are to be set in the flat-response positions. The volume control is to be initially set in the middle of its range. The output connectors are to be connected to a resistive load matched to the manufacturer's output-load rating. Speakers provided with the product are to be electrically replaced with an equivalent resistive load unless the manufacturer requests that the speakers provided or sold with the product be used.

38.8 The sine wave oscillator output and amplifier volume control are to be adjusted to deliver maximum undistorted output power. The amplifier input used for the sine wave oscillator output is to be selected such that the sine wave is not distorted at a stage (for example, preamp) prior to amplification. Maximum undistorted output power is to be determined by visually examining the wave shape for clipping using an oscilloscope. If there is a question about clipping or flattening of the output sine wave, a distortion analyzer may be used to measure the total harmonic distortion (THD) present in the waveform. The THD is to be no greater than 1 percent. This is to be repeated for the range of audio load impedance taps and corresponding wattage ratings for the amplifier.

38.9 Each unused receptacle or connector, other than a conventional parallel-slot receptacle that is used to supply power to another product or accessory, is to be loaded to its maximum rating.

38.10 Other types of products not covered by 38.2 – 38.4 are to be tested under conditions closely approximating normal operating conditions.

39 Temperature Test

39.1 When a product is tested as specified in this section:

a) The temperature at any part shall not be sufficiently high to constitute a risk of fire or to adversely affect any materials employed and

b) A thermal- or overcurrent-protective device shall not function.

39.2 The temperatures specified in Table 39.1 are based on an assumed ambient temperature of 25°C (77°F). A test may be conducted at an ambient temperature within the range of 10 – 40°C (50 – 104°F).

Table 39.1
Maximum acceptable temperatures

Materials and components	°C	(°F)
A. MOTORS		
1. Class A insulation system on coil windings of an AC motor having a frame diameter not more than 7 inches (178 mm) and of a universal motor[a,b]		
a) In an open motor:		
Thermocouple or resistance method	100	212
b) In a totally enclosed motor:		
Thermocouple or resistance method	105	221
2. Class A insulation systems on coil windings of an AC motor having a frame diameter of more than 7 inches (178 mm), and of a DC motor[a,b]		
a) In an open motor:		
Thermocouple method	90	194
Resistance method	100	212
b) In a totally enclosed motor:		
Thermocouple method	95	203
Resistance method	105	221
B. COMPONENTS		
1. Capacitor[c]:		
a) Electrolytic	65	149
b) Other type	85	185
2. Conductor, rubber- or thermoplastic-insulated[c]:	60	140
3. Fuse:		
Class G, J, L, T, or CC:		
Tube	125	257
Terminals	90	194
Other[d]	90	194
4. Rectifier		
a) Selenium[d]	75	167
b) Silicon[d,e]	100	212
5. Windings of a relay, solenoid, magnet, transformer, and the like (except motor coil windings) with Class 105 insulation systems[a]		
Thermocouple method	90	194
Resistance method	100	212
6. Wood and other combustible material	90	194
C. ELECTRICAL INSULATION – GENERAL		
1. Fiber employed as electrical insulation	90	194

Table 39.1 Continued on Next Page

Table 39.1 Continued

Materials and components	°C	(°F)
2. Phenolic composition employed as electrical insulation or as a part the deterioration of which could result in a risk of fire of electric shock[d]		
a) Laminated	125	257
b) Molded	250	302
3. Varnished-cloth insulation	85	185
D. SURFACES		
1. Exterior surface of an overall enclosure	90	194
2. Enclosure of polymeric material[d]		
a) Portable product	65	149
b) Stationary product	50	122
3. Handle or knob	See Table 39.2	

[a] At a point on the surface of a coil where the temperature is affected by an external source of heat, a hot-spot temperature not higher than 105°C (221°F) on the surface of a coil winding is acceptable if the temperature, as measured by the resistance method, is not more than that specified in the table.

[b] The motor diameter is to be measured in the plane of the laminations as the diameter of the circle circumscribing the stator frame. All lugs, fins, boxes, and the like used solely for motor mounting, cooling, assembly, and connection are to be excluded.

[c] A capacitor operating at a temperature higher than that specified in the table may be judged on the basis of its marked temperature rating. If not marked with a temperature rating, it may be investigated to determine its acceptability at the higher temperature.

[d] This limitation does not apply to an insulated conductor, a rectifier, a material, or component that has been investigated and determined to be acceptable for a higher temperature.

[e] A rectifier operating at a temperature higher than 100°C (212°F) may be judged on the basis of its case temperature at the actual current compared with the case temperature at rated current – derating curves.

Table 39.2
Maximum surface temperature

Location	Composition of surface[a]	
	Metal	Nonmetallic
Handles or knobs that are grasped for lifting, carrying, or holding	50°C (122°F)	60°C (140°F)
Handles or knobs that are contacted but do not involve lifting, carrying, or holding, and other surfaces subject to contact and user maintenance	60°C (140°F)	85°C (185°F)

[a] A handle, knob, or the like made of a material other than metal, that is plated or clad with metal having a thickness of 0.005 inch (0.13 mm) or less is considered to be, and is judged as, a nonmetallic part.

39.3 During a test conducted at an ambient temperature of 25°C (77°F), an observed temperature shall not exceed the values specified in Table 39.1.

39.4 If a test is conducted at an ambient temperature other than 25°C (77°F), an observed temperature shall be corrected as described in 39.5. A corrected temperature shall not exceed the values specified in Table 39.1.

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

39.6 If a corrected temperature exceeds the values specified in Table 39.1, at the request of the manufacturer, the test may be repeated at an ambient temperature closer to 25°C (77°F).

39.7 The product is to be operated until thermal equilibrium is reached:

a) At the input measured in the Power-Input Test, Section 38;

b) With all unused receptacles loaded to their maximum rating; and

c) With the product mounted, positioned, closed, or enclosed to represent intended use when use conditions are not specified in this section.

Exception: A product incorporating an amplifier and provided with auxiliary input jacks with or without tone generators is to be tested as described in 39.8.

39.8 The equipment is to be operated with a pink noise audio input signal (band-limited at 12 decibels per octave, 20 hertz to 20 kilohertz, equal energy per octave) connected to each input affecting the power consumption of the unit, coupled through a filter circuit with a frequency roll-off of minimum 12 decibels per octave as follows. The amplitude-probability distribution shall be three standard deviations. The low and high frequency figures of the amplifier mentioned as follows are those given by the manufacturer:

a) Low Frequency – Corner frequency (point where audio signal is down 3 decibels) of high pass filter set at 50 hertz or as close as practicable to twice the low frequency response figure, whichever is greater.

b) High Frequency – Corner frequency of low pass filter set at 20 kilohertz or as close as practicable to one half the high frequency response limit figure, whichever is lower.

The signal amplitude is to be adjusted to cause the unit to deliver power equal to one-eighth of the measured maximum undistorted output power as described in the Power-Input Test, Section 38, or one-eighth of the manufacturer's rated output power, whichever is greater, into the matching load impedance that produced the maximum input power consumption. The output power is to be calculated using the relation:

$$P = \frac{E^2}{R}$$

in which:

E is the voltage measured by a true rms indicating voltmeter across the noninductive resistive output load R.

Exception: At the manufacturer's request, the temperature test may be conducted using a 1 kilohertz or geometric mean frequency sine wave input signal instead of the pink noise audio input signal. Pink noise shall be used where the construction of the amplifier is such that using a sine wave does not represent loading of the amplifier.

39.9 Thermal equilibrium is considered attained when three successive readings taken at 15-minute intervals indicate that the temperature of the part has not changed by more than ±1/2°C over the 30-minute period.

39.10 Ordinarily, the temperature of a coil or winding is to be measured by means of thermocouples mounted on the outside of the coil wrap. If the coil is inaccessible for mounting thermocouples– for instance, a coil immersed in sealing compound, or if the coil wrap includes thermal insulation or more than 1/32 inch (0.8 mm) of cotton, paper, rayon, or similar insulation – the resistance method is to be used. For the thermocouple-measured temperature of a coil of an alternating-current motor other than a universal motor having a frame diameter of 7 inches (178 mm) or less, as specified in item A of Table 39.1, the thermocouple is to be mounted on the integrally applied insulation of the conductor.

39.11 It is common practice to employ thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wire and a potentiometer-type instrument, and such equipment is to be used whenever referee temperature measurements by thermocouples are necessary.

39.11 revised March 18, 2010

39.12 When determining the temperature by the change in resistance method, the windings are to be at room temperature at the start of the test. The temperature of a winding is to be calculated by using the following equation:

$$T = \frac{R}{r}(k + t_1) - k$$

in which:

T is the temperature in degrees C;

R is the resistance of the coil at the end of the tests in ohms;

r is the resistance of the coil at the beginning of the test in ohms;

k is 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum. Values of the constant (k) for other grades must be determined; and

t_1 is the room temperature at the beginning of the test in degrees C.

39.13 Rubber-like and felt materials are to be removed from supporting feet to the extent that they are likely to be worn off in service. Horizontal ventilating screens that are subject to the accumulation of dust and lint and that have holes less than 3/64 inch (1.2 mm) in diameter are to be covered with loose cotton.

39.14 The product is to be set up or mounted as in actual service and connected to a supply circuit of the voltage specified for normal operation in Table 33.1.

39.15 The product is to be placed on a horizontal supporting surface and spaced 1 inch (25.4 mm) from a vertical wall surface of wood or comparable material.

Exception No. 1: The product may be operated in the open if ventilation or other cooling factors are arranged so that operation against a wall will not increase operating temperatures.

Exception No. 2: If the construction of the product is such that a spacing greater than 1 inch is maintained, the product is to be operated at that spacing.

39.16 Doors and covers that may be closed during operation of the product are to be closed during the test.

Exception: Consideration may be given to the actual conditions of normal operation of the product, including the changing of tape reels, cassettes, and the like.

39.17 During the temperature test, the temperature on surfaces that may be contacted by the user shall not be more than the values specified in Table 39.2. If the test is conducted at a room temperature of other than 25°C (77°F), the results are to be corrected to that temperature.

40 Audio-Output Test

40.1 The audio-output potential of exposed or accessible output terminals shall not exceed 100 volts when tested as specified in 40.2.

40.2 A variable-frequency signal generator is to be connected to the input terminals, and an adjustable load resistor is to be connected across the output terminals. If the output terminals are marked to indicate the load impedance that should be connected, the test impedance is to be adjusted to have a value equal to the rated output-load impedance of the amplifier, and the input-signal voltage is to be adjusted to such a value that the device delivers maximum available undistorted-sine-wave power to the load. If the output terminals are marked with a voltage rating, the value of the test-load impedance is to be adjusted to the value calculated on the basis of the rated power output of the amplifier ($R = E^2/W$), and the input-signal voltage is to be adjusted to give the maximum available undistorted-sine-wave power to the load. After the adjustments specified above are made in accordance with the marking on the output terminals, the output circuit is to be opened and the potential across the output terminals measured. The test is to be conducted over the range from 60 to 100 hertz – in steps of 10 – by adjusting the signal generator. Throughout these tests, the product is to be connected to a supply circuit of the voltage as specified in normal operation in Table 33.1.

41 Dielectric Voltage-Withstand Tests

41.1 General

41.1.1 The insulation and spacings of a product shall withstand without breakdown for 1 minute the application of the test potentials specified in Table 41.1.

Exception: This requirement does not apply if an investigation shows that such breakdown will not result in a risk of fire or electric shock.

Table 41.1
Dielectric voltage-withstand test potentials

Component being tested	Applied potential	Applicable paragraphs
Primary circuit	1000 V, 60 Hz	41.2.1 and 41.2.2
Isolating transformer	1000 V, 60 Hz	41.3.1
Primary insulation	1000 V, 60 Hz	41.4.1
Output circuit	4E[a] DC, (1270 V minimum)	41.5.1
Power transformer	3E[a] DC, (500 V minimum)	41.6.1 – 41.6.4
Direct-connected power supply	3E[a] DC, (1270 V minimum)	41.7.1 – 41.7.3
Printed-wiring assembly	2E[a] + 1000 V, DC	41.8.1
Basic insulation	1000 V, 60 Hz	13.1.9
Supplementary insulation	2500 V, 60 Hz	13.1.10
Reinforced insulation	3500 V, 60 Hz	13.1.11

[a] E is the maximum peak potential between the parts when measured with the product operated under the conditions described in 41.9.2 – 41.9.5.

41.1.2 The dielectric voltage-withstand tests are to be conducted with the product at its normal operating temperature.

41.1.3 In conducting the dielectric voltage-withstand test, the applied 60-hertz voltage is to be monitored with a voltmeter having a minimum resistance of 2000 ohms per volt. Breakdown, not leakage, is to be the criterion of nonacceptability. Breakdown is caused by insufficient insulation or spacing and is indicated by an abrupt decrease or retarded advance of the voltmeter reading. Leakage is the normal flow of current due to imperfect insulating materials and can vary with the applied voltage.

41.1.4 The 60-hertz test potentials specified in Table 41.1 are to be obtained from a testing transformer, the output voltage of which can be varied. The direct-current test potential is to be obtained from any convenient direct-current supply having an output of sufficient potential and that can be varied. The applied potential is to be increased from zero until the required test value is reached and is to be held at that value for 1 minute. The increase in the applied potential is to be at a substantially uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter.

41.2 Primary circuit

41.2.1 A 1000-volt, 60-hertz potential shall be applied between any live part conductively connected to the supply circuit and any exposed metal part, dead metal part, or user terminal such as an audio-jack-ground lead.

41.2.2 If an isolating power transformer is not a part of the product, the test specified in 41.2.1 is to be conducted with each vacuum tube removed, filament circuit short-circuited, and electrolytic capacitor and plate-cathode rectifier terminals short-circuited.

41.3 Isolating power transformer

41.3.1 If an isolating power transformer is employed, a 1000-volt, 60-hertz potential shall be applied between any live or current-carrying part of the primary or power-supply circuit and any live or current-carrying part of the secondary circuit.

41.4 Primary insulation

41.4.1 A 1000-volt, 60-hertz potential shall be applied across each capacitor, winding separation, or other insulation required for reducing the risk of electric shock or that, if short-circuited, would involve a risk of fire, either directly or indirectly.

Exception: The potential need not be applied across insulation in the secondary circuit of an isolating power transformer.

41.5 Output circuit

41.5.1 If a product has provision for connection of an external speaker, a direct-current potential of four times the maximum direct-current, open-circuit voltage measured in the output tube or transistor circuit, but not less than 1270 volts, shall be applied across a blocking capacitor (other than an electrolytic type) and between the primary and secondary windings of an isolating-output transformer, the output circuit of which is isolated from the chassis and used for speaker coupling.

41.6 Power-transformer secondary

41.6.1 If a power transformer is employed, the secondary circuit of which involves a risk of fire or electric shock, a direct-current potential of three times the maximum voltage determined in accordance with 41.9.1 – 41.9.5, but not less than 500 volts, shall be applied between live parts of opposite polarity in the secondary circuit and between such live parts and accessible metal parts. An electrolytic capacitor may be accepted under the provision of 43.1.

41.6.2 Each electrolytic capacitor, tube, transistor, lamp, and the like, is to be removed from the circuit. A bleeder resistor or other power-consuming device is to be disconnected in the negative side of the circuit.

41.6.3 The voice-coil-circuit connections and the frame of the loudspeaker are to be connected electrically to the chassis so that the insulation of the output transformer or capacitor is stressed.

41.6.4 A tone control, switch, or other component part involving user control elements is to be adjusted to the various operating positions that provide for the connection of these parts in the circuit under test.

41.7 Direct-connected power supply

41.7.1 If a direct-connected power supply is employed, a direct-current potential of three times the maximum voltage determined in accordance with 41.9.1 – 41.9.5, but not less than 1270 volts, is to be applied between live parts of opposite polarity on the load side of the rectifier.

41.7.2 Each electrolytic capacitor, tube, transistor, lamp, and the like is to be removed from the circuit. A bleeder resistor or other power-consuming device is to be disconnected at the negative side of the circuit. Anode and cathode terminals of the rectifier are to be short-circuited.

41.7.3 The test potential may be obtained from any convenient direct-current supply the voltage of which can be varied. Starting at zero, the applied potential is to be increased gradually until the required test value is reached or until breakdown occurs.

41.8 Printed-wiring assembly

41.8.1 A printed-wiring assembly shall withstand the specified potential between printed-wiring parts, and between printed-wiring parts and other parts where electrical breakdown over the surface of the printed-wiring board insulating material would result in a possible risk of electric shock.

41.9 Maximum voltage test

41.9.1 The maximum voltage used as a basis for the calculation of the dielectric voltage-withstand potentials specified in 41.5.1 – 41.8.1 shall be determined in accordance with 41.9.2 – 41.9.5.

41.9.2 To obtain the maximum voltage, any combination of tubes and fuses may be removed.

41.9.3 An automatic voltage-regulating device is to be rendered inoperative.

Exception: The device need not be rendered inoperative if, upon investigation, it is found that the device can be relied upon to prevent an increase in voltage. The investigation is to take into consideration any likely breakdown or malfunction in either the regulating device or the product, and the possibility of the device being disconnected, if it is not permanently connected in the circuit.

41.9.4 A connector or comparable part that is likely to be disconnected during normal operation or user servicing is to be both connected and disconnected during the test so that the maximum voltage may be obtained.

41.9.5 If a complex voltage is involved, the peak value of the voltage is to be measured.

42 Leakage Current After Humidity Conditioning Test

42.1 A portable product shall comply with the requirements for leakage current in 36.1.2, following exposure for 48 hours to air having a relative humidity of 88 ±2 percent at a temperature of 32 ±2°C (90 ±4°F).

42.2 A sample of the product is to be heated to a temperature just above 34°C (93°F) to reduce the likelihood of moisture condensation during conditioning. The heated sample is then to be placed in a humidity chamber and is to remain for 48 hours under the conditions specified in 42.1. After the conditioning, the sample is to be tested unenergized as specified in 36.1.8(a). The sample is then to be energized and tested as specified in 36.1.8 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

43 Capacitor Test

43.1 If the maximum voltage across an electrolytic capacitor is more than its marked operating-voltage rating when measured under the conditions specified in 41.9.2 – 41.9.5, the capacitor shall not short-circuit when subjected to the test specified in 43.2.

43.2 The product is to be operated until the capacitor reaches normal operating temperature after which all tubes are to be removed other than the power rectifier and any other tubes that are necessary to produce maximum direct-current voltages. The voltage is measured across the capacitor for 15 minutes. If there is any increase of the leakage current or a corresponding decrease in voltage, two additional samples are to be tested under the same conditions. The capacitor is acceptable if all three samples operate for 15 minutes without short-circuiting.

44 Low-Energy Circuit Tests for Low-Voltage, Limited-Energy Circuits

44.1 General

44.1.1 A transformer, transformer-impedance combination, or a transformer and regulating circuit, intended to comply with 27.1.2 shall be tested for compliance as specified in this section.

44.2 Current capacity

44.2.1 In order to comply with the requirements specified in 27.1.2, under any noncapacitive condition of loading (including short circuit), the output current shall not be more than that specified in Table 27.1 at 1 minute after the primary is energized. If two or more secondary windings supply interconnected circuits, the sum of the outputs shall not exceed the values specified in Table 27.1.

44.2.2 If a fixed-series impedance or a regulator circuit is relied upon to limit the output, that impedance or regulator circuit is to be included in the circuit during the test. A multiple-winding transformer is to have one secondary winding tested with all the other secondary windings open-circuited, and is to be allowed to cool to room temperature again before another winding is tested. All overcurrent-protective devices that may terminate the test are to be rendered inoperative. If the transformer winding, other impedance, or transformer overtemperature protector opens the circuit in less than 1 minute after the primary is energized, the current shall not be more than the values specified in Table 27.1 just prior to opening of the circuit.

44.3 Volt-ampere capacity

44.3.1 In order to comply with 27.1.2, the maximum output shall not exceed the values specified in Table 27.1. If two or more secondary windings supply interconnected circuits, the sum of the outputs shall not exceed the values specified in Table 27.1.

44.3.2 The maximum volt-ampere output capacity is to be determined as follows. The primary winding of the transformer, at room temperature, is to be connected as intended in the product and the secondary winding in question is to be connected to a variable-resistance load. If a fixed-series impedance or a regulator circuit is relied upon to limit the output, that impedance or regulator circuit is to be included in the circuit during the test. A multiple-winding transformer is to have one secondary winding tested with all the other secondary windings open-circuited, and is to be allowed to cool to room temperature again before another winding is tested. All overcurrent-protective devices that may terminate the test are to be rendered inoperative. The primary winding is to be connected to a source of rated voltage. The load on the secondary is to be varied in approximately ten increments from open-circuit to short-circuit conditions in 2-1/2 minutes. For each step or increment in the resistance, the product of the output voltage and current is to be recorded, plotted, and drawn as a smooth curve.

44.4 Continuous operation

44.4.1 The secondary of a transformer, the output of a transformer-impedance combination or a transformer-regulating circuit that limits the current or the output as specified in 27.1.2 is to be subjected to continuous operation for not longer than 7 hours at short-circuit conditions and maximum power to the externally connected resistor without producing a risk of fire or electric shock. Protective devices may be left intact for the short-circuit and maximum-power tests. Following the test, the measurement specified in 44.2.1, 44.2.2, 44.3.1, and 44.3.2 are to be repeated. The open-circuit secondary voltage and either:

a) The secondary current under any condition of noncapacitive loading (including short-circuit) after 1 minute or

b) The volt-ampere output capacity of the secondary winding

shall still comply with Table 27.1.

Exception: If the short-circuit test continues for 7 hours, then the maximum-power test need not be conducted.

44.4.2 To determine compliance with the requirement in 44.4.1, the product is to be tested as specified in 46.1.1 – 46.1.9. Three complete tests are to be conducted, using new components when necessary.

44.5 Abnormal-operation

44.5.1 If a regulating or other type of circuit is located between the points being measured and the power supply, the opening or short-circuiting, singly, of any unreliable component in that circuit shall not cause the open-circuit secondary voltage to exceed 30 volts AC or 60 volts DC, and either:

a) The secondary short-circuit current shall be 8 amperes or less after 1 minute or

b) The output capacity of the secondary winding shall be 250 volt-amperes or less.

45 Low-Energy Circuit Tests for Nonhazardous Secondary Circuits

45.1 Power and voltage determination

45.1.1 To determine compliance with 27.2.1, the source of supply for a nonhazardous secondary circuit shall be subject to the tests specified in 45.1.2 – 45.3.1.

45.1.2 A source of power for a component part or assembly is to be investigated to determine the points nearest the power supply not capable of:

a) Producing an open-circuit voltage exceeding:

1) 30 volts AC or 60 volts DC where wet contact is not likely to occur and

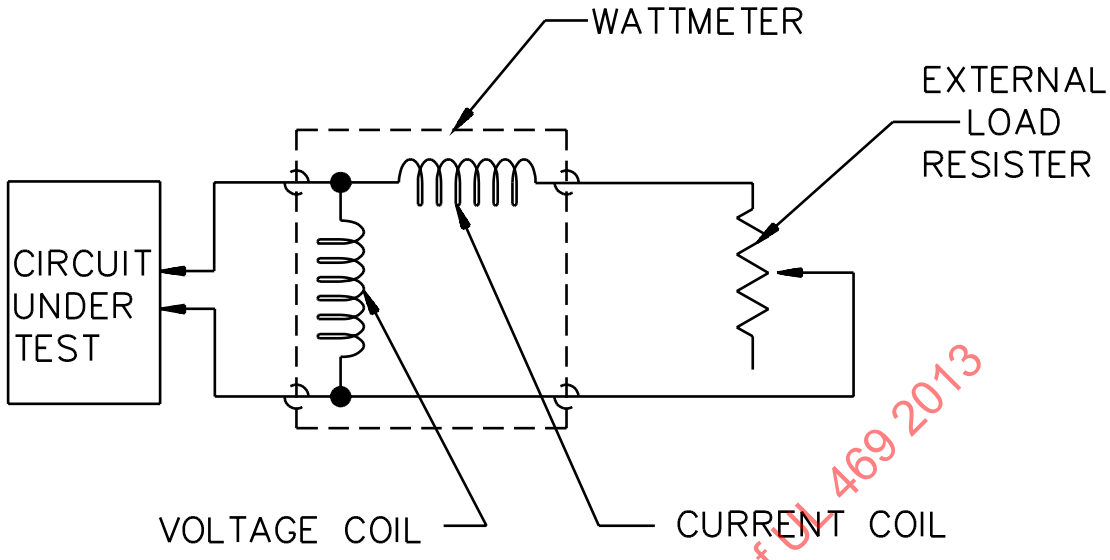
2) 21.2 volts peak where wet contact is likely to occur, and

b) Delivering a power of more than 15 watts into an external resistor connected singly between each of these points and any return to the power supply.

45.1.3 The measurements specified in 45.1.2 are to be made with the product operating normally – with no signal input for amplifier circuits – and with all components and circuits in place.

45.1.4 To locate the points not capable of delivering more than 15 watts of power that are mentioned in 45.1.2(b), an adjustable resistor is to be set for maximum resistance and then connected to a wattmeter and the circuit under investigation as illustrated in Figure 45.1. The external resistor is to be adjusted until it consumes the maximum power as indicated by a peak reading of the wattmeter. If the reading is more than 15 watts, the desired point has not been located and it is then necessary to move the input to the wattmeter resistor to other points away from the supply side of the circuit. If an acceptable protective device is used in the product, a shorting switch is to be connected across the protective device in a closed position. The external resistor is to be adjusted for maximum resistance before being connected in the circuit. The resistor is then to be adjusted so the power it dissipates is exactly 15 watts as indicated by the wattmeter reading. The switch across the protective device is then to be opened and the time required for the protective device to open is to be recorded. If the protective device opens the circuit in 5 seconds or less, the desired point not capable of delivering more than 15 watts has been located.

Figure 45.1
Connection of wattmeter



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45.2 Abnormal operation

45.2.1 If a regulating or other type of circuit is located between the points being measured and the power supply, the opening or short-circuiting – singly – of any unreliable component in that circuit shall not cause the limits in 45.1.2 to be exceeded.

45.3 Continuous operation

45.3.1 The points determined by the measurements specified in 45.1.2 – 45.2.1 shall be investigated to determine that a risk of fire or electric shock is not produced under the conditions of separately short-circuiting them or loading them to maximum power.

45.3.2 As a result of the test specified in 45.3.1, no components located between the points being tested and the power supply shall be affected to such a degree– for example, by a change in value or characteristics – as to cause the limits in 45.1.2 to be exceeded.

45.3.3 To determine whether a product complies with the requirements in 45.3.1, it is to be tested as specified in 46.1.1 – 46.1.9.

45.3.4 If the short-circuit tests specified in 45.3.1 continue for 7 hours, it is not necessary that the maximum-power test be conducted.

46 Abnormal-Operation Tests

46.1 General

46.1.1 For abnormal-operation tests, the product is to be connected to a supply circuit fused at 30 amperes and placed on a white-tissue-paper-covered softwood surface. Exposed dead metal parts are to be connected to earth ground through a 1-ampere nontime-delay fuse. The supply-circuit connection is to be such that the maximum potential exists between the protective device of the product, if any, and the chassis.

46.1.2 A single layer of cheesecloth is to be draped loosely over the entire product.

46.1.3 A part of the product subject to removal during user servicing may be omitted if it is:

a) Not necessary for the functioning of the product,

b) Not exposed to view during normal operation, and

c) Not held captive.

46.1.4 The product is to be operated both with and without a signal input, as specified in 38.3 – 38.10, unless it can be established that one test will produce the most severe conditions. The supply-circuit voltage is to be in accordance with Table 33.1.

46.1.5 Inherent overheating protection, if provided, is to be investigated to determine its acceptability.

46.1.6 An abnormal-operation test involving stalling a motor or short-circuiting or overloading a component or circuit to maximum power is to be conducted until an unacceptable condition develops, the circuit under test burns open, or no further change is likely to take place, but not for longer than 7 hours.

46.1.7 The term maximum power referred to in 46.1.6 is defined as the maximum power that the source of power is capable of delivering into an external variable resistor connected between the points being investigated and any return to the source of power.

46.1.8 An unacceptable condition is considered to exist if an abnormal-operation test results in any of the following:

a) The single layer of cheesecloth glows or flames.

b) The tissue paper glows or flames.

c) Flame resulting from the test continues for more than 30 seconds.

d) The 1-ampere fuse connected to earth ground opens.

e) An opening develops in the overall enclosure larger than that permitted by the accessibility requirements in 10.1.2 and 10.1.3.

f) The product does not withstand without breakdown the dielectric voltage-withstand test specified in 41.2.1 and 41.3.1.

46.1.9 If the circuit is interrupted by the opening of a component or protective device, the test is to be repeated twice, using new components when necessary.

46.1.10 A manually reset overload-protective device is to perform acceptably for 50 cycles of operation under the most unfavorable overload conditions.

46.2 Component abnormal-operation test

46.2.1 An unacceptable condition shall not result when a product is operated under abnormal conditions that are likely to occur during normal use.

46.2.2 The test conditions are to be as specified in 46.1.1 – 46.1.9.

46.2.3 Malfunction of a component connected in hazardous circuitry and likely misuse of the product that may result in a risk of fire or electric shock are to be simulated during the abnormal tests. Only one fault is to be assumed at a time. Examples are:

a) Jamming of tape, paper rolls, and the like, that are likely to stall or overload a drive motor.

b) Malfunction of a fan or blower that provides ventilation. During this test the fan or blower is to be disconnected rather than stalled.

c) Stalling of rotors of all motors due to bearing wear, loss of lubrication, or the like.

d) Solenoid with plunger blocked in the de-energized position.

e) Incorrect setting of an input-voltage selector.

f) Short-circuiting of any unreliable component.

Exception: It is not necessary to short-circuit a component connected in a circuit that is not capable of delivering more than 50 watts of power.

46.2.4 To locate the points not capable of delivering more than 50 watts of power as mentioned in the Exception to 46.2.3(f), an adjustable resistor is to be set for maximum resistance and then connected to a wattmeter and the circuit under investigation. See Figure 45.1. The external resistor is to be adjusted until it consumes the maximum power as indicated by a peak reading of the wattmeter. If the reading is more than 50 watts, the desired point has not been located and it is then necessary to move the input to the wattmeter to other points away from the supply side of the circuit. If an acceptable protective device is used in the product, a shorting switch is to be connected across the protective device in the closed position. The external resistor is to be adjusted for maximum resistance before being connected in the circuit. The resistor is then to be adjusted so the power it dissipates is exactly 50 watts as indicated by the wattmeter reading. The switch across the protective device is then to be opened and the time required for the protective device to open is to be recorded. If the protective device opens the circuit in 60 seconds or less, the desired point not capable of delivering more than 50 watts has been located.

46.2.5 The dielectric voltage-withstand test required by 46.1.8(f) is to be conducted while the power supply is in a heated condition and need only be conducted after the last test on the power supply is completed, unless it is necessary to replace components after conducting the tests.

46.2.6 In conducting the short-circuit tests required by 46.2.3(f), connections in the components are to be short-circuited as described below:

a) Vacuum tube:

1) Plate to cathode terminal of a rectifier.

2) Cathode to heater terminals.

3) Any two heater terminals.

4) A heater terminal and a terminal of any other element of the tube such that at least one heater or portion thereof remains in the test circuit.

5) Any two elements of the tube that are likely to short-circuit; for example, elements that are adjacent to each other. The short-circuit is to be simulated by shorting the elements at the tube-socket terminals.

b) Solid-state rectifier – any two terminals.

c) Electrolytic capacitor – any two terminals.

d) Transistor – any two terminals.

46.3 Audio-output-fault conditions

46.3.1 In an amplifier audio-output circuit tested in accordance with 46.3.2 – 46.3.4, the voltage between any accessible parts of the audio-output circuit shall not exceed:

a) 60 volts peak for voltages that do not reverse in polarity or

b) 60 volts peak and 84.8 volts peak-to-peak for voltages that reverse in polarity.

Exception: This requirement does not apply if the current through a 500-ohm noninductive resistor connected between the parts complies with the following equation:

$$T \leq 2 + \left(\frac{20\sqrt{2}}{I}\right)^{1.43}$$

in which:

T is the duration (in seconds) measured from the time that the instantaneous value of current first exceeds 7.1 milliamperes, until the time that the current falls below 7.1 milliamperes for the last time. The interval between occurrences shall be equal to or greater than 60 seconds if the current is repetitive; and

I is the peak current (in milliamperes), which shall not exceed 809 milliamperes regardless of duration.

46.3.2 A variable resistor is to be connected between any two terminals of a discrete unreliable component – for example, a vacuum tube, diode, electrolytic capacitor, transistor, or integrated circuit– located in the audio-output circuit. The amplifier is to be operated under no-input signal conditions with no load connected to the audio output.

46.3.3 The variable resistor is to have a resistance value high enough so that when initially connected across the terminals of the component in the audio-output circuit being tested there is no effect on circuit operation. The variable resistor is also to be capable of being reduced to zero resistance and of conducting large amounts of current.

46.3.4 With the product connected to a supply circuit in accordance with 33.3.1 and Table 33.1 and operating normally under no-load conditions, the variable resistor is to be slowly reduced in value and the voltage at the audio output monitored. If the product ceases to function before the voltage at the audio output exceeds the values specified in 46.3.1, the cause of the malfunction is to be determined. If a component other than a fuse or overload protector or limiter has been damaged, it is to be replaced by either an open circuit or a short circuit, whichever produces the more unfavorable results. The test is to be continued until zero resistance of the variable resistor is reached, the maximum voltage reached, or until the voltage is reduced or interrupted by the opening of a fuse, overload protector, or limiter.

46.3.5 If the maximum value of output voltage measured according to 46.3.4 exceeds the values specified in 46.3.1, a 500-ohm noninductive resistor is to be connected between the parts. The test specified in 46.3.4 is to be repeated, however, the current through the 500-ohm resistor rather than the open-circuit voltage is to be monitored.

46.3.6 The results are acceptable if the current through the resistor satisfies the requirements for electric shock current specified in 36.2.1.1.

46.3.7 If a fuse or other replaceable circuit-protective element is relied upon to open the circuit, the product is to be marked in accordance with 64.8.1 and 64.8.2.

46.4 Endurance

46.4.1 If solid-state circuitry provides sensing, cut-off, limiting, or the like, to remove or prevent hazardous potentials appearing at the speaker terminals, the product with such circuitry shall complete 100,000 cycles of operation simulating each fault that is intended to interrupt, clear, or guard against.

46.4.2 Three samples of the product are to be subjected to the cycling test. Upon completion of the required number of cycles, the tests specified in 46.3.4 and 46.3.5 are to be repeated with acceptable results.

46.5 Abnormal temperature test

46.5.1 Each channel of equipment incorporating a power amplifier employing external speaker connections is to be loaded with a resistive value as specified in 38.3. Each channel is to be driven with a 1 kilohertz sine wave input or a sine wave at the geometric mean frequency of the specified frequency response limits of the channel. The output level of each channel is to be set at a voltage that will produce one-third maximum undistorted output power or one-third of the manufacturer's rated output power, whichever is greater. The determination of maximum undistorted output power is described in 38.8. The supply circuit voltage is to be the test voltage for intended operation as specified in Table 33.1. The amplifier is to operate under these conditions for a period of 7 hours, until thermal equilibrium as specified in 39.9 is established, or until a protective circuit or a protective device operates.

46.5.2 If a protective circuit or a protective device operates before temperatures stabilize or before 7 hours have elapsed at the one-third level, the test described in 46.5.1 is to be repeated with the protective circuit or protective device repaired or replaced and the output level of the equipment set at one-fourth maximum undistorted output power or one-fourth the manufacturer's rated output power, whichever is greater, until stabilization occurs. If a protective circuit or a protective device operates at the one-fourth level, the equipment is to be repaired and the test repeated at the one-fifth and, if necessary, one-sixth levels until thermal stabilization occurs.

46.5.3 The test specified in 46.5.1 is to be repeated at the one-third level only (set while the equipment is loaded with the resistive value specified in 38.3) with the resistive loads replaced with a resistive load equal to one-half the value used in 38.3, and a short accomplished by an appropriate shorting device applied at the output terminals. The amplifier is to operate under these conditions for a period of 7 hours, until thermal equilibrium as specified in 39.9 is established, or until a protective circuit or a protective device operates.

Exception: The test described in 46.5.3 need not be performed on equipment with internal factory-wired speakers.

46.5.4 As a result of the test described in 46.5.1 – 46.5.3, there shall not be risk of fire or electric shock as described in 46.1.8. Transformers used in the equipment shall comply with the temperature limits specified in Table 46.1.

Exception: The temperature on the transformer need not be measured if the transformer complies with the construction and performance requirements in the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411, or with the construction and performance in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1 and the Standard for Low Voltage Transformers – Part 3: Class 2 and 3 Transformers, UL 5085-3.

46.5.4 revised November 3, 2009

Table 46.1
Maximum temperature rises under abnormal temperature conditions

Condition	Type of protection	Maximum temperature rises									
		Class 105,		Class 130,		Class 155,		Class 180,		Class 120,	
		°C	(°F)	°C	(°F)	°C	(°F)	°C	(°F)	°C	(°F)
1	Integral, non-replaceable, non-resettable protector, including open primary winding, resulting in the replacement of the transformer	130	234	155	279	180	324	205	369	245	441
2	None or any other form of protection	110	198	135	243	160	288	185	333	225	205

47 Switching-Device Test

47.1 Each switch and other current-interrupting device shall comply with the requirements for that component. The actual load controlled in the product may be used in place of the artificial load specified in the requirements applicable to the component.

Exception: Overload and endurance tests may be omitted for switching contacts in isolated secondary circuits if the controlled load is limited to 100 volt-amperes or less.

47.2 A switch or other device that controls a motor of a product is to be operated for 50 cycles making and breaking the locked-rotor current of the product. There shall be no electrical or mechanical malfunction of the device or undue pitting or burning of the contacts and the fuse in the grounding connection shall not open.

Exception: The test need not be conducted if the switch or other device is:

a) Interlocked so that it will not have to break the locked-rotor-motor current or

b) Has been investigated and determined to be acceptable for the intended use.

47.3 To determine if the switch or other control device is capable of performing acceptably in the overload test specified in 47.2, the product is to be connected to a grounded supply circuit with the rotor of the motor locked in position. 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 is located in the ungrounded conductor of the supply circuit. If the product is intended for use on direct current, or on direct current as well as alternating current, the exposed dead metal parts of the product are to be connected so as to be positive with respect to a single-pole, current-rupturing, control device. The device is to be operated at a rate of not more than 10 cycles per minute, unless a faster rate of operation is agreeable to those concerned.

48 Solid-State Switch Test

48.1 Abnormal operation

48.1.1 A product containing a solid-state component or device that functions as a switch in a hazardous-energy circuit shall operate as intended when subjected to the following tests in the order in which they are presented:

a) 50 cycles of operation consisting of making and breaking the actual or rated-output load.

b) 50 cycles of overvoltage while connected to an input of 110 percent of rated-input voltage and to actual or rated-output load.

c) 50 cycles of undervoltage, while connected to an input of 85 percent of rated-input voltage and to actual or rated-output load.

48.2 Voltage-surge test

48.2.1 The switch is to be subjected to ten random applications of a 3-kilovolt surge impulse at 60-second intervals as specified in 48.2.2. There shall be no tripping of circuit protection, the product shall remain operable after the test, and the product shall not develop an unacceptable condition as specified in 46.1.8.

48.2.2 The sample is to be connected to a supply of rated voltage. A grounding lead of the sample, if provided, is to be connected to the supply conductor serving as the neutral. The sample is to be in the on condition with no load connected. For each application, the surge is to have the specified initial peak amplitude of 3 kilovolts when applied to the 60-hertz supply to the unit under test. Each of the ten applications is to be random with respect to the phase of the 60-hertz supply voltage.

48.2.3 The surge generator is to have a surge impedance of 50 ohms. When there is no load on the generator, the wave form of the surge is to be essentially as follows:

a) Initial rise time, 0.5 microsecond between 10 percent and 90 percent of peak amplitude;

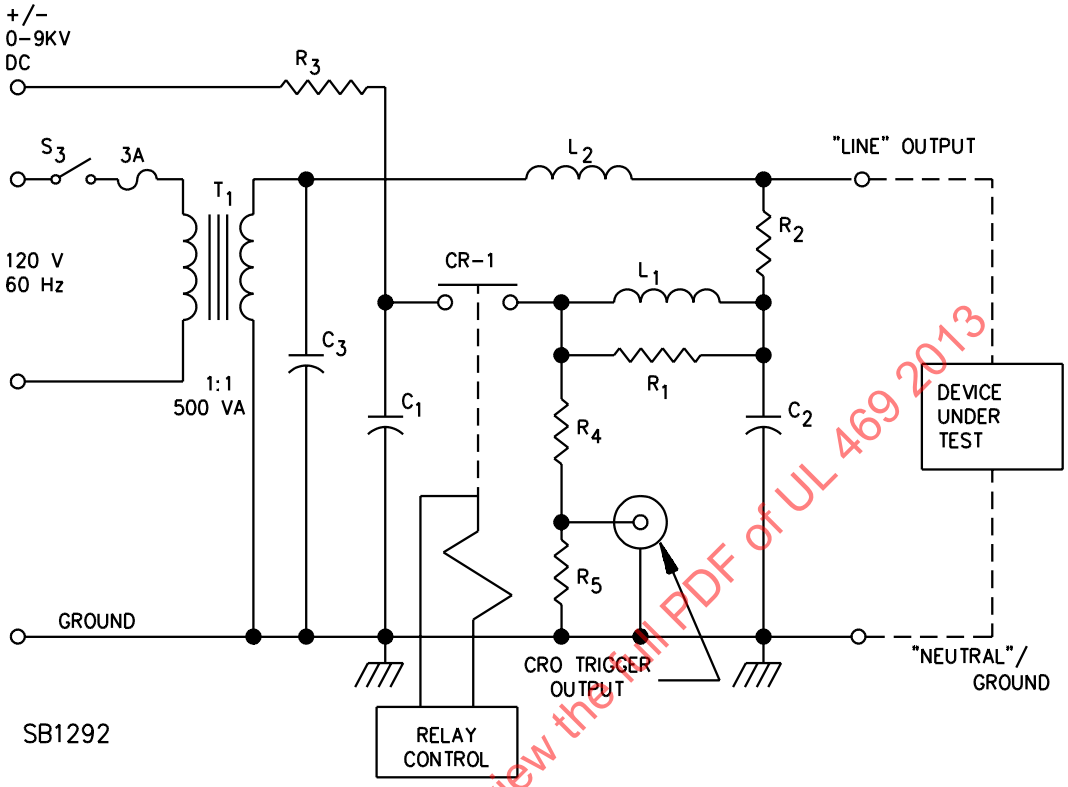
b) The period of the following oscillatory wave, 10 microseconds; and

c) Each successive peak, 60 percent of the preceding peak.

Figures 48.1 and 48.2 show a typical surge generator and control relay.

Figure 48.1
Typical surge-generator circuit

Figure 48.1 revised March 18, 2010



C_1 = 0.025 µF, 10 kV

C_2 = 0.01 µF, 10 kV

C_3 = 4 µF, 400 V

L_1 = 15 µH [23 turns, 23 AWG (0.26 mm^2) wire, 0.7 inch (17.8 mm) diameter air core]

L_2 = 70 µH [28 turns, 23 AWG wire, 2.6 inch (66 mm) diameter air core]

R_1 = 22 ohms, 1 W, composition

R_2 = 12 ohms, 1 W, composition

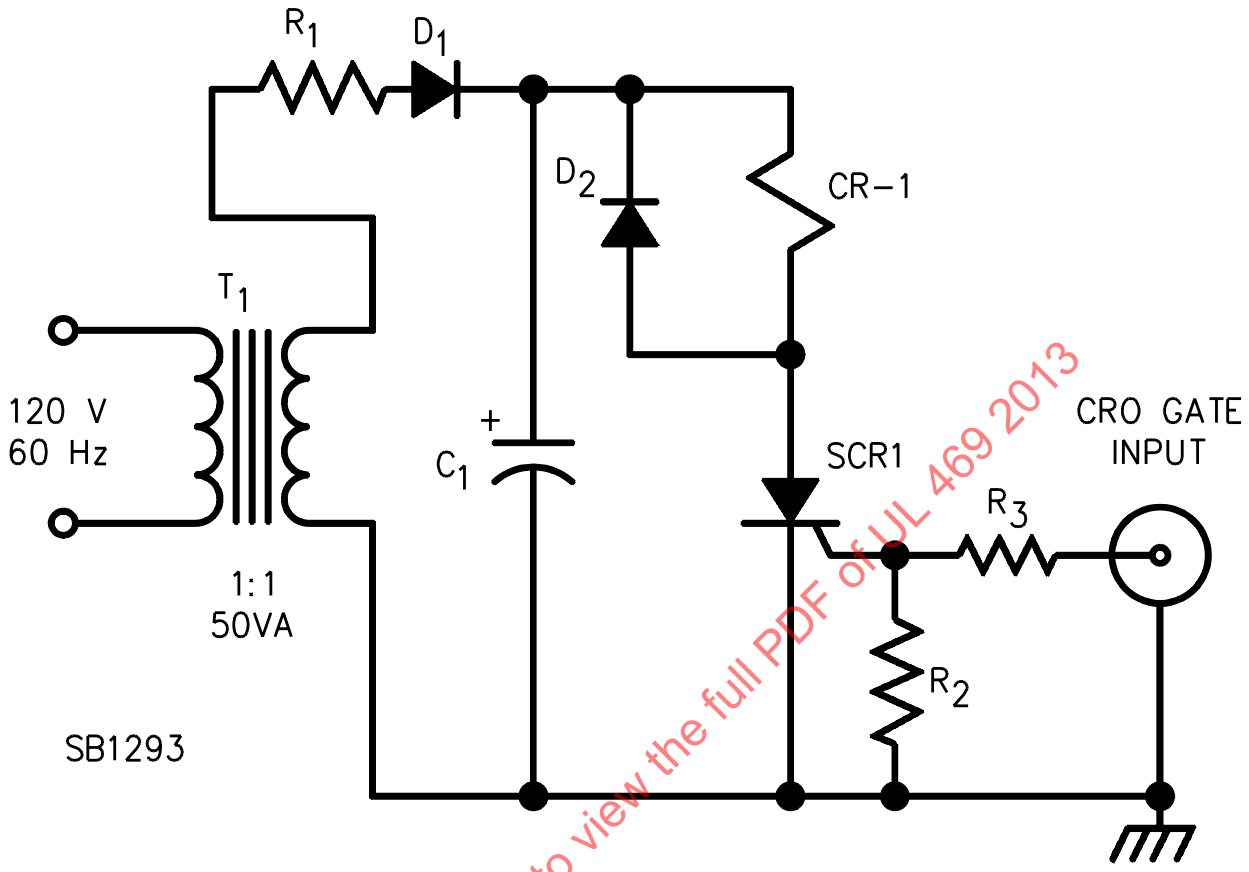
R_3 = 1.3M ohms (12 by 110K ohms, 1/2 W)

R_4 = 47K ohms (10 by 4.7K ohms, 1/2 W)

R_5 = 200 ohms, 1/2 W

CR-1 = Relay

Figure 48.2
Relay control circuit for surge generator



C_1 = 32 µF, 250 V

CR-1 = Relay GE CR 2790 E 100 A2 or equivalent

D_1 = IN5060 or equivalent

D_2 = IN5060 or equivalent

R_1 = 10K ohms, 1 W

R_2 = 1K ohms, 1/2 W

R_3 = 1K ohms, 1/2 W

SCR1 = GE C 122B or equivalent

T_1 = Triad N4S X or equivalent

49 Protective-Circuit Test

49.1 If a protective or limiting function to reduce a risk of fire or electric shock is accomplished through the use of solid-state circuitry to provide sensing, cutoff, limiting, or the like, such circuitry shall be evaluated in accordance with the Military Standardization Handbook Reliability Prediction of Electronic Equipment, MIL-HDBK-217B – September, 1974. The theoretical predicted reliability shall be equal to or greater than 95 percent for 20,000 hours. In addition, a product provided with protective, limiting, or sensing circuitry to reduce a risk of fire or electric shock shall withstand 100,000 cycles of operation simulating the fault or faults that the circuitry is intended to interrupt, clear, or protect against.

Exception: Solid-state circuitry that is used to reduce the risk of fire or electric shock at speaker terminals under fault conditions and that is tested in accordance with 46.4.1 and 46.4.2 need not be further tested.

50 Remote-Control and Interconnection Cable Test

50.1 Cable-short-circuit test

50.1.1 A single- or multiple-conductor cable employed as specified in Exception Nos. 2 and 3 to 20.1 shall be subjected to short circuits between conductors of the cable, and between any conductor of the cable and earth or any other accessible part.

50.1.2 The test conditions for compliance with 50.1.1 are specified in 46.1.1 – 46.1.6 and 46.1.8 – 46.1.10.

50.2 Cable-arcing test

50.2.1 The arc caused by short-circuiting or grounding the conductors of a single-wire or a multiple-conductor cable employed as specified in Exception No. 3 to 20.1 shall not ignite surgical cotton when tested as specified in 50.2.2.

50.2.2 The cable or cord is to be connected to the product and to the remote unit in the intended manner. The insulation of one of the conductors is to be removed so as to expose the bare conductor for a length of approximately 1/16 inch (1.6 mm). Surgical cotton is to be placed in intimate contact with the bared portion of the conductor. With the product operating at rated frequency and maximum voltage an ordinary straight brass pin connected to a conductor of opposite polarity, or to another available return, is to be touched repeatedly during a 15-minute period to the bared conductor in an attempt to cause arcing.

51 Strain-Relief Test

51.1 The attachment of the power-supply cord to the product shall withstand for 1 minute a force of 35 pounds (156 N) applied to the cord as specified in 51.2. The results of the test are not acceptable if any of the following occur:

a) The insulation or covering on the flexible cord is cut or torn.

b) The bushing slides through the hole in the chassis or enclosure.

c) Cemented-on bushings slide on the cord.

d) An interlock connector is separated from the product, or is damaged so that it does not perform its intended function.

51.2 The force is to be applied by a steady pull of 35 pounds (156 N). With the chassis in the cabinet in the normal manner, the force is to be applied from any angle possible.

51.3 If the integrity of the strain-relief means is dependent upon a polymeric material, the test in 51.1 is to be conducted both before and after the temperature stability test in 55.8.2.

52 Separable-Connector Test

52.1 A separable user-accessible connector shall perform acceptably and shall not be damaged when tested as specified in 52.2 – 52.4.

52.2 The test is to be conducted with the product in normal operation.

52.3 A connector is to be made to make and break its load at 6-second intervals for 10 cycles if it is in a secondary circuit or on the load side of a rectifier, and for 50 cycles if it is in the primary (power supply) circuit.

52.4 A separable connector is considered one not held in place by a screw, clamp, or the like, and that does not require the use of a tool to accomplish the separation.

53 Flexing Test

53.1 Wiring that is subject to flexing during normal use and that involves a risk of fire or electric shock, such as wiring to a pull-out tape-player drawer or the like, shall be subjected to the flexing test specified in 53.2. The results of the test are acceptable if the wire insulation is not cut, abraded, or otherwise damaged, and the dielectric voltage-withstand test specified in 41.2.1 is conducted with acceptable results.

53.2 The wiring subject to flexing during normal use is to be subjected to 30,000 cycles of operation simulating normal use.

54 Solderless Wire-Wrap Connections Tests

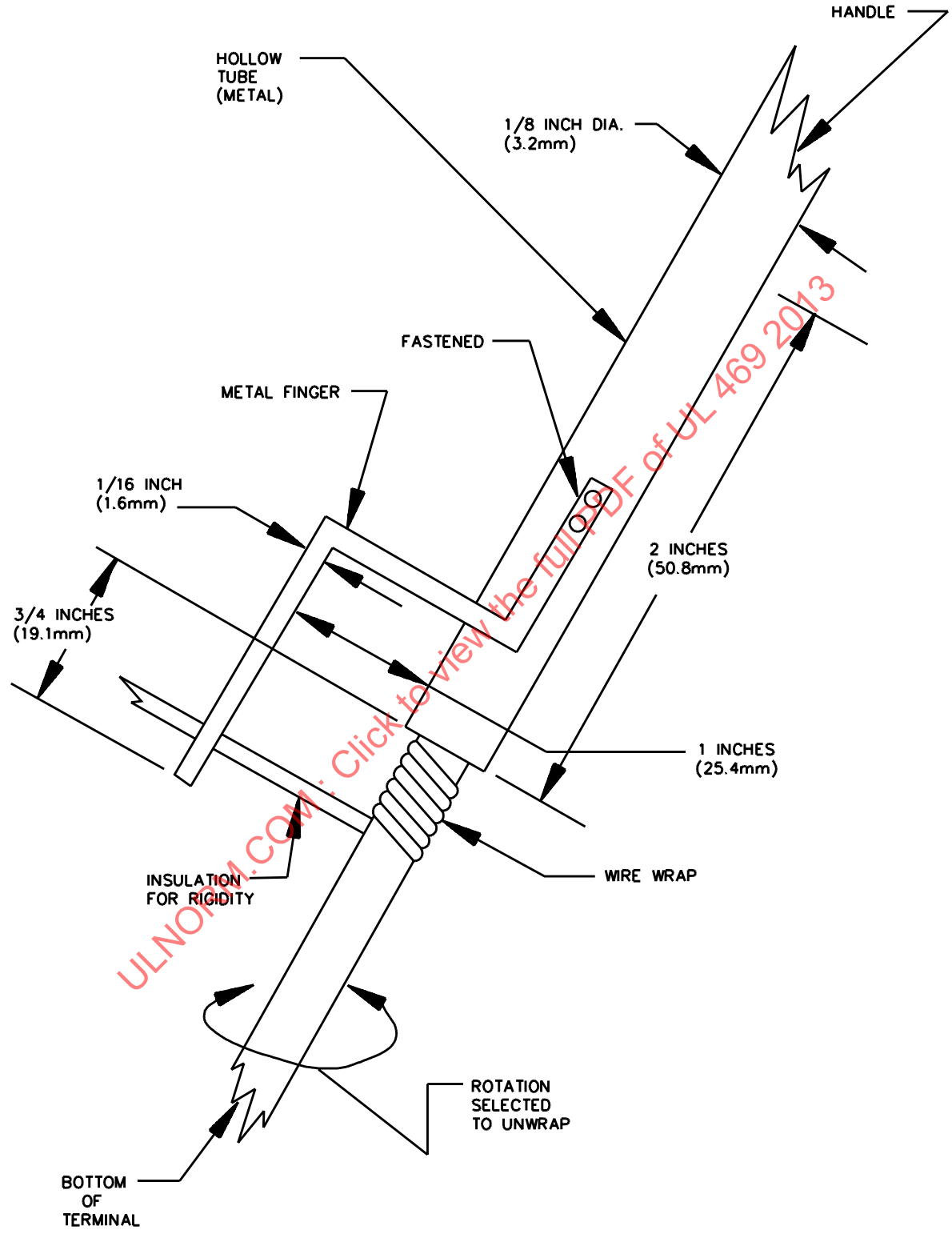
54.1 General – contact points

54.1.1 Contact points on a solderless wire-wrap connection shall be tested as described in 54.2.1 and 54.3.1 and shall produce compression or flow of the conductor rather than a nick that weakens the mechanical strength such that fracture may occur.

54.2 Unwrapping test

54.2.1 The conductor shall be capable of being sufficiently unwrapped (all turns do not have to be unwrapped) to free the wire from the terminal without breaking. The conductor is to be unwrapped so that additional twist or undue stress is not induced. Five samples are to be tested with no conductor fracture. If one conductor fracture occurs, the test is to be repeated on ten additional samples with no conductor fracture. A tool as illustrated in Figure 54.1 is to be used.

Figure 54.1
Unwrapping tool

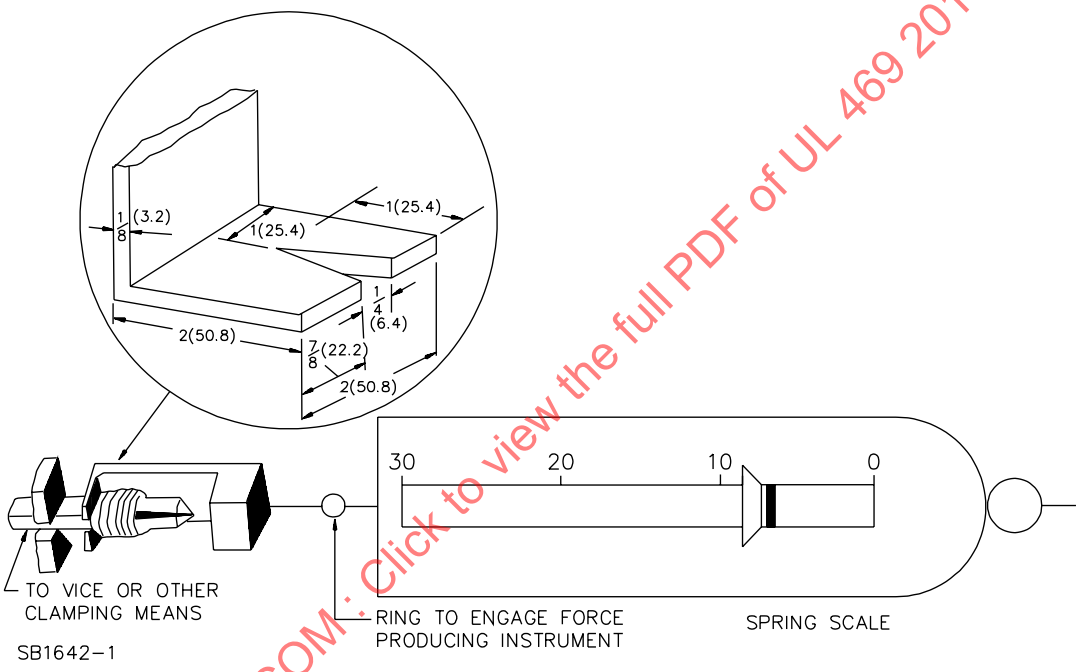


54.3 Strip-force test

54.3.1 Using a tool as illustrated in Figure 54.2, the strip force required to displace the complete wrap a distance equal to the diameter of the wire shall not be less than 6.6 pounds (29.4 N). The stripping force is to be applied evenly and gradually so that any inertial force is negligible. The clearance between the tool and terminal is to be such that no binding occurs between the tool slot and terminal. The number of samples to be tested is to be the same as for the unwrapping test described in 54.2.1. A metal ring is to be provided on the device as illustrated in Figure 54.2 to engage the force-producing instrument.

Figure 54.2
Typical pull test

All dimensions in inches (mm)



55 Strength of Enclosure Tests

55.1 General

55.1.1 A product shall be subjected to the applicable tests specified in this section. The results are acceptable if there is:

a) No development of an opening larger than that acceptable in accordance with Accessibility of Live Parts, Section 10.

b) No effect on the performance of the product so as to introduce an additional risk of fire, electric shock, or injury to persons.

c) No exposure of a moving part to unintentional contact that may result in injury to persons.

55.2 Enclosure-loading test

55.2.1 The overall enclosure of a portable product weighing more than 10 pounds (4.5 kg) shall be subjected for 1 minute to the loading test specified in 55.2.2.

55.2.2 The complete product is to be set on a 2-inch (50.8-mm) diameter steel ball resting on a horizontal surface having dimensions not less than those of the base of the product. A weight that exerts a force of 0.25 times the weight of the product in pounds (kg) plus 4 pounds (1.8 kg) is to be placed on top of the product, directly over the steel ball. Rubber-like and felt materials are to be removed from supporting feet to the extent that they are likely to be worn off in normal service. Supporting feet that are not permanently secured to the enclosure are to be removed.

55.3 Pressure test

55.3.1 The product shall comply with the requirements in 55.1.1 after any point on the overall enclosure, including grilles and other nonrigid surfaces, other than the bottom, is subjected to a force of 20 pounds (89 N) for 1 minute. The force is to be applied by a 1/2-inch (12.7-mm) diameter rod, the end of which is rounded to a 1/2-inch-diameter hemisphere. The force is to be applied normal to the plane of the enclosure surface.

Exception: The rod may pass through a grille or other nonrigid surface if parts inside the enclosure that involve a risk of electric shock are acceptably insulated and no moving part or risk of fire is involved.

55.3.2 Any point on the bottom of the overall enclosure of a product weighing 10 pounds (4.5 kg) or less shall be subjected to a 1-minute application of a force of 15 pounds (67 N) as specified in 55.3.1.

55.4 Impact test

55.4.1 A product not normally hand supported shall be subjected to an impact on any surface that is exposed to a blow during normal use.

55.4.2 The impact is to be produced by allowing a steel sphere, 2 inches (50.8 mm) in diameter and weighing approximately 1.18 pounds (535 g), to fall vertically from rest through a distance of 51 inches (1.3 m) to strike the surface being tested. For surfaces other than the top of an enclosure, the steel sphere is to be suspended by a cord and allowed to swing as a pendulum, dropping through a vertical distance of 51 inches. The test is to be conducted with or without any attachments recommended by the manufacturer in place so as to result in the most severe condition.

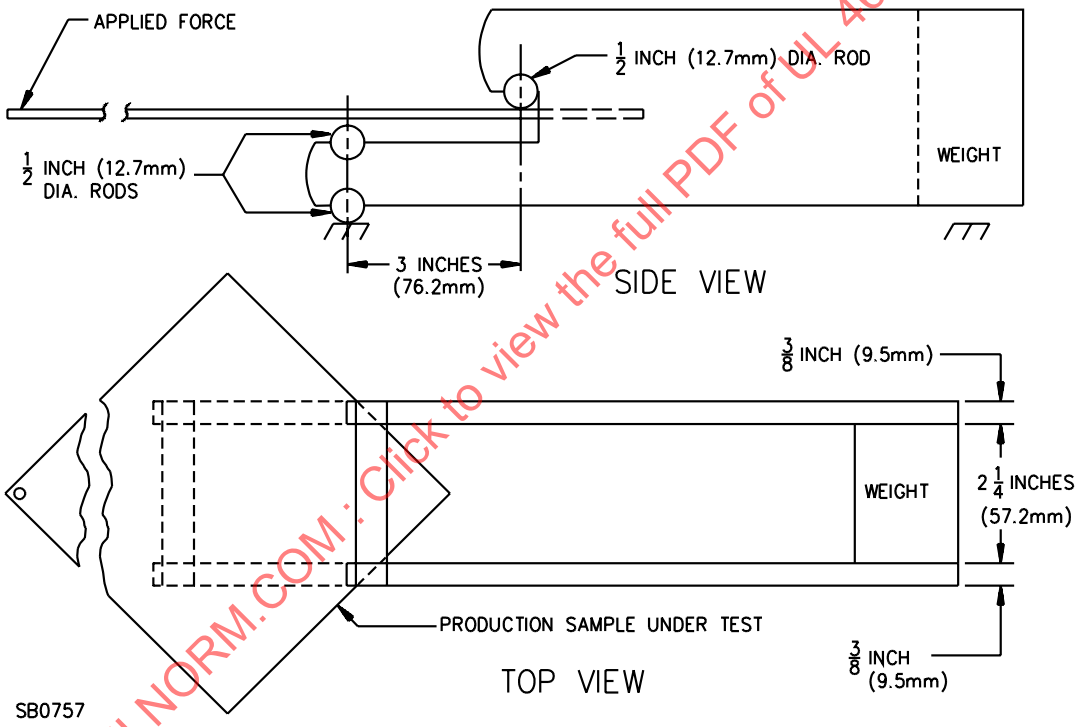
55.4.3 If the enclosure or guard mentioned in 29.3 is made of a polymeric material, the impact test is to be performed on the samples in the as-received condition.

55.5 Back-cover-bending test

55.5.1 The back cover of an overall enclosure of pressed wood or similar material used to render parts involving a risk of electric shock inaccessible, shall be subjected to a bending moment of 5 pound-feet (6.8 N·m). No part of the cover that is relied upon to reduce a risk of fire, electric shock, or injury to persons shall be permanently damaged.

55.5.2 The bending moment applied to the back cover is to be obtained by the apparatus illustrated in Figure 55.1. An edge or a corner of the part to be tested is to be inserted to make contact with the vertical edges of the two side pieces of the device. A downward force is to be applied, in a direction perpendicular to the part, to the opposite edge of the part at a point directly opposite the device. The force is to be gradually increased until the weight of the device is lifted.

Figure 55.1
Apparatus for bending test



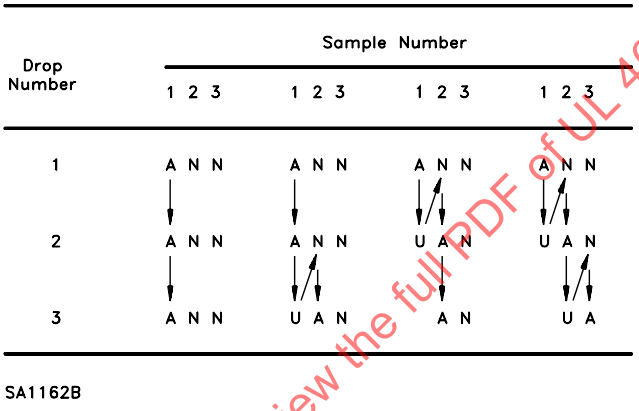
55.6 Drop test

55.6.1 Each of three samples of a product that is normally hand supported shall be subjected to the impact that results from the product being dropped through a distance of 3 feet (914 mm) to strike a hardwood surface in the positions most likely to produce adverse results.

55.6.2 The hardwood surface mentioned in 55.6.1 is to consist of a layer of nominal 1-inch tongue-and-groove oak flooring mounted on two layers of nominal 3/4-inch thick plywood. The assembly is to rest on a concrete floor or the equivalent during the test.

55.6.3 The test is to be conducted so that each sample strikes the surface in a position different from those of the other two samples. Three individual samples may be employed for the tests, or if the manufacturer so elects, fewer samples may be used in accordance with Table 55.1. The overall performance is acceptable upon completion of any one of the procedures represented in the table. If any sample does not comply with the test criteria on its first drop in any of three positions, the results of the test are unacceptable.

Table 55.1
Procedure for drop test on hand-supported products



Arrows indicate sequence of test procedure.

A – Acceptable results from impact

U – Unacceptable results from impact

N – No test necessary

55.7 Handle-strength test

55.7.1 A handle used to support or carry a portable product shall withstand a force of four times the weight of the product. The handle, its securing means, or that portion of the enclosure to which the handle is attached shall not be damaged as a result of the test.

55.7.2 The weight of the product plus a weight that exerts a force of three times the weight of the product is to be used. The load is to be uniformly applied over a 3-inch (76-mm) width at the center of the handle, without clamping. The load is to be started at zero and gradually increased so that the test value is attained in 5 – 10 seconds and maintained for 1 minute. If more than one handle is furnished on the product, and the product cannot be readily carried by only one handle, the force is to be distributed between the handles. The distribution of forces is to be determined by measuring the percentage of the

product weight sustained by each handle with the product in the normal carrying position. If a product is furnished with more than one handle but can be carried by only one handle, each handle is to sustain the total force.

55.8 Enclosure temperature-stability test

55.8.1 An enclosure of polymeric material shall withstand one of the temperature-stability conditions described in 55.8.2 without shrinkage, warpage, or any other distortion of the enclosure, as determined after cooling to room temperature, that results in any of the following:

a) Interference with the operation or user servicing of the product. Component parts such as knobs, windows, and inserts that are distorted as a result of the oven and temperature-stability tests can be removed to eliminate interference with the operation or user servicing of the product, if the removal of the parts does not result in the product not complying with the above requirements.

b) Openings larger than those acceptable under the requirements specified in Accessibility of Live Parts, Section 10.

55.8.2 The temperature-stability test specified in 55.8.1 is, at the manufacturer's option, to be conducted in either of the following ways:

a) The complete product is to be placed for 7 hours in an air-circulating oven. The oven is to be maintained at a temperature of 10°C (18°F) higher than the maximum operating temperature of the enclosure, measured at the hottest spot on the inside of the enclosure, under intended operating conditions, but not less than 70°C (158°F). The product is not to be operated during the test.

b) A sample of the complete product is to be placed in a cubical, unvented test cell having a volume not less than 40 times that of the product and arranged so that the air circulation within the cell simulates typical room conditions. The air temperature within the cell, as measured at the base of the product, is to be maintained at 60°C (140°F). The product is to be connected to a 130-volt (260 volts for a product rated at a nominal 230 volts) supply circuit and operated continuously under the conditions described in the Temperature Test, Section 39, for 7 hours while resting on a supporting surface having an area approximately equal to that of the product base, and centrally located in the test cell.

56 Stability Tests

56.1 A portable product weighing 10 pounds (4.5 kg) or more and not normally hand supported shall not tip over when placed on a plane that is inclined 10 degrees from the horizontal. See 56.3.

56.2 A stationary product shall not tip over when subjected to an externally applied horizontal force of 20 percent of the weight of the product or 25 pounds (11.3 kg), whichever is less, as described in 56.3 and 56.4.

56.3 The product is to be placed on a smooth, hard surface and is not to be energized during the tests required by 56.1 and 56.2. The tests are to be conducted under the conditions most likely to cause the product to overturn. The following conditions of test are to be such as to result in the least stability:

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

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

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

d) Direction in which the product is tipped.

56.4 For the test required by 56.2, the specified force is to be applied in a horizontal direction to that point on the product most likely to overturn the product but is not to be applied more than 5 feet (1.5 m) above floor level. The legs or points of support may be blocked to prevent the product from sliding during the application of the force.

57 Exposure to Rain Test

57.1 After conditioning as specified in 57.3, the leakage current of a product that may be subjected to rain or moisture as specified in 11.1 shall not be more than 0.5 milliampere when tested for leakage current in accordance with 36.1.1 – 36.1.9, if the open-circuit potential between the accessible part and earth ground or any other accessible part is more than 21.2 volts peak.

57.2 Before the test is started, the resistivity of the water is to be no more than 3675 ohm-centimeters measured at 25°C (77°F). At the conclusion of the test, the resistivity of the water is to be no more than 3800 ohm-centimeters at 25°C.

57.3 The product is to be positioned as in actual service and is to be subjected for 1 hour – not operating – to a water spray. The water-spray equipment is to consist of three spray heads mounted in a water-supply pipe rack as illustrated in Figure 57.1. The spray heads are to be constructed in accordance with the details shown in Figure 57.2. That part of the product most likely to permit the entrance of water is to be placed in the focal area of the spray heads. The water pressure is to be maintained at 5 pounds per square inch (34 kPa) at each spray head. The spray is to be directed at an angle of 45 degrees to the vertical toward the product. The leakage-current test is to be conducted immediately upon conclusion of the wetting period and is to be discontinued when the leakage current stabilizes.