UL 813

STANDARD FOR SAFETY

Commercial Audio Equipment

UL Standard for Safety for Commercial Audio Equipment, UL 813

Seventh Edition, Dated December 13, 1996

Summary of Topics

This revision to UL 813 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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.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 813

Standard for Commercial Audio Equipment

The first, second, and third editions were titled Standard for Sound-Recording and -Reproducing Equipment.

First Edition – April, 1930
Second Edition – November, 1954
Third Edition – May, 1973
Fourth Edition – September, 1978
Fifth Edition – October, 1985
Sixth Edition – December, 1992

Seventh Edition

December 13, 1996

This UL Standard for Safety consists of the Seventh Edition including revisions through October 4, 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 audio equipment and accessories, rated 300 volts or less, that are intended for use in commercial enterprises or establishments and other locations such as churches, schools, theaters, and factories. This equipment is for use on supply circuits in accordance with the National Electrical Code, NFPA 70.

1.2 Commercial audio equipment includes amplifiers, preamplifiers, mixers, signal processors, public address and centralized sound systems, intercommunicating devices and systems, phonographs, tape players, and recorders, radio receivers, tuners, and tuner-amplifiers, power supplies intended for use with commercial sound systems, special effects units, and integral amplifier-speakers.

1.3 These requirements also cover accessories for use with commercial audio equipment such as tape erasers and head demagnetizers.

1.4 These requirements do not cover equipment that is covered by individual requirements separate from this standard such as:

a) Dictating and transcribing machines for office use;

b) Musical instruments and accessories for non-professional use;

c) Household type amplifiers, tuner-amplifiers, phonographs, radio receivers, and recorders; and

d) Amateur radio equipment.

1.5 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 or of electric shock or injury to persons shall be evaluated using appropriate additional component and end-product requirements to maintain the level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard does not comply with this standard. Revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

1.5 revised December 7, 1999

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 is not required to comply with a specific requirement that:

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

b) Is superseded by a requirement in this standard.

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

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

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 Unless otherwise indicated, all voltage and current values mentioned in this standard are root-mean-square (rms).

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 CORD-CONNECTED EQUIPMENT – Equipment intended to be connected to the supply circuit by means of a flexible cord.

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

3.4 HAZARDOUS ENERGY – Circuit energy that involves a possible source of fire or electric shock.

3.5 INSULATION, FUNCTIONAL – The insulation necessary for the intended functioning of the equipment and for basic protection against electric shock.

3.6 INSULATION, REINFORCED – An improved functional insulation with such mechanical and electrical qualities that it, provides the same degree of protection against electric shock as an insulation system comprised of both functional insulation and supplementary insulation.

3.7 INSULATION, SUPPLEMENTARY (PROTECTIVE) – An independent insulation provided in addition to the functional insulation to protect against electric shock in case of failure of the functional insulation.

3.8 INTERLOCK – A device that automatically eliminates electrical shock from a part that becomes accessible when the enclosure of the part is opened or a cover is removed.

3.9 LIVE PART – A part involving a possible source of fire or electric shock.

3.10 ORDINARY TOOL – Flat-bladed and Phillips screwdriver and pliers.

3.11 POWER AMPLIFIERS – Equipment capable of sufficiently increasing the amplitude or power of a low level electric audio signal to drive a speaker. Equipment may be portable, rack mounted, or permanently installed, with output terminals for connection to speaker loads, or with self contained speaker(s).

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3.12 PRIMARY CIRCUIT – Circuit that is conductively connected to the supply circuit.

3.13 RACK MOUNTED EQUIPMENT – Equipment that is provided with means for rack mounting.

3.14 SECONDARY CIRCUIT – Circuit that is conductively connected to the secondary winding of an isolating transformer.

3.15 SIGNAL PROCESSING UNITS – An amplifier or other equipment connected to a low level audio signal source to present required input and output impedances and provide equalization, buffering, isolation, mixing, or gain so the signal may be further processed.

CONSTRUCTION

4 General

4.1 The equipment shall be constructed so that:

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

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

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

4.2 The materials and components referred to in 4.1 and in other 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 transformer that is intended to be connected across the supply circuit shall comply with the construction requirements in the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411.

5 Enclosures

5.1 General

5.1.1 Equipment 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 or electric shock. The enclosure shall constructed so that it will protect the various parts of the equipment against mechanical damage.

5.1.2 Equipment 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.

5.1.3 The bottom shall be complete so as to protect all electrical parts. When evaluating the bottom of movable equipment, consideration shall be given to the possibility of the equipment being placed on objects that might damage wiring or other electrical components.

5.1.4 The enclosure of permanently connected equipment shall be constructed of metal.

Exception: Panel meters or other polymeric parts may serve as part of the required enclosure defined in 5.1.8 if they are found to be in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

5.1.5 The thickness of a sheet metal enclosure shall be as indicated in Table 5.1.

5.1.6 The minimum thickness of cast metal shall be in accordance with Table 5.2.

5.1.7 The thickness of a wooden enclosure shall be no less than 1/2 inch (12.7 mm) for those portions of the enclosure that serve as a supporting frame for equipment weighing 10 pounds (4.54 kg) or more.

Exception No. 1: The thickness of a wooden enclosure may be thinner than 1/2 inch if investigated and determined to provide equivalent strength.

Exception No. 2: Those portions of a wooden enclosure that do not serve as a support of parts or as structural members of the frame may be 1/8 inch (3.2 mm) thick.

5.1.8 A polymeric enclosure or part of an enclosure used on cord-connected equipment shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, when used to:

a) Render inaccessible all or any parts that may otherwise present the risk of electric shock or injury to persons or

b) Reduce the risk of propagation of flame initiated by electrical disturbance within the equipment.

5.2 Corrosion resistance

5.2.1 Iron and steel parts shall be resistant to corrosion by means of enameling, galvanizing, plating, or the equivalent if the corrosion of such parts would result in a risk of fire, electric shock, or injury to persons.

Exception No. 1: In certain instances where the oxidation of iron or steel is not likely to be appreciable due to:

a) The exposure of the metal to air, moisture, and temperature and

b) The thickness of metal.

A surface of sheet metal or a cast iron part within an enclosure may not be required to be corrosion resistant.

Exception No. 2: The requirement does not apply to bearings, laminations, or minor parts of iron or steel, such as washers and screws.

Table 5.1
Minimum thickness of sheet metal

Maximum dimensions of enclosure				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)	inches^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]	–	0.045	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	0.046	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 1.52	Over 1500	Over 0.97	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 in thickness if zinc coated and not less than 0.032 inch in thickness if uncoated.

Table 5.2
Minimum thicknesses of cast metal

Metal	At base of threads, at small, flat, unreinforced surfaces and at surfaces that are reinforced by curving, ribbing, and the like (or are otherwise of a shape or size) to provide physical strength,		At relatively large unreinforced flat surface,	
	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

6 Mechanical Assembly

6.1 A switch, lampholder, attachment-plug, pressure wire connector, or similar component shall be mounted securely and shall be made resistant to turning.

Exception No. 1: The requirement that a switch be made resistant to turning may be waived when all of the following conditions are met:

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

b) The means of mounting the switch makes it unlikely that operation of the switch loosens it.

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

d) Intended 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 made resistant to turning if rotation cannot reduce spacings below the minimum acceptable values.

6.2 The means for turn resistance specified in 6.1 is to consist of more than friction between surfaces. For example, a lock-washer may be used as the means for making a small stem-mounted switch or other device that has a single-hole mounting means resistant to turning.

7 Supply Connections – Permanently Connected Equipment

7.1 General

7.1.1 Permanently-connected equipment shall be provided with means for permanent connection to the primary-circuit power. Cord connected equipment that is intended to be fastened in place or located in a dedicated space shall be provided with means for permanent connection to the primary-circuit power, unless connection by means of a supply cord is necessary to facilitate the interchange of units; or removal is necessary for maintenance and repair, in which case, the shortest feasible length of cord shall be used.

7.1.2 A unit intended for permanent connection to the branch circuit shall have provision for such connection.

7.1.3 A sheet-metal member to which a wiring system is to be connected in the field shall have a thickness not less than 0.032 inch (0.81 mm) if of uncoated sheet steel, not less than 0.034 inch (0.86 mm) if of galvanized sheet steel, not less than 0.044 inch (1.11 mm) if of sheet aluminum, and not less than 0.043 inch (1.09 mm) if of sheet copper or sheet brass.

7.1.4 A terminal box or compartment shall be provided in which branch-circuit connections to a permanently wired unit are to be made and shall be such that these connections can be readily made and inspected without disturbing the wiring or the unit after the unit is installed as intended.

7.1.5 The volume of a field wiring compartment provided with pigtail leads for connection to the supply wiring shall not be less than indicated in Table 7.1.

Table 7.1
Minimum size of field wiring compartment

Size of lead, AWG	Size of lead, (mm^2)	Wire space within compartment for each lead, $inches^3$	Wire space within compartment for each lead, (cm^3)
14	2.1	2	32.8
12	3.3	2.25	36.9
10	5.3	2.5	41.0
8	8.4	3	49.2
6	13.3	5	81.9

7.1.6 A pigtail lead shall be no more than two wire sizes smaller than the copper supply conductor to which it will be connected. For example, if 14 AWG (2.1 mm^2) supply conductors will be used, the pigtail leads provided shall not be smaller than 18 AWG (0.82 mm^2).

7.1.6 revised May 7, 2010

7.1.7 No electrical component shall be mounted on a part, such as the cover of a wiring terminal compartment, that must be removed for the connection or inspection of field wiring.

Exception: This requirement does not apply to a unit in which the power supply circuit wires are intended to be connected to an attachment plug receptacle.

7.1.8 A terminal compartment intended for the connection of a supply raceway shall be attached to the unit so that it is resistant to turning.

7.2 Separation of circuits

7.2.1 Field installation conductors of any circuit shall be separated by barriers from:

a) Field- and factory-installed conductors connected to any other circuit, unless the conductors of both circuits are insulated for the maximum voltage in either circuit; and

b) An uninsulated part of any other circuit in the unit and from any uninsulated live part, the short-circuiting of which results in a risk of fire or electric shock.

7.2.2 Separation of some field-installed conductors from others and from uninsulated live parts connected to different circuits can be accomplished by arranging the openings in the enclosure for the various conductors (regarding the terminals or other uninsulated live parts) so that there is no likelihood that the conductors, or parts of different circuits, can be intermingled. If no more openings are provided in the enclosure than are necessary for proper wiring of the unit and each opening is opposite a set of terminals, it is to be assumed in determining compliance with 7.2.1, that conductors entering the enclosure through any such opening will be connected only to the terminals opposite that opening. If more openings are provided in the enclosure than are necessary for the intended wiring of the unit, it is to be assumed (in determining compliance with 7.2.1) that conductors will enter the enclosure through openings not opposite the terminals for which they are intended to be connected, and may touch insulated conductors and uninsulated live parts of other circuits.

7.3 Wiring terminals

7.3.1 Permanently connected equipment shall be provided with wiring terminals or leads for the connection of conductors having an ampacity no less than the current rating of the equipment. A wiring terminal shall be provided with a soldering lug or an acceptable pressure wire connector, firmly bolted or held by a screw.

Exception: A wire-binding screw may be used at a wiring terminal intended to accommodate a 10 AWG (5.3 mm^2) or smaller conductor if an upturned lug or the equivalent is provided to hold the wire in position. A fixed wiring terminal shall be prevented from turning.

7.3.1 revised May 7, 2010

7.3.2 A field-wiring terminal shall be prevented from turning or shifting in position by means other than friction alone. For example, two screws or rivets, square shoulders or mortises, dowel pins, lugs, offsets, connecting straps or clips fitted into an adjacent part, or some similar method may be used.

7.3.3 A wire-binding screw shall not be smaller than No. 10 (4.8 mm diameter).

Exception: A No. 8 (4.2 mm diameter) machine screw may be used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) conductor, and a No. 6 (3.5 mm diameter) screw may be used for the connection of a 16 or 18 AWG (1.3 or 0.82 mm^2) conductor.

7.3.3 revised May 7, 2010

7.3.4 A 14 AWG (2.1 mm^2) is the smallest conductor that is to be used for branch-circuit wiring and thus is the smallest conductor that is to be anticipated at a terminal for connection of a branch-circuit conductor.

7.3.4 revised May 7, 2010

7.3.5 A terminal plate for a wire-binding screw shall be of metal not less than 0.050 inch (1.27 mm) in thickness and shall have not less than two full threads in the metal.

7.3.6 A terminal plate formed from stock having the minimum required thickness as given in 7.3.5 may have the metal extruded at the tapped hole for the binding screw so as to provide two full threads.

7.3.7 An upturned lug or a cupped washer shall be capable of retaining a supply conductor as described in 7.3.1, but shall be not smaller than 14 AWG (2.1 mm^2), under the head of the screw or the washer.

7.3.7 revised May 7, 2010

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

7.3.9 Permanently connected equipment rated at 125 or 125/250 volts (3-wire) or less shall have one terminal or lead identified for the connection of the grounded circuit conductor of the power supply circuit.

7.3.10 If a lampholder is provided, the identified terminal or lead specified in 7.3.8 and described in 7.3.11 shall be connected to the screw shell of the lampholder. A fuse or single-pole switch, circuit breaker, or automatic control shall not be connected to the identified grounded conductor.

Exception: A single-pole automatic control without a marked off position may be connected to the grounded conductor.

7.3.11 The plug and receptacle shall be polarized if a unit or chassis within a rack or similar enclosure is provided with an attachment plug for supply connection to a receptacle that is part of the equipment, and if the unit or chassis has an Edison screw shell lampholder or a single-pole switch connected on the load side of the plug.

7.3.12 A field-wiring terminal intended for the connection of a grounded neutral supply conductor shall be identified by means of a metallic coating that is substantially white in color and shall be easily distinguishable from the other terminals; or proper identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as on an attached wiring diagram. If wire leads are provided instead of terminals, the identified lead shall have a white or gray color and shall be easily distinguishable from the other leads.

7.3.12 revised May 7, 2010

7.3.13 The distance between any pressure terminal connector intended for field wiring and the wall of the enclosure toward which the conductor is directed or through which the conductor may be intended to pass shall be as indicated in Table 7.2. However, the spacings may be less where the wall or other obstruction lies outside of the area occupied by the conductor that is bent or deflected to a radius no less than the distance given in Table 7.2.

Table 7.2
Minimum wire bending space

Size of wire, AWG	Size of wire, (mm^2)	Minimum bending space terminal to wall, inches	Minimum bending space terminal to wall, (mm)
14 – 10	2.1 – 5.3	Not specified	
8 – 6	8.4 – 13.3	1-1/2	38.1
4 – 3	21.2 – 26.7	2	50.8
2	33.6	2-1/2	63.5
1	42.4	3	76.2

8 Supply Connections – Cord- and Plug-Connected Equipment

8.1 General

8.1.1 Cord-connected equipment shall be provided with a length of flexible cord and an attachment plug.

8.1.2 Cord-connected equipment provided with an input voltage selector shall not create a risk of fire or electric shock when tested in accordance with 48.1.14 (e).

8.1.3 Cord connected equipment shall be provided with instructions and be marked in accordance with 64.10.1 and 64.11.1.

8.1.4 The construction of the supply circuit voltage selector shall be such that the supply circuit voltage setting cannot be changed unintentionally.

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

8.1.6 Equipment that can be set to different rated supply circuit voltages shall be constructed so that the indication of voltage to which the equipment is set is externally visible in the area adjacent to the rating information.

8.2 Power supply cords and cord sets

8.2.1 The ampacity of the cord shall be no less than the marked rating of the equipment.

8.2.2 A power supply cord or cord set shall be one of the types indicated in Table 8.1, or the equivalent. 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.

Revised 8.2.2 effective December 1, 1998

Table 8.1
Types of power supply cords intended for use

Revised Table 8.1 effective December 1, 1998

Equipment	Type of cord	Maximum length, feet	(m)
Amplifiers[a], general use	Non-Integral SPT-2, SV, SVT, SVE	10	3.1
	SJ, SJT, SJE	25	7.6
Amplifier speakers	SJ, SJE, SJT	25	7.6
Intercommunication systems	Non-Integral SPT-2, SV, SVE, SVT	10	3.1
Public address systems	Non-Integral SPT-2, SV, SVE, SVT	10	3.1
	SJ, SJE, SJT	25	7.6
Sound systems[b]	SJ, SJE, SJT	25	7.6
Phonographs, tape players, and recorders	Non-Integral SPT-2, SV, SVE, SVT	10	3.1
	SJ, SJE, SJT	25	7.6
Tape erasers and head demagnetizers	Non-Integral SPT-2, SV, SVE, SVT	10	3.1

[a] Includes mixers, preamplifiers, power supplies, radio tuners, and other equipment that is used in conjunction with an amplifier.

[b] A sound system may be comprised of a number of different components (amplifier, tape recorder, record changer, radio tuner, and the like) as may be found in a school sound system or a language teaching system.

8.2.3 20 AWG conductors may be employed in appliance wiring material constructions as referenced in 8.2.2 when:

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.

8.2.3 revised May 7, 2010

8.2.4 The length of the cord shall not be more than the value shown in Table 8.1 and not less than specified in 8.2.6.

8.2.5 The length of the cord shall not be less than 5 feet (1.52 m).

Exception: Equipment specifically intended for use in a location where a power receptacle will be available adjacent to the equipment may use a cord shorter than that specified.

8.2.6 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 equipment. The length of a cord set is to be measured from the face of the attachment plug to the face of the appliance coupler.

8.3 Appliance coupler

8.3.1 An appliance coupler used as part of a separable cord set shall be constructed so that the appliance coupler cannot readily be used to defeat the conventional interlock device.

8.3.2 The conventional interlock device referred to in 8.3.1 has nominally 3/32 inch (2.4 mm) diameter pins, spaced 5/16 inch (7.9 mm) apart, measured between pin centers.

8.4 Cord strain relief

8.4.1 The power supply cord shall be attached to the equipment so that a mechanical strain 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 equipment to which it is attached; or

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

8.5 Cord push-back relief

8.5.1 The power supply cord or leads shall be provided with a means that prevents them from being pushed inside the enclosure if, when pushed inside, any of the following occurs:

a) The insulation of the cord or leads is subjected to temperatures or voltages above the assigned ratings,

b) The cord or leads contact a sharp edge or moving part that could damage the insulation,

c) The cord or leads displace a part resulting in reduction of spacings in hazardous circuitry or a strain on internal connections, or

d) The cord or leads remain inside the equipment enclosure and cannot be retrieved when the equipment is marked in accordance with 65.1.1.

Exception: Subitem (d) does not apply when a separate cord storage compartment that has been evaluated is provided.

To determine compliance with this criteria, the cord (or leads) shall be subjected to the Pushback Relief Test, Section 54.

8.5.1 revised December 13, 1996

8.6 Cord-bearing surface

8.6.1 If a knot in a power supply cord serves as strain relief, the surface against which the knot may bear or with which it might come in contact shall be free from projections, sharp edges, burrs, fins, and the like that cause abrasion of the insulation on the cord.

8.7 Cord and wire routing

8.7.1 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.

8.8 Attachment plug

8.8.1 The attachment plug shall have an American Standard configuration of pins and American Standard ratings. It shall be a type intended for use with a current no lower than the rated current for the equipment, and at a voltage equal to the rated voltage of the equipment. If the equipment 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 equipment shall be acceptable for the voltage for which the equipment is intended to be connected when it is shipped from the factory.

8.8.2 The attachment plug of the power supply cord of equipment provided with a 15- or 20-ampere general-use convenience receptacle shall be a 3-wire grounding type. The attachment plug of the power supply cord of all other equipment that is not required to be grounded shall be polarized or of the grounding type.

8.8.3 The supply cord polarity of a 3-conductor cord shall be identified as follows:

a) The line conductor shall be black, the identified (neutral) conductor shall be white, and the grounding conductor shall be green, or

b) The line conductor shall be brown, the identified (neutral) conductor shall be light blue, and the grounding conductor shall be green with one or more yellow stripes.

Revised 8.8.3 effective December 1, 1998

8.8.4 When 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 be connected to the ungrounded side of the line when used in the primary circuit.

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8.9 Bushings

8.9.1 At the point at which a supply cord passes through an opening in a wall, barrier, or the overall enclosure, there shall be a bushing or the equivalent that is secured in place and that has a smooth, rounded surface against which the cord can bear. If a cord other than Type S, SE, SO, ST, STO, STOO, SJ, SJE, SJO, SJOO, SJT, SV, SVE, SVO, SVOO, SVT, SVTO, or SVTOO is used and the wall or barrier is of metal, an insulating bushing shall be provided.

8.9.2 When the exit for the cord is wood, wood composition, or an insulating material, a surface free of fins, burrs, and the like is considered similar to a bushing.

8.9.3 Ceramic, porcelain, and phenolic materials and some molded compositions are not prohibited from being used for insulating bushings. Separate bushings of wood or rubber are not to be used.

Exception: A soft rubber bushing is capable of being used in the frame of a motor when the bushing is no less than 3/64 inch (1.2 mm) thick, and when the bushing is located so that it is not exposed to oil, grease, oily vapor, or other substance having a harmful effect on rubber. When a soft rubber bushing is used in a hole in a metal motor frame, the hole shall be free from sharp edges, burrs, projections, and the like, which are capable of cutting into the rubber.

8.9.4 Fiber is not prohibited from being used when the finished bushing is not less than 3/64 inch (1.2 mm) thick and is formed and secured in place so that it is not adversely affected by ordinary moisture. Sheet fiber not less than 0.028 inch (0.71 mm) thick is capable of being used under the same conditions.

8.9.5 A bushing of the same material as and molded integrally with the supply cord is acceptable on an appliance wiring material construction that has been determined to be equivalent to Non-Integral Type SPT-2 cord, or heavier cord or wiring material when 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.

Revised 8.9.5 effective December 1, 1998

8.9.6 An insulated metal grommet is capable of being used in place of an insulating bushing when 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.

9 Audio Output Connections

9.1 An amplifier or similar equipment having an audio output potential greater than 300 volts when tested as described in 43.2 shall be provided with one of the following to permit connection of the output circuit:

a) Means for connection of conduit complying with 7.1.2 – 7.1.8, and wire-binding screws, No. 6-32 (3.5 mm diameter) or larger, quick-connect terminals, or leads. When wire-binding screws are provided, the terminals shall comply with the requirements in 7.1.5 – 7.1.7. When quick connect terminals are provided, the terminals shall comply with the requirements in 9.2.

b) A length of permanently attached Non-Integral Type SPT-2, Type SV, SVE, SVT, SJ, SJE, SJT flexible cord, an appliance wiring material construction that has been determined to be equivalent to Non-Integral Type SPT-2 cord, or the equivalent, and an acceptable appliance coupler. The cord shall be provided with strain relief and a bushing complying with the requirements in 8.3.1 – 8.7.1 and 8.9.1 – 8.9.6.

c) An opening that will permit the field installation of a flexible cord and wire-binding screws, quick connect terminals or leads as described in 9.1 (a). Such an opening shall be provided with an insulating bushing as described in 8.9.1 – 8.9.6.

Exception: The constructions described in 9.1 (b) and (c) are not to be used when the equipment is intended for supply connection by means of conduit.

Revised 9.1 effective April 1, 2001

9.2 If the following conditions are met, quick-connect terminals may be used for field connection as described in 9.1 (a):

a) The male tabs are firmly mounted in place.

b) Mating female connectors are provided with the equipment.

c) Strain relief is provided with the appliance so that stress on the conductors will not be transmitted to the terminals.

Exception: Strain relief is not required when a separate wiring compartment or barrier is provided so that a disconnected terminal will not be connected to a live part or an accessible dead metal part.

d) The installation instructions include information for assembly of a terminal to a conductor, and the utilization of strain relief as follows:

1) In the case of a terminal intended to be assembled to a wire or wires by a specific tool, the tool designation is specified.

2) Instructions for preparation of the conductors, such as twisting strands of the conductors together before assembly.

3) The size and type of wire (solid or stranded).

4) If strain relief is required, identification of the strain relief means and instructions for its use.

e) The quick connect terminals are acceptable for use with the size and type (solid or stranded) of wire specified.

f) If a strain relief means is provided, it performs as intended when installed in accordance with the installation instructions and when tested in accordance with 53.1 and 53.2.

9.3 Spacings at field wiring terminals provided on an amplifier or similar equipment having an audio output potential greater than 300 volts when tested as described in 43.2 shall comply with 26.1.1.

Added 9.3 effective April 1, 2001

9.4 A receptacle shall be constructed so that it will not receive the blades of a standard attachment plug as described in the Standard for Attachment Plugs and Receptacles, UL 498.

Added 9.4 effective April 1, 2001

9.5 Live parts of audio output terminals for an amplifier or similar equipment having an audio output potential greater than 120 volts when tested as described in 43.2 shall comply with the accessibility requirements of 34.1.1 – 34.1.3.

Added 9.5 effective April 1, 2001

10 Auxiliary Power Connections

10.1 An auxiliary input connection provided for operation of the equipment from an alternative source of power, such as a Class 1 power limited source, shall comply with the applicable portions of Sections 7 and 8 if hazardous energy is involved.

10.2 An attachment plug provided for connection to the alternative power source shall not be of a type that is commonly used for line power.

10.3 If the auxiliary power source is not provided with overcurrent protection in accordance with the National Electrical Code, ANSI/NFPA 70, such protection shall be provided as part of the equipment.

10.4 Auxiliary power output connections provided as a power source for other equipment, battery charging of external batteries, and similar items shall comply with 9.1 (a) – (c) when energy is involved.

10.4 revised September 10, 1999

10.5 Auxiliary input and output power connections shall be marked in accordance with 64.7.1.

11 Lampholders

11.1 The terminals of a lampholder shall be 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 location, insulation, or arrangement of the lampholder terminals and other live parts, including the lamp base, shall be such that there is a reduction of the risk of grounding or of electric shock while in use or while servicing. Soft rubber shall not be used for the insulation of a lampholder shell.

12 Receptacles

12.1 An unused receptacle (such as one provided for the attachment of an accessory) that involves hazardous energy shall not be of the type used as a receptacle for a single-prong, shielded-type phonograph plug; shall involve line power only if of the conventional parallel-slot type; or comply with 27.1.8.

12.2 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 no 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. If the mounting surface is conductive, the face of the receptacle shall project no less than 3/32 inch (2.4 mm) from that part of the mounting surface.

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

Exception: The projections are acceptable if the blades of the attachment plug are prevented from being inserted to make electrical contact with the female contacts of the receptacle.

13 Switches

13.1 General

13.1.1 A switch connected to wiring involving a risk of fire or electric shock shall be of a type intended for that use and shall have an electrical rating no less than that of the load it controls.

13.2 Switch current rating

13.2.1 Regarding the requirement in 13.1.1, the ampere rating of a supply circuit control switch is to be equal to or greater than the maximum steady state (rms) current it controls as determined during the input test. For a power amplifier supply circuit control switch, the ampere rating is to be equal to or greater than the maximum steady state (rms) current it controls as determined during the input test in 41.2.2, at one-third maximum undistorted power output or at one-third of the manufacturer's rated output power, whichever is greater.

14 Protective Devices

14.1 General

14.1.1 A protective device, such as a fuse, manual reset overcurrent device, or a fusible resistor, shall be constructed for the purpose of overload protection.

14.1.2 A protective device or component relied upon to reduce the risk of fire or electric shock shall comply with the requirements for that component and also shall comply with 42.1.3 – 42.1.5.

14.2 Circuits

14.2.1 When a protective or limiting function to reduce the risk of fire or electric shock is accomplished through the use of solid-state circuitry to provide sensing, cut-off, or limiting, the circuitry shall be investigated in accordance with the Military Standardization Handbook Reliability Prediction of Electronic Equipment, MIL-HDBK-217F-September 1995. The theoretical predicted reliability shall be equal to or greater than 95 percent for a period of 20,000 hours. Additionally, equipment with protective or limiting circuitry shall complete 100,000 cycles of operation simulating the fault(s) that it is intended to interrupt, without increasing the risk of fire or electric shock.

14.3 Fuses

14.3.1 A fuse that is user serviceable as described in 35.1 shall be mounted or guarded so that no live part will be exposed to unintentional contact. The arrangement shall be such that at any time during replacement the fuse will not be gripped or held by any part of the fuseholder while live parts are exposed.

14.3.2 A clip for a cartridge fuse shall be mounted securely, resistant to turning, and provided with end stops.

14.4 Battery circuit protection

14.4.1 A fuse or other overcurrent protective device shall be provided in a circuit intended for use with an external battery or in equipment having a self-contained battery if a risk of fire is involved.

14.4.2 When an external battery is used and the battery supply cord is provided by the manufacturer, the fuse or protective device shall be located no more than 5 inches (127 mm) from the battery connecting means.

15 Capacitors

15.1 A capacitor shall use 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 comply with the requirements in 25.2.1.

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

15.2 revised May 7, 2010

15.3 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, a current of more than 1 ampere passes through it when the equipment is in a heated condition. 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.

b) A capacitor used for antenna blocking or line-by-pass in equipment provided with external antenna terminal(s) that might be grounded.

c) A capacitor used for line-by-pass in equipment provided with a terminal or connector intended to be grounded.

15.4 The voltage rating of a capacitor shall equal or exceed the maximum steady-state potential to which the capacitor is subjected during intended operation of the unit.

16 Batteries

16.1 General

16.1.1 A battery of a combination supply circuit and battery-operated equipment shall not be connected to the supply circuit unless the live current-carrying parts are insulated, arranged, or otherwise protected to reduce the risk of fire or electric shock.

16.1.2 The terminals of a battery contained within equipment shall be protected to reduce the risk of unintentional short circuiting during installation and while in service.

16.2 Automotive-type battery cord connections

16.2.1 The flexible cord used with an automotive type battery shall be Type SPT-2, non-integral SPT-2, or SVT.

Revised 16.2.1 effective December 1, 1998

16.2.2 A plug constructed to engage an automobile cigar lighter type receptacle is an example of an acceptable connecting means.

16.2.2 reinstated effective December 1, 1998

16.2.3 Alternating-current, battery-type equipment that is intended to be powered from a separable type battery supply cord is not to use a connector on the equipment that has a configuration that engages the alternating current appliance coupler described in 8.2.5 and 8.3.1.

17 Motors

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

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

17.2 revised October 4, 2013

18 Coil Windings

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

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18.2 With regard to the requirement in 18.1, fiber, cloth, and similar moisture absorptive materials shall be provided with impregnation or otherwise treated to resist the absorption of moisture. Cross over lead insulation for a coil winding shall be provided with a covering of paper, waxed or otherwise treated to resist the absorption of moisture as described in the Exception to 25.2.1.

Exception: Enameled wire is not required to be treated to reduce absorption of moisture.

19 Sleeving, Tape, Tubing, and Wire Insulation

19.1 General

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

Exception: Sleeving, tape, tubing, and wire insulation located in nonhazardous secondary circuits and segregated or routed from wiring located in hazardous energy circuits or low voltage, limited energy circuits need not comply with this requirement.

19.2 Mechanical protection

19.2.1 The wiring and connections between parts within the equipment shall be protected or enclosed to reduce the risk of mechanical damage.

19.2.2 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.

19.2.3 When user servicing involves moving assemblies that have wiring connections to other parts of the equipment, any wiring (other than a flexible cord) that involves a risk of electric shock and that may be handled during such servicing shall have supplementary insulation consisting of two thicknesses of insulating tape or a length of equivalent tubing, alternatively, the equipment construction shall be constructed so that the circuits are not energized during the servicing operation.

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

19.2.5 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.

19.2.6 A metal clamp or guide used for routing stationary internal wiring shall be provided with smooth, well-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.

19.2.7 A hole through which insulated wires pass in a sheet metal wall within the overall enclosure of the equipment shall be provided with a smooth, well-rounded surface upon which the wires may bear to reduce the risk of abrasion of the insulation. A flexible cord as specified in 20.1 shall be provided with bushings and strain relief in accordance with 8.4.1, 8.5.1, and 8.9.1 – 8.9.6.

Exception: The requirement for cord bushings and strain relief does not apply if the construction is such that the cord will not be subject to stress or motion.

19.2.8 A hook up wire provided with thermoplastic insulation with a wall thickness less than 1/32 inch (0.8 mm) shall be located entirely within a chassis or be constructed so that it will not be subject to:

a) Mechanical damage,

b) Flexing during intended operation, or

c) Handling during user servicing.

19.2.9 Wire smaller than 24 AWG (0.21 mm^2) shall be located or enclosed so as to reduce the risk of mechanical damage, taking into consideration the effects of vibration, impact, and handling during user servicing.

19.2.9 revised May 7, 2010

19.2.10 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 relief and push back stop as described in 8.4.1, 8.5.1, and 8.6.1.

19.2.11 The acceptability of wiring that is subject to flexing during intended use (such as wiring to a pull-out record changer drawer) shall be subjected to the flexing test described in 55.1.

19.3 Primary wiring

19.3.1 The primary wiring of power transformer operated equipment (including the transformer primary winding leads but not the primary winding) having a power supply input of more than 300 watts shall be no smaller than 18 AWG (0.82 mm^2).

Exception: If an investigation shows that overloading of the primary wiring due to a fault in the circuits connected to the secondary of the transformer itself does not result in a risk of fire, the wiring may be smaller than 18 AWG.

19.3.1 revised May 7, 2010

19.4 Types of wire

19.4.1 The internal wiring of the equipment shall be of a type able to withstand exposure to oil or grease, and to the temperature, voltage, and other conditions of service to which the wiring is likely to be subjected.

19.4.2 Thermoplastic insulated wire with an insulation thickness of not less than 0.007 inch (0.18 mm) shall be used at 300 volts peak or less; 1/64 inch (0.4 mm) at 600 volts peak or less; and 1/32 inch (0.8 mm) at 1000 volts peak or less.

20 Remote Control and Interconnecting Cables

20.1 A cable used as an interconnecting cable or for the connection of a remote control or similar use shall be Type SJ flexible cord or the equivalent. The cable shall have an ampacity rating of not less than the current rating of the equipment, accessory, or equipment section it supplies. When the cable is permanently attached to the equipment, it shall be provided with a cord exit, strain relief, and push-back relief as described in 8.4.1, 8.5.1, 8.6.1, 8.7.1, and 8.9.1 – 8.9.6.

Exception No. 1: A cable used solely for external interconnection between units or a system and that is not handled during intended operation shall be of a type no less serviceable than the supply cord.

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Exception No. 2: Integral Type SPT-1 flexible cord or the equivalent shall be used for connection of a remote control or similar use under the following conditions:

a) 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 does not occur, and 21.2 volts peak where wet contact occurs when the current between these points is more than 0.5 milliampere when tested in accordance with 40.1.1 – 40.1.7, and

b) The equipment does not involve a risk of fire or electric shock when it is subjected to the short circuit test described in 52.1.1.

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 a comparable cord or cable may be used for the connection of a remote control or the like, under the conditions stated in Exception No. 2, with the added condition that the arcing test described in 52.2.1 and 52.2.2 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 a comparable cord or cable may be used for the connection of a remote control if the cord or cable is located in a secondary circuit that does not present a risk of fire or electric shock as described in Nonhazardous Secondary Circuits, Section 33.

Revised 20.1 effective December 1, 1998

20.2 If the remote control circuit is supplied from a bell-ringing or Class 2 transformer, the short circuit and arcing tests described in Exception Nos. 2 and 3 to 20.1 are not required.

20.3 Cords and wires 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: Cords or wires that are securely fastened to the enclosure walls by means of clamps, staples, or similar items or are located so that they will not be subject to handling during user servicing need not be provided with strain relief means.

20.4 Interchassis cables and wiring within an overall enclosure shall be neatly arranged and routed by means of clamps, string ties, or similar means in spaces where damage during user servicing is not likely to occur.

21 Splices and Connections

21.1 General

21.1.1 All splices and connections 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 parts or other live parts that could cause a risk of fire or electric shock, or a reduction of spacings below the minimum required for the application. Vibration shall be considered when evaluating the acceptability of electrical connections.

21.1.2 A lead is considered to be mechanically secure when one or more of the following is provided:

a) At least a three-quarter wrap around a terminal.

b) The lead is inserted through an eyelet or opening of a terminal block or printed wiring board prior to soldering.

c) It is twisted with other conductors.

d) The lead is inserted into a U- or V-shaped slot in the terminal prior to soldering.

21.1.3 The soldering of a lead along a flat surface (identified as tack soldering) is not acceptable.

Exception: Tack soldering of a lead is acceptable if it can be demonstrated that a risk of fire, electric shock, or injury to persons does not exist with the lead(s) detached.

21.1.4 A splice shall have insulation equivalent to that of the wires involved if permanence of spacing between the splice and other metal parts is not provided.

21.1.5 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.

21.2 Wire-wrapped connections

21.2.1 A solderless wrapped connection is acceptable if it is not subject to movement or flexure of the wires during conditions of intended operation or user servicing.

21.2.2 Only solid, copper wire in 24, 22, or 20 AWG (0.21, 0.32, or 0.52 mm^2) may be used. Other sizes and types of wire may be subjected to an investigation.

21.2.2 revised May 7, 2010

21.2.3 A terminal shall be constructed of copper or brass and shall have at least two sharp edges. A terminal of other material may be subjected to an investigation.

21.2.4 The wrap shall have at least 20 points on the corners of the terminal in contact with the wire. At least 16 points shall be closely wrapped with no overlapping. The term ″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 21.1 for the typical number of wraps. A lesser number of wraps may be subjected to an investigation to determine equivalence.

Table 21.1
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

21.3 Aluminum terminations

21.3.1 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 determined acceptable for the combination of metals involved at the connection point.

21.3.2 Regarding 21.3.1, 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 or heat cycling.

22 Friction-Fit Electrical Connectors

22.1 A disconnecting part, such as an electrical connector, secured by friction fit only, is to be evaluated for a possible source of fire or electric shock in its most extreme disconnected position.

Exception: Such investigation need not be conducted if the part complies with one or more of the following:

a) The part is capable of withstanding a separation force of 500 grams (approximately 1.1 pounds) 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, so that a risk of fire, electric shock, or injury to persons can not result if the part becomes disconnected; or

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

23 Connector and Component Displacement

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

23.2 The requirement in 23.1 applies to any handling, disconnection, or displacement (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 intended operation or user servicing.

23.3 A barrier, mechanical restraint, or the effect of gravity are to be considered as a means of fastening a connector. However a fastening means that relies solely on friction between parts is to be investigated with regard 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.

23.4 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.

24 Integrated Circuits

24.1 An integrated circuit not supplied by a low-voltage, limited-energy circuit as described in 32.2 and in the Test for Low-Voltage, Limited-Energy Circuits, Section 46, shall be constructed of materials and subjected to the tests indicated in Table 24.1.

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Table 24.1
Requirements for integrated circuits involving hazardous energy

Table 24.1 revised November 13, 1998

Alternative	Type of construction	Minimum flammability classification[a]		Printed wiring assembly		External pin arcing test[b]	Abnormal operation tests required[c]
		Enclosure	Terminal support	Flammability classification[a]	Recognized printed wiring board		
I	Hybrid[d]	HB	V-1	V-1	Required	Not required	1, 2, 3, 4
II	Hybrid[d]	5V (or metal)	5V	Not required	Not required	Not required	1, 3
III	Hybrid[d]	5V (or metal)	V-1	Not required	Not required	Required on terminal material	1, 3
IV	Hybrid[d]	V-2	5V	Not required	Not required	Required on enclosure material	1, 3
V	Hybrid[d]	V-2	V-1	Not required	Not required	Required on enclosure and terminal materials	1, 3
VI	Nonhybrid[e]	V-2	Not applicable	Not applicable	Not applicable	Not required	1, 3

NOTE – Hazardous circuitry is defined as that not supplied by a low-voltage, limited-energy circuit as described in 32.2 or by a nonhazardous circuit as described in 33.2.

[a] The flammability classification is to be determined by tests described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

[b] Tests shall be conducted following the intent of 52.2.1 and 52.2.2, except arcing is to be across the terminal support material rather than across cotton.

[c] The abnormal operation tests in this column are identified by the numbers that follow, and results determined by the conditions in 48.1.9.

1) Short circuit tests at external IC pins.

2) Short circuit tests at an IC assembly.

3) Unreliable component short circuit tests at external IC pins.

4) Unreliable component short circuit tests inside assembly.

[d] A hybrid construction typically consists of an aluminum or ceramic substrate printed wiring board, with chips or 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.

[e] 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, shall have a minimum flammability classification of V-2. The arcing test at the pins of the integrated circuit will not be necessary.

25 Materials

25.1 General

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

25.1.2 Materials shall be classified with regard to flammability, resistance to hot-wire ignition, resistance to high-current-arc ignition, dielectric breakdown strength, and volume resistivity when used in the applications as described in 25.1.3 and 25.1.4.

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

Exception No. 2: Generally, external accessories that are not permanently attached to the equipment such as a microphone, tape cartridge, screwdriver, tape cassette, tape reel, phonograph record, headphone, earphone, 45 RPM adapter, remote control unit not involving hazardous energy, bottle of lubricating oil, signal level balancing mechanism, and the like are exempt from flammability requirements. However, such accessories are to comply with 25.1.1.

Exception No. 3: Dial strings, drive belts, lacing thread, woven (cloth) materials, felt, and similar items segregated from hazardous energy parts need not comply with this requirement.

Exception No. 4: Fiber and similar material that is equal to or less than 0.01 inch (0.25 mm) thick is also exempt from this requirement.

Exception No. 5: Small parts as indicated in note (g) to Table 25.1 need not comply with this requirement.

25.1.3 Materials located in low-voltage, low-energy circuitry shall comply with the appropriate flammability classification as shown in Table 25.1.

25.1.4 Materials located in hazardous circuitry as described in note (a) to Table 25.1 or in contact with uninsulated hazardous circuitry shall comply with the appropriate flammability rating and dielectric breakdown strength and volume resistivity when used in the circuit locations and used as shown in Table 25.1.

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

25.2 Guard and barrier insulating material (to render live parts inaccessible)

25.2.1 A guard or barrier of insulating material used to render live parts inaccessible shall:

a) Be not less than 0.028 inch (0.71 mm) thick and

b) Have a burning-test classification of V-2.

Exception: Fiber or the equivalent that is at least 0.013 inch (0.33 mm) thick can be used to cover a splice within the overall enclosure. If it is not less than 0.013 inch thick, a covering of paper, waxed or otherwise treated to resist the absorption of moisture, can be used for the cross over lead of a coil winding connected in a circuit involving a source of electric shock within the overall enclosure. A covering of paper that is not less than 0.028 inch (0.71 mm) thick can be used on an electrolytic capacitor or similar part. A fiber shell of a metal-jacketed pilot lampholder covering all live parts may have a minimum thickness of 0.020 inch (0.51 mm).

25.2.1 revised November 13, 1998

Table 25.1
Material requirements for various applications

Table 25.1 revised November 13, 1998

Application			Material	Properties					
					Resistance to ignition		Electrical		
				Minimum flammability class[b]	Minimum hot wire[c]	Minimum high current[d]	Dielectric breakdown strength[e]	Volume resistivity[f]	Small parts exception[g]
Enclosures			All	Refer to Section 5					N/A
Dust covers			All	HB	–	–	–	–	Yes
All external and internal parts not classified as part of a required enclosure	Hazardous circuitry[a]	Polarity only on material[h]	Polymeric	HB	7 sec	60 arcs	Required	Required	No – electrical
				V-2	–	–	Required	Required	Yes – flammability and resistance to ignition
		Opposite polarity on material[h]		V-1[i]	–	–	Required	Required	No
	LVLE[j] circuitry			HB	–	–	–	–	Yes
	Hazardous circuitry[a]	Polarity only on material[h]	Low density polymeric foam[k]	HBF	7 sec	60 arcs	Required	Required	No – electrical
				HF-2	–	–	Required	Required	Yes – flammability and resistance to ignition
		Opposite polarity on material[h]		HF-1	–	–	Required	Required	No
	LVLE[j] circuitry			HBF	–	–	–	–	Yes

Table 25.1 Continued on Next Page

Table 25.1 Continued

Speaker or decorative grilles, not part of a required enclosure		Foam	Refer to above requirements for low density polymeric foam					
		Molded	Refer to above requirements for polymeric parts					
		Woven (cloth)	Refer to Section 58					
Printed wiring board	Hazardous circuitry[a]	All	V-1	–	–	Required	Required	No
	LVLE[J] circuitry		HB	–	–	–	–	No
	Non-hazardous circuitry[a]		HB	–	–	–	–	Yes
Connector insulation	Hazardous circuitry[a]	Polymeric	V-2	–	–	–	–	No
	LVLE[J] circuitry		HB	–	–	–	–	Yes

[a] Hazardous circuitry – Hazardous circuitry is defined as that not supplied by a low-voltage, limited-energy circuit as described in 32.2 or by a nonhazardous circuit as described in 33.2.

[b] The flammability classifications V-0, V-1, V-2, HB, HF-1, HF-2, and HBF are to be determined by the tests described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. For parts as described in 25.1.2, a material classified using 1/16 inch (1.6 mm) thick bar specimens can be accepted in lesser thicknesses in the end product.

[c] Hot Wire Resistance to Ignition – Hot wire ignition performance is expressed as the number of seconds needed to ignite standard specimens that are wrapped with resistance wire that dissipates a specified level of electrical energy. Bar samples are to be used for this test. For parts as described in 25.1.2, a material classified using 1/16 inch (1.6 mm) thick bar specimens can be accepted in lesser thicknesses in the end product. Refer to the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, for details of the test.

[d] High-Ampere Arc Resistance to Ignition – High-ampere arc ignition performance 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 at a standard rate on the surface of the material. Bar samples are to be used during this test. For parts as described in 25.1.2, a material classified using 1/16 inch (1.6 mm) thick bar specimens can be accepted in lesser thicknesses in the end product. Refer to the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, for details of the test.

Table 25.1 Continued on Next Page

Table 25.1 Continued

[e] Materials shall have a dielectric breakdown strength of at least 175 volts per mil 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 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies, ASTM D149-1995. These are minimum values usually characteristic of the majority of materials classed as insulators. Higher values may be needed to perform acceptable in the end product.

[f] Materials 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 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing, ASTM D618-1995, 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 Test Methods for DC Resistance or Conductance of Insulating Materials, ASTM D257-1993. These are minimum values usually characteristic of the majority of materials classed as insulators. Higher values may be needed to perform acceptably in the end product.

[g] Small parts where indicated in Table 25.1 are to comply with the following criteria:

a) Maximum volume does not exceed 4000 cubic millimeters, and

b) Maximum dimension does not exceed 60 millimeters, and

c) The part is 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.

[h] Polarity is defined as the condition of being electrically energized positive or negative with regard to some electrical reference point. In regard to Table 25.1 then:

a) Opposite polarity across material means that positive or negative and the reference point are both in contact with the material in question, such as shown in parts A and B in Figure 25.1 where the absolute value of V_1 is greater than the absolute value of V_2.

b) Polarity only on material means that 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 25.1 where the absolute value of V_1 is greater than the absolute value of V_2.

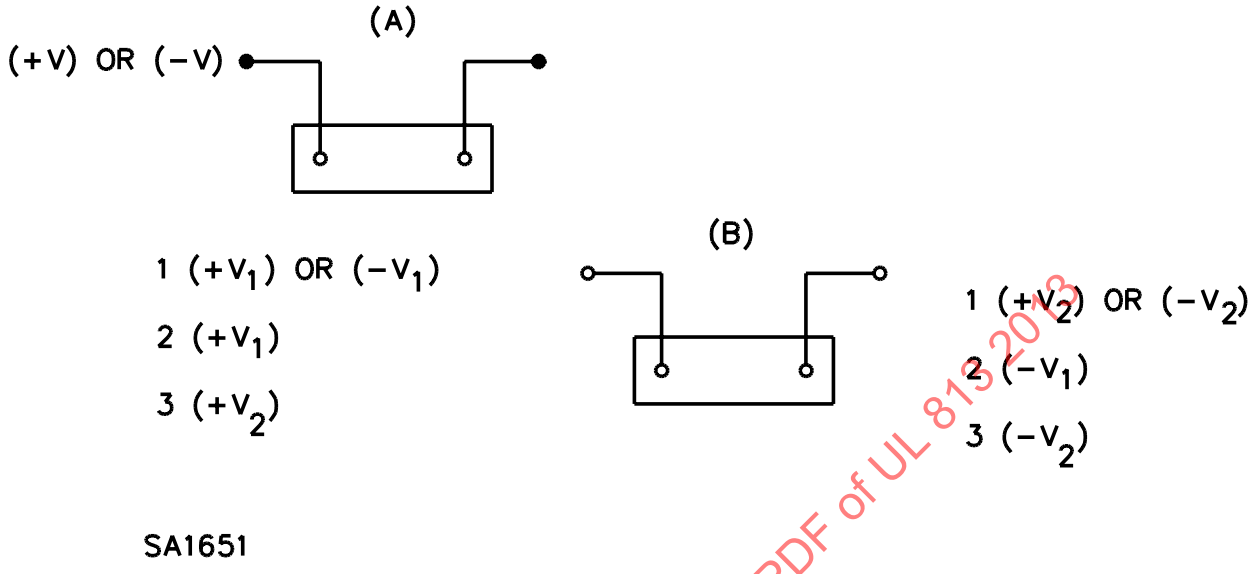
[i] Insulating materials having a flammability classification of V-2 or HB may be used for the direct support of live parts provided the material complies with the direct support requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

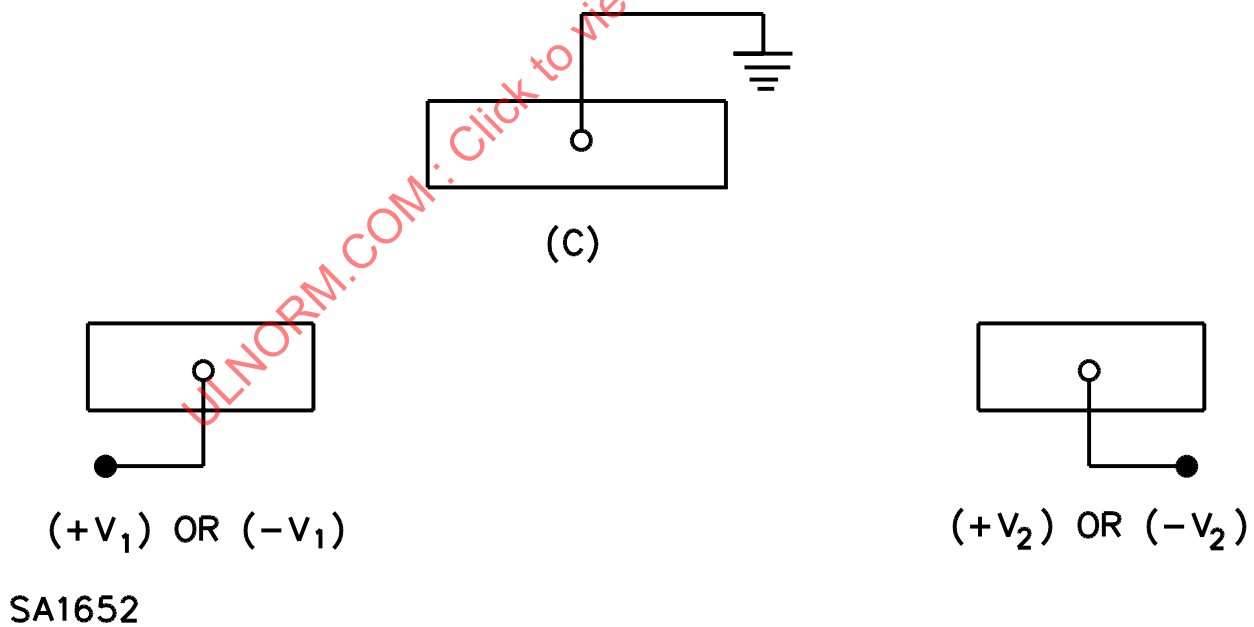
[j] LVLE signifies Low-Voltage, Limited-Energy.

[k] 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.

Figure 25.1
Opposite polarity

Figure 25.1 revised February 6, 1998





26 Spacings

26.1 Field-wiring terminals

26.1.1 The spacing between wiring terminals of opposite polarity, and the spacing between a wiring terminal and any other uninsulated metal part not of the same polarity, shall be no less than that specified in Table 26.1.

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Table 26.1
Spacings at wiring terminals

Potential involved volts	Minimum spacings					
	Between wiring terminals, through air or over surface,		Between terminals and other uninsulated metal parts not always of the same polarity[a]			
			Over surface,		Through air,	
	inch	(mm)	inch	(mm)	inch	(mm)
250 or less	1/4	6.4	1/4	6.4	1/4	6.4
more than 250	1/2	12.7	1/2	12.7	3/8	9.5

[a] Applies to the sum of the spacings involved where an isolated dead metal part is interposed.

26.2 Primary circuits

26.2.1 In primary circuits, other than at field-wiring terminals, spacings shall not be less than 1/16 inch (1.6 mm) through air or over surface between uninsulated live parts of opposite polarity, and between an uninsulated live part and a dead metal part. 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 will be maintained with the movable part in any position.

Exception No. 1: The spacings specified above do not apply to the inherent spacings of a component of the equipment, such as a snap switch. The acceptability of spacings on a component is based on the requirements that cover the component.

Exception No. 2: Spacings are not specified between parts of opposite polarity (other than spacings to ground and spacings between primary and secondary circuits) if one or both of the following conditions exist:

a) Series impedance is 10,000 ohms or more in a circuit in which the voltage is 125 volts or less.

b) Series impedance is 20,000 ohms or more in a circuit in which the voltage is greater than 125 volts but less than 250 volts.

Exception No. 3: On printed-wiring boards having a minimum flammability classification of V-1, spacings (other than spacings to ground and spacings between primary and secondary circuits) are not specified between traces of different potentials connected in the same circuit if either:

a) The spacing provided between traces withstands a dielectric voltage-withstand test conducted in accordance with 45.8.1 or

b) A risk of fire or electric shock does not result from short-circuiting the spacings between traces as described in 48.3.1.

26.2.1 revised November 13, 1998

26.3 Secondary circuits

26.3.1 Secondary circuit spacings shall be judged on the basis of the Dielectric Voltage-Withstand Test, Section 45.

Exception: Low-voltage, limited-energy and nonhazardous secondary circuits, as described in Sections 32 and 33, respectively, need not comply with this requirement.

26.4 Barriers and liners

26.4.1 A barrier or liner of fiber or similar material used where spacings would otherwise be insufficient between uninsulated live parts of opposite polarity involving a source of fire or electric shock or between such parts and exposed dead metal parts shall not be less than 1/32 inch (0.8 mm) thick.

Exception No. 1: Insulation built into a component part may be less than 1/32 inch thick.

Exception No. 2: When the barrier or liner is used with an air spacing no less than one half the required spacing through air, the thickness may be less than 1/32 inch but no less than 1/64 inch (0.4 mm) provided the barrier or liner is:

a) Constructed of an insulating material that is resistant to moisture and is mechanically strong when exposed or otherwise likely to be subjected to mechanical injury,

b) Held in place, and

c) Located so that it is affected adversely by the operation of the equipment during service.

27 Grounding

27.1 General

27.1.1 When a grounding means is provided on the equipment, all exposed dead metal parts and all dead metal parts within the enclosure that are exposed to contact during any servicing operation and are likely to become energized shall be connected to the grounding means.

27.1.2 Regarding the requirement in 27.1.1 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, and 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 relays, solenoids, and similar items.

27.1.3 When a means for grounding is provided on the equipment even though it is not required, it shall comply with the requirements in 27.1.4 – 27.3.4.

Exception: Two-wire equipment with a performance ground (for example, a chassis ground terminal) need not comply with the requirements for grounding.

27.1.4 It may not be practical to connect certain conductive parts (antennas, antenna terminals, control shafts, and mounting screws) described in 27.1.1 to the grounding means. Such parts are not considered likely to become energized if supplementary insulation is used in addition to the functional insulation provided. Where it is impractical to provide separate functional insulation and supplementary insulation, reinforced insulation shall be used.

27.1.5 Functional insulation is to have:

a) A dielectric voltage-withstand capability of 1000 volts for 1 minute, and

b) Minimum acceptable through-air or over-surface spacings of 1/16 inch (1.6 mm).

27.1.6 The thickness, insulation qualities, and the resistance to deterioration with aging of material used as supplementary insulation shall be no less than that which would be required for the same material used as functional insulation. The minimum spacing through supplementary insulation used in circuits shall be 1/32 inch (0.8 mm). This insulation is to have a dielectric voltage-withstand capability of at least 2500 volts for 1 minute. The minimum through air or over surface spacings between conductive parts separated by supplementary insulation shall be 1/16 inch (1.6 mm).

27.1.7 The insulation qualities and resistance to deterioration with aging of materials used as reinforced insulation shall not be no less than the total of that which would be required for the combination of functional and supplementary insulation. The minimum spacing through reinforced insulation used in circuits shall be 5/64 inch (2 mm) and this insulation is to have a dielectric voltage-withstand capability of at least 3500 volts for 1 minute. The minimum through air or over surface spacings between live parts and accessible conductive parts shall be 1/8 inch (3.2 mm).

27.1.8 A convenience receptacle that is provided on equipment 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 equipment.

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

27.1.10 Any appropriate instrument may be used to determine whether the equipment complies with the requirement in 27.1.9. However, if unacceptable results are recorded, an alternating current of at least 25 amperes from a power supply of no more than 12 volts is to be passed from the point of connection of the equipment grounding means to a point in the grounding circuit, and the resulting drop in potential is 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.

27.2 Cord connected equipment

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

27.2.2 An equipment grounding conductor of a flexible cord shall be:

a) Finished to be either green 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, by a screw or other means (not likely to be removed during servicing not involving the power supply cord), to the frame or enclosure of the equipment. Solder alone shall not be used for securing the grounding conductor.

27.2.3 The screw specified in 27.2.2(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 used to prevent the screw from becoming loosened by vibration.

27.2.4 If two or more appliances are electrically or mechanically connected to one another and one of them is grounded, each unit of the system that has a separate power supply cord shall have an equipment grounding conductor in the power supply cord. If the appliances 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.

27.2.5 Regarding power supply conductors, equipment shall be constructed so that the grounding connection is made first and broken last when the equipment:

a) Is provided with a power supply cord or cord set incorporating a separable appliance coupler and

b) Has conductive parts that are connected to the grounding conductor that might be contacted during the connection or disconnection of the appliance coupler at the equipment end of the cord.

27.2.6 A grounding adapter when packaged in conjunction with equipment provided with a grounding type supply cord shall be marked or tagged with instructions for its proper use. The adapter shall not be attached to the attachment plug before reaching the user.

27.2.7 Dual-voltage rated equipment (such as 120/240 volts) provided with a grounding type supply cord shall be provided with a 120/240 volt, grounding type adapter tagged with instructions for its proper use.

27.3 Permanently connected equipment

27.3.1 A field-wiring terminal or lead for the connection of an equipment grounding conductor shall be provided.

27.3.2 A field-wiring terminal or lead for the connection of an equipment grounding conductor shall be a screw-type connector capable of securing a conductor of the proper size.

27.3.3 A wire-binding screw or screw-type wire connector shall be located so that it is unlikely to be removed during the intended servicing of the equipment, and the wire-binding screw shall have upturned lugs or the equivalent to retain the conductor. A wire-binding screw intended for the connection of the equipment grounding conductor shall have a green colored head that is hexagonal, slotted, or both. A screw-type pressure-wire connector intended for connection of such a conductor shall be plainly

identified by the marking ″G,″ ″GR,″ ″GND,″ ″Ground,″ ″Grounding,″ or the like, or by a marking on a wiring diagram provided on the equipment. The following graphical symbol ⏚ (IEC Publication 417, Symbol 5019) may be used for this purpose.

27.3.3 revised February 6, 1998

27.3.4 The surface of an insulated lead intended solely for the connection of an equipment grounding conductor shall be green with or without one or more yellow stripes, and no other lead shall be so color coded.

Exception: The requirements in 27.3.4 that cover the color coding of grounding leads apply to internal wiring that is visible in a wiring compartment in the area in which field connections are to be made. They do not apply to leads or wiring of low voltage circuits that are intended to be field connected to Class 2 wiring and that are separated or segregated from high voltage circuit field wiring connections by barriers.

28 Separation of Circuits

28.1 Insulated conductors of different circuits shall be separated or segregated from each other and from uninsulated live parts connected to different circuits.

Exception: When conductors are provided with insulation rated for the highest voltage involved, such separation is not required.

28.2 Segregation of insulated conductors may be accomplished by clamping, routing, or a similar means which provides permanent separation from insulated or uninsulated live parts of a different circuit.

28.3 A barrier used to separate the wiring of different circuits shall be held in place and shall be of metal or of an insulating material of such strength as to withstand exposure to mechanical damage.

28.4 An unclosed opening in a barrier for the passage of conductors shall be no larger than 1/2 inch (12.7 mm) in diameter and there shall be no unused openings.

28.5 The closure for any other opening shall present a smooth surface wherever an insulated wire may contact it. The area of any such opening with the closure removed shall not be larger than required for the passage of the necessary wires.

28.6 The minimum thickness of a metal barrier shall be the same as the minimum thickness required for a metal enclosure, as indicated in Tables 5.1 and 5.2.

28.7 A barrier of insulating material shall not be less than 0.028 inch (0.71 mm) thick and shall be thicker if it is determined that it may be deformed to defeat its purpose.

29 Live Parts

29.1 Current-carrying parts shall be of silver, copper, a copper base alloy, stainless steel, aluminum, or other materials 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 or semiconductor devices).

Exception No. 2: Blued steel or steel with an equivalent corrosion resistance may be used for the current carrying arms of mechanically or magnetically operated leaf switches but not elsewhere.

29.2 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 can result in a reduction of spacings below the minimum values.

29.3 Friction between surfaces is not considered a sufficient means to prevent shifting or turning of a live part, but a properly applied lock washer may be used.

29.4 A contact of a socket, separable connector, or similar device connected in a circuit involving a risk of fire shall be made of nonferrous spring metal.

30 Electric Shock

30.1 Shock current and voltage

30.1.1 A risk of electric shock is considered to exist at any part exposed only during user servicing if:

a) The open circuit potential between the part and earth ground or any other accessible part exceeds the values specified in Table 30.1; and

b) Any of the following conditions exist:

1) The continuous current flow through a 500-ohm resistor exceeds the limits specified in Table 30.2; or

2) The combination of magnitude and duration of peak current flow exceeds the limits specified in 30.3.1; or

3) The combination of capacitance and voltage exceeds the limits specified in 30.3.2.

30.1.2 Any part accessible during user servicing is to be tested for shock current in accordance with 40.2.1 – 40.2.6.

Table 30.1
Maximum voltages

Wave form		Fundamental frequency, Hz		Maximum volts[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 no more than 20 volts.[c]	Where the instantaneous voltage does not reverse in polarity	Any		60 volts peak
	Where the instantaneous voltage does reverse in polarity	Any		60 volts peak and 84.4 volts peak-to-peak[d]
Where the change in instantaneous voltage for any duration equal to 5 percent 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 peak
		3	4	55 peak
		4	5	50 peak
		5	6	45 peak
		6	7	40 peak
		7	8	35 peak
		8	9	30 peak
		9	10	25 peak
		10	200	24.8 peak
		200	300	26 peak
		300	400	28 peak
		400	500	31 peak
		500	600	34 peak
		600	700	37 peak
		700	800	41 peak
		800	900	46 peak
		900	1000	51 peak
		1000	1400	56 peak
		1400		60 peak
	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 38.1.

[b] "Wet contact not likely to occur" generally refers to indoor or sheltered locations that are not as intended to be 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 the wave form and determining the change in instantaneous voltage in that segment. See Figure 30.1.

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

Table 30.2
Maximum current during user servicing

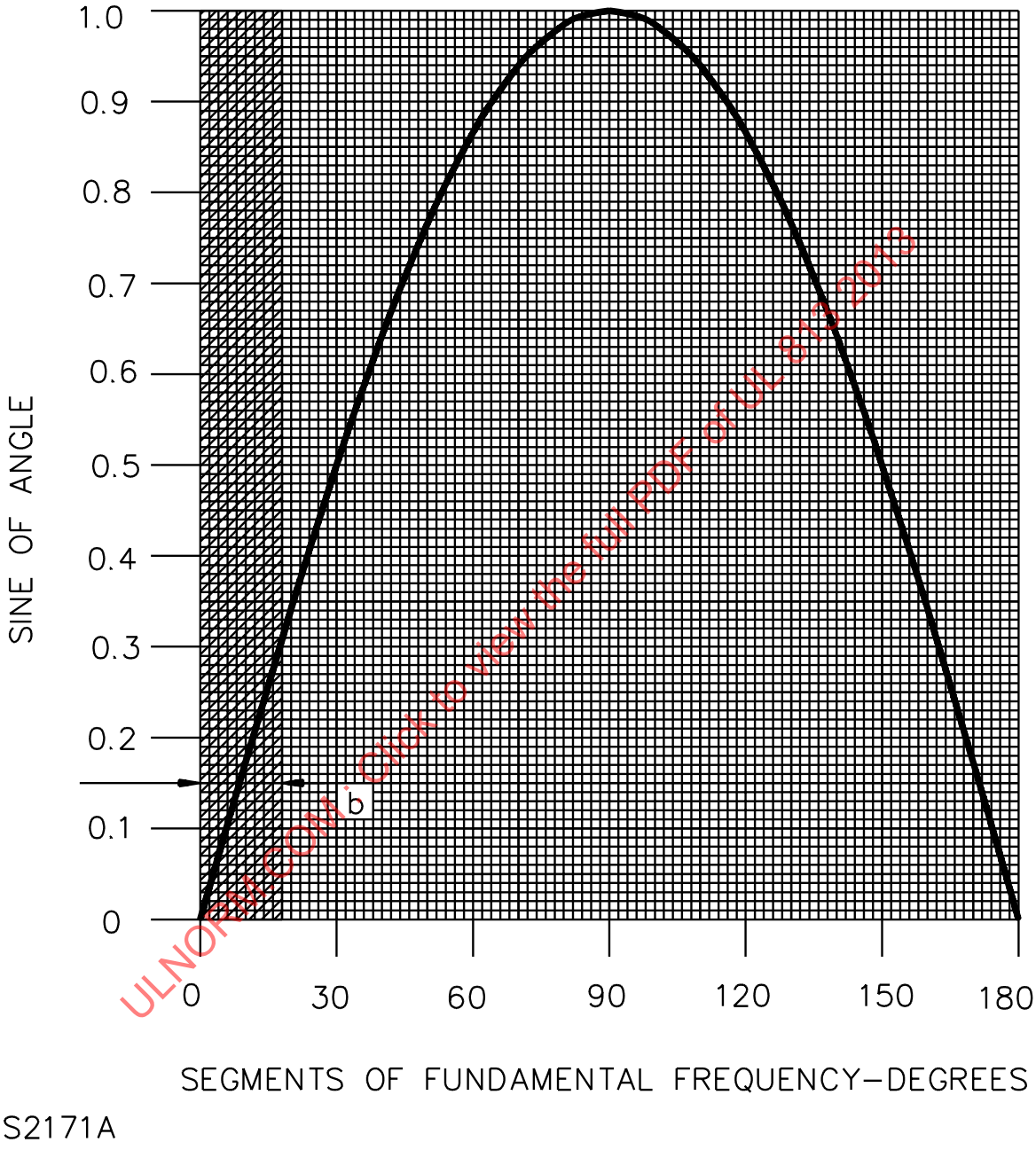
Alternating current, direct current, and combinations thereof	Fundamental frequency, Hz[a]		Maximum current in milliamperes, through a 500-ohm resistor	
	Greater than	But not greater than	Where the instantaneous current does not reverse in polarity	Where the instantaneous current does reverse in polarity
			Peak	Peak-to-peak
Where the change in instantaneous current for any duration equal to 5 percent of the period of the fundamental frequency of the wave form is no more than 3.3 milliamperes	0	100	14.2	14.2
	100	500	18.8	18.8
	500	1000	22.0	22.0
	1000	2000	28.2	28.2
	2000	3000	34.6	34.6
	3000	4000	39.2	39.2
	4000	5000	44.0	44.0
	5000	6000	50.2	50.2
	6000	b	55.0	55.0
Where the change in instantaneous current for any duration equal to 5 percent of the fundamental frequency of the wave form is more than 3.3 milliamperes	0	3	10.0	(No values determined)
	3	4	9.2	
	4	5	8.3	
	5	6	7.5	
	6	7	6.7	
	7	8	5.8	
	8	9	5.0	
	9	10	4.2	
	10	200	4.1	
	200	300	4.3	
	300	400	4.7	
	400	500	5.2	
	500	600	5.7	
	600	700	6.2	
	700	800	6.8	
	800	900	7.7	
	900	1000	8.5	
	1000	1400	9.3	
	1400	b	10.0	

[a] Straight line interpolation between adjacent values in the table is to be used to determine the maximum allowable current values corresponding to frequencies not shown in the table.

[b] No upper limit.

Figure 30.1
Sine wave

Figure 30.1 revised February 6, 1998



NOTES

1 Values of the sine for angles from 0 to 180 degrees.

2 b is eighteen-degree (5 percent) segment if started at zero.

30.2 Leakage current

30.2.1 When tested in accordance with 40.1.1 – 40.1.7, 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 30.1, 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.

30.3 Transient electric shock

30.3.1 The duration of a transient current (unidirectional or alternating) through a 500-ohm resistor, connected between any part exposed only during user 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. Typical calculated values appear in Table 30.2.

Exception: The peak current shall not exceed 809 milliamperes regardless of the duration.

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

$$C = \frac{88{,}400}{E^{1.43}(\ln E - 1.26)} \quad for \quad 42.4 \leq E \leq 400$$

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

in which:

C is the maximum capacitance of the capacitor in microfarads and

E is the potential in volts across the capacitor prior to discharge.

E is measured 5 seconds after the capacitor terminals are accessible by the removal or opening of an interlocked cover or similar device. Typical calculated values appear in Table 30.3.

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

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Table 30.3
Electric shock – stored energy

Potential across capacitor, volts	Maximum capacitance, μF
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
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	124.0
45	150.0
42.4	169.0
40	186.00[a]
30	319.00[a]
25	452.00[a]
21.2	625.00[a]

[a] Outdoor use or where wet contact is likely to occur only.

30.4 Antenna connections

30.4.1 Each terminal provided for the connection of an external antenna shall be conductively connected to the supply circuit. The conductive connection shall have a maximum resistance of 12.0 megohms and a wattage rating of minimum 1/2 watt and shall be effective with the power switch in the on or off position.

Exception No. 1: The conductive connection is not required to be provided when:

a) Such a connection is established in the event of electrical breakdown of the antenna isolating means;

b) The breakdown does not result in a source of electric shock; and

c) In a construction provided with an isolating power transformer, the conductive connection between the supply circuit and chassis does not exceed a resistance of maximum 12.0 megohms.

Exception No. 2: A component comprised of a capacitor with a built-in shunt resistor that complies with the requirements for antenna isolating capacitors may be rated minimum 1/4 watt.

30.4.2 The maximum resistance specified in 30.4.1 is not to exceed 12.0 megohms, assuming the maximum tolerance of the resistor value used; that is, a resistor rated 10.0 megohms with 20 percent tolerance or a resistor rated 10.9 megohms with a 10 percent tolerance may be used.

31 Risk of Fire

31.1 A risk of fire is considered to exist at any component connected to a source of power either under intended 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 considered not to exist if one or more of the following conditions exist:

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

b) There is additional series impedance not less than 20,000 ohms in a circuit where the voltage is more than 125 volts but no more than 250 volts.

c) Material, such as cotton, is not ignited under any service condition of breakdown or failure of the part itself. The arcing test for cables is given in 52.2.1 and 52.2.2.

d) A component is connected in a low-voltage, limited-energy circuit as described in 32.2.

e) A component is connected in a nonhazardous circuit as described in Nonhazardous Secondary Circuits, Section 33.

32 Low-Voltage, Limited-Energy Circuits

32.1 There are no specifications for spacings in a low-voltage, limited-energy circuit other than as may be required to prevent contact with an uninsulated live part of another circuit.

32.2 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 32.1. 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 not-inherently-limited transformer coupled with an overcurrent protective device in the output circuit;

c) A combination transformer and fixed impedance; or

d) An arrangement equivalent to 32.2(a), (b), or (c).

Table 32.1
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 no more than 30 volts AC or DC[b]	Over 30 volts but no more than 60 volts DC[b]	0 – 15 volts AC or DC[b]	Over 15 volts but no more than 20 volts AC or DC[b]	Over 20 volts but no more than 30 volts AC or DC[b]	Over 30 volts but no more than 60 volts DC[b]
Power limitation (volt-amperes)[c]	–	–	–	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 38.1.

[a] Maximum output voltage, regardless of load, with applied voltage as specified in Table 38.1.

[b] The waveform shall comply with the requirements in Table 30.1

[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.

32.3 The secondary winding of the transformer and the fixed series impedance or regulator specified in 32.2(b) and (c) are to be evaluated as part of the hazardous energy circuit.

32.4 The overcurrent-protective device specified in 32.2:

a) Shall not be of an automatically-reset type and

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

32.5 A component or assembly described in 32.2 shall be subjected to the tests described in Test for Low-Voltage, Limited-Energy Circuits, Section 46.

33 Nonhazardous Secondary Circuits

33.1 There are no 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.

Exception No. 1: Printed wiring boards shall comply with the requirements described in Table 25.1.

Exception No. 2: Wiring not segregated or routed from wiring involving risk of fire or electric shock shall be rated VW-1.

33.2 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 the applicable value specified in Table 30.1 and

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

33.3 An overcurrent protective device may be used to limit the available power to 15 watts or less.

33.4 To determine compliance with 33.2, the source of supply for a nonhazardous secondary circuit shall be subjected to the tests described in Test for Nonhazardous Secondary Circuits, Section 47.

34 Accessibility of Live Parts

34.1 General

34.1.1 A live part including audio output or speaker terminals that involves a source of electric shock shall not be accessible to the extent that it is touchable during intended operation or servicing by the user.

34.1.2 The accessibility of a live part is to be determined in accordance with Table 34.1.

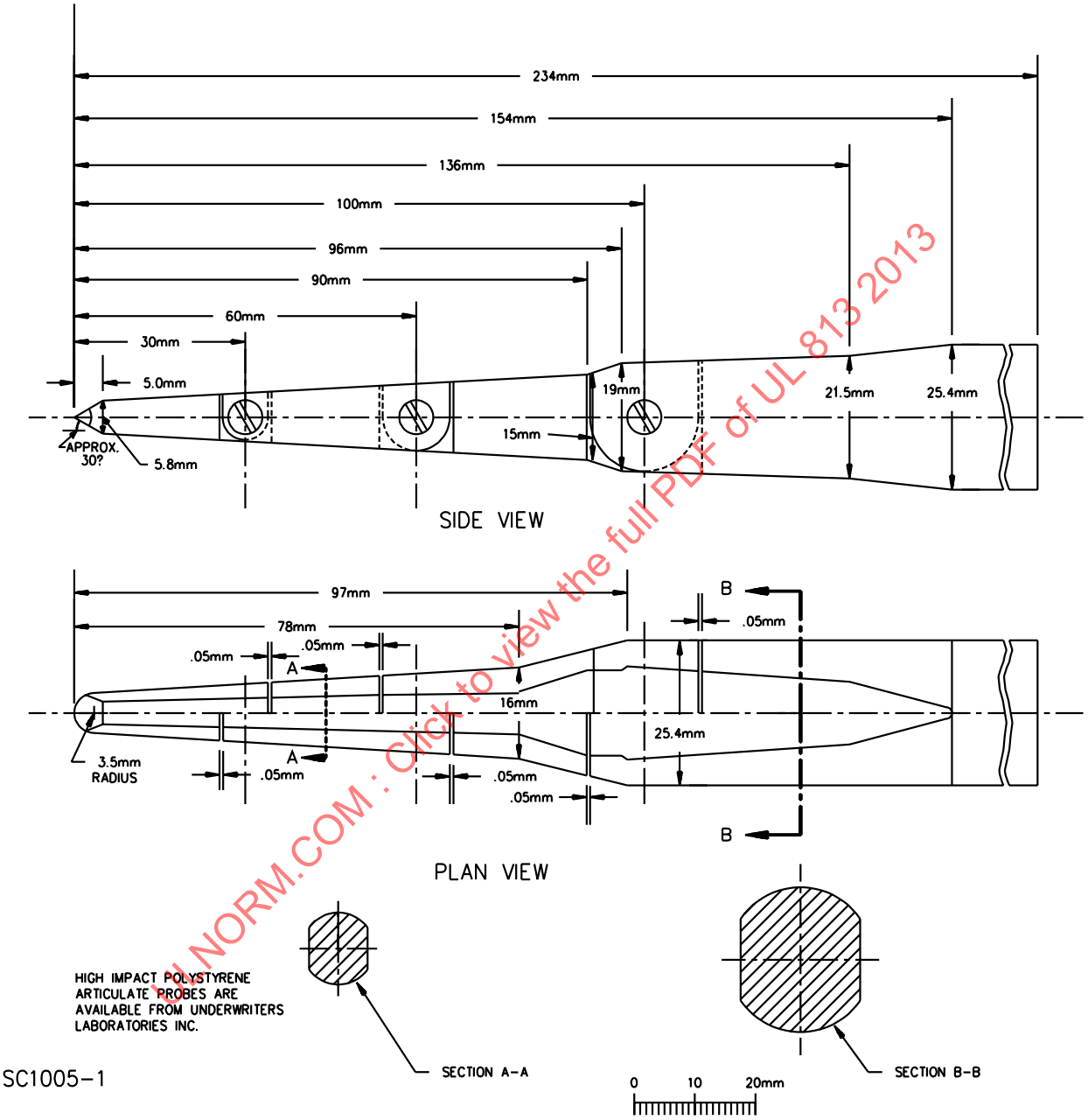
Table 34.1
Recessing of live parts

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]
	More than 1 but no more than 2 (50.8)	5D
1 (25.4) but no more than 2 (50.8)	More than 2 (50.8) but no more than 3 (76.2)	6D
More than 2 (50.8) but no more than 3 (76.2)	–	7D

[a] D is the diameter of the largest sphere that passes through the opening.
[b] See Figure 34.1 for a description of the probe. No force is to be applied to the probe to determine accessibility.

Figure 34.1
Probe for determining accessibility of live parts

Figure 34.1 revised February 6, 1998



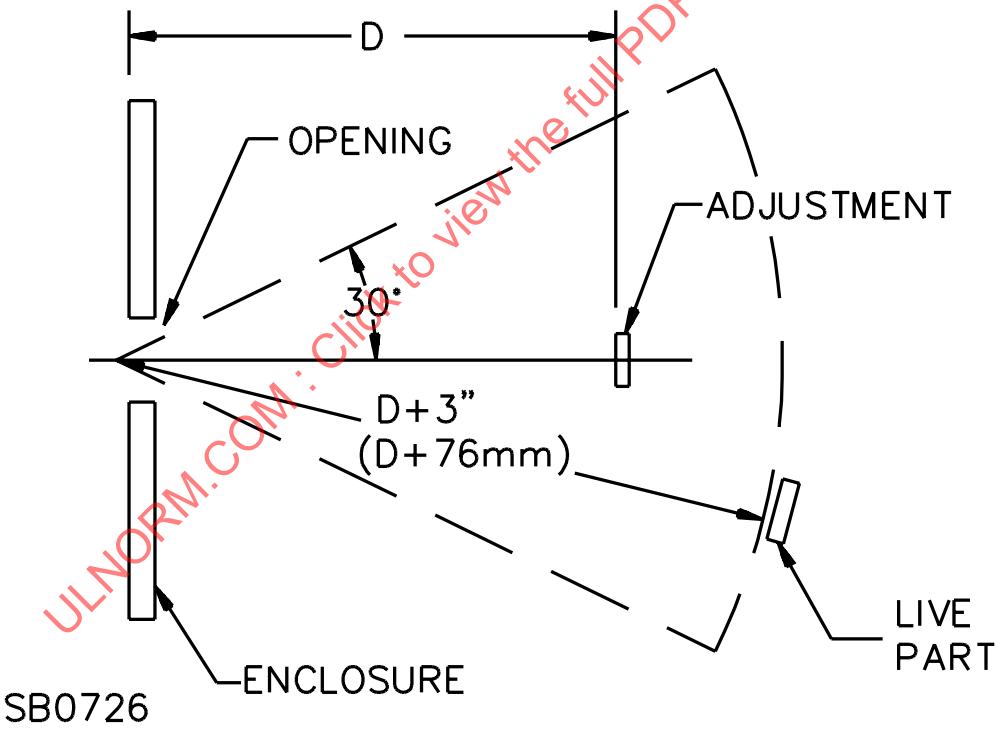
34.1.3 Regarding the application of the accessibility probe, the probe may be articulated into any configuration and may be rotated or angled to any position before, during, or after insertion into the opening. The penetration may be to any depth allowed by the opening size, including minimal depth combined with maximum articulation.

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

34.2 Adjustment opening

34.2.1 A part beyond an opening that might be used in making an adjustment (considered a function of user servicing) is not considered to be accessible when 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 34.2, the length of the rod inside the opening is not to exceed the distance D between the opening and the face of the adjusting mechanism by more than 3 inches (76.2 mm).

Figure 34.2
Accessibility of live part through adjustment opening



34.3 Top opening

34.3.1 An opening in the top of the equipment enclosure shall be such that a freely suspended, vertical test pin, 5/32 inch (4 mm) in diameter, is not able to penetrate to a depth of 4 inches (100 mm) if such penetration results in a risk of electric shock. The equipment enclosure shall be tested under the conditions described in 34.3.2.

Exception No. 1: An opening (D) in a top surface that makes an angle of 30 degrees or more with the horizontal is acceptable if the opening projection onto a horizontal plane (D') as shown in Figure 34.3 does not exceed 5/32 inch (4 mm) when measured in the direction of the horizontal projection of a line tangent to the maximum slope of the surface in which the opening is located. The upper edge of the opening is the point of tangency between a vertical line and the enclosure above the opening. The lower edge of the opening is the point of tangency between the enclosure below the opening and a line that slopes downward away from the enclosure at an angle of 5 degrees to the horizontal.

Exception No. 2: An opening in the top of an overall enclosure having a dimension larger than 5/32 inch (4 mm) and protected by a knob, handle, louver, or similar part is acceptable if a falling object cannot pass directly through the opening in a vertical direction and, the construction is such that an object placed at any point on the enclosure top does not slide or roll into the top opening. This generally requires a 1/16-inch (1.6-mm) high lip on the surface surrounding the opening. A knob protecting an opening is to be on its shaft as far as possible without actually contacting the enclosure.

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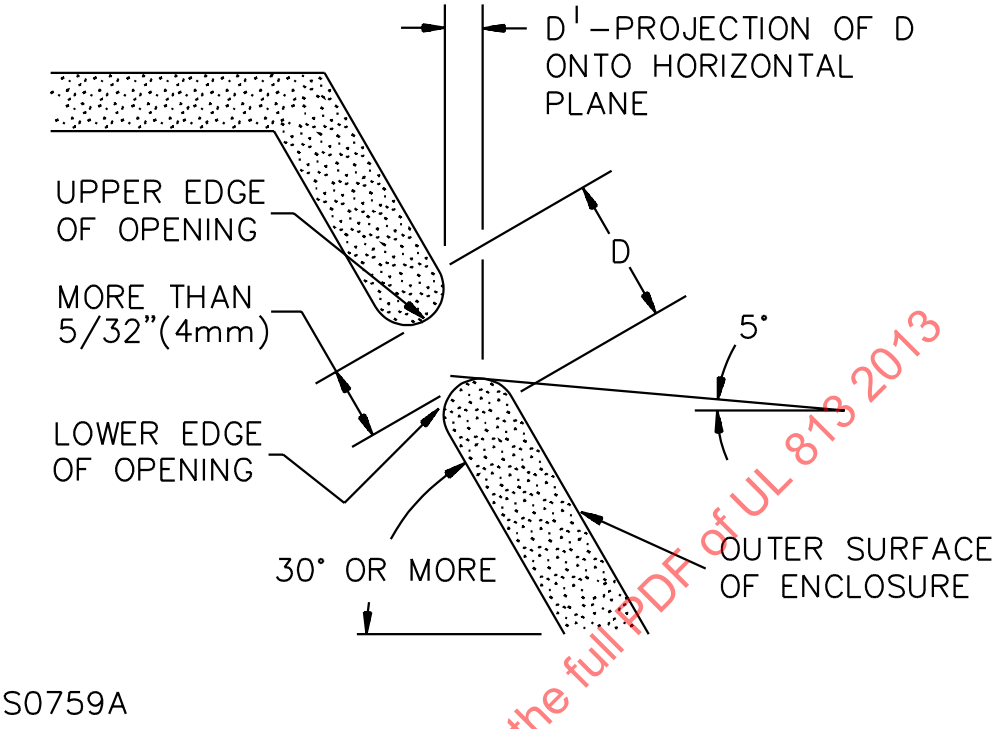
Figure 34.3
Cross section of enclosure opening



34.3.2 With regard to 34.3.1, each of the following is to be applied.

a) The top of the equipment enclosure shall be any portion of the enclosure that is a part of the area in an overhead view of the equipment when the equipment is resting on a horizontal surface.

b) Only the drawers and covers needed for operation shall be opened.

c) Each push button shall be in the position that creates the largest opening that the construction permits.

34.4 Protective screens and barriers

34.4.1 Protective screens or barriers, openings larger than those covered in Table 34.1, irregular openings, and openings in flexible materials are to be considered regarding the intent of the requirements.

34.5 Control shaft

34.5.1 A control shaft that involves a possible source of electric 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.

34.5.2 A setscrew, sealing compound, or a device that depends upon friction to prevent removal of a knob from the exterior of the enclosure shall not be used.

34.6 Captive part

34.6.1 A part of the equipment shall be made captive or shall otherwise be arranged to prevent its omission when that part:

a) Is subject to removal during user servicing,

b) Is not essential for the functioning of the equipment,

c) Is not exposed to view during intended use, and

d) If omitted, may produce a risk of electric shock.

34.7 Octal base tube socket

34.7.1 An octal base tube socket shall have its pin contacts recessed 0.057 inch (1.4 mm) minimum and shall prevent contact between a pin connected to any accessible metal part of a tube and socket contact that involves a source of electric shock.

34.8 Interlocks

34.8.1 An interlock to reduce the risk of electric shock or injury to persons shall be located so that unintentional operation is unlikely and constructed and installed so that the interlock complies with one or more of the following:

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

1) Damaging the equipment,

2) Making wiring connections or alterations,

3) The usage of 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.) When two momentary contact switches must be operated to energize the equipment, the arrangement shall comply with 34.8.1(a)(4). 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.

b) The interlock device of the equipment is such that during intended 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.

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

5) The equipment is marked as required in 65.2.1.

34.8.2 A part that is recessed more than 2-1/2 inches (63.5 mm) from the edge of the cabinet opening, usually in 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.

34.8.3 When 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.

35 User Servicing

35.1 User servicing includes the following:

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

b) Fuse – Replacement of a fuse other than:

1) One intended to be soldered in place.

2) One not readily perceptible by the user; a fuse is not readily perceptible if located within a chassis, compartment, or enclosure within the overall equipment that makes the fuse invisible to the user. If the enclosure has a cover, it is to be one that:

i) Does not need to be opened or removed during intended operation or user servicing,

ii) Can be opened or removed only with a tool, and

iii) Is prevented from being discarded.

A fuse is readily perceptible if recognizable during intended operation or user servicing, either visually or by touch, or if the fuse is indicated, either on the equipment or on literature packed with it.

Exception: The literature specified in 35.1(b)(2) does not include schematic circuit diagrams or instructions for service personnel as described in 66.1.2.

3) One that is within a compartment provided with the marking described in 65.1.1.

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 accomplished with ordinary tools, with the equipment in operation, and without defeating the interlock.

e) Unmarked Adjustment – Adjustment of an unmarked adjustable control accomplished without a tool, with the equipment in operation, and without defeating the interlock.

f) Terminals, Jacks, Connectors – User accessible terminals, jacks, and connectors (including those that are recessed) intended for connection of other accessories and equipment such as microphones, speakers, turntables, tape recorders, amplifiers, and preamplifiers.

36 Field-Installed Accessories

36.1 For these requirements, accessory equipment is defined as a piece of equipment intended to be attached or added to equipment by the user and of a size so that it may be marked for identification by a catalog number or its equivalent. Accessory equipment is usually dependent upon the basic appliance for mechanical or electrical support or input and may or may not, by itself, perform a complete function.

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

36.3 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 appliance or as a part of the building wiring.

37 Protection Against Injury To Persons

37.1 General

37.1.1 A risk of injury to persons is considered to exist when:

a) A power-operated moving part such as a gear or linkage is accessible during intended operation;

b) A sharp edge, burr, or projection is present that can cause injury during user assembly, use, or cleaning; or

c) The degree of stability of the equipment or the equipment on a cart or stand used with it is such that it can contribute to the risk of injury.

37.1.2 Equipment shall be subjected to the tests described in 37.2.1 – 37.4.1 and Strength of Enclosure Test, Section 56, to determine whether the conditions described in 37.1.1 are present.

37.2 Power-operated moving parts

37.2.1 The accessibility of a power-operated moving part (such as a gear or linkage) is to be determined by the applicable accessibility requirements in 34.1.1 – 34.1.4 and 34.4.1. 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. The requirement does not apply to any of the following constructions:

a) A pick-up arm assembly, turntable, or similar part on the top surface of a record changer or player.

b) A tape reel or tape drive mechanism that must be exposed for intended use. However, a gear or linkage is to be evaluated for accessibility when the construction permits that part to move with a tape reel, cartridge, or cassette removed from its operating position.

c) A gear or linkage that is accessible only after lifting a side or corner of a spring-mounted motor board (record changer or record player chassis). Accessibility to a power-operated moving part is to be determined with the record changer or record player in its intended playing position. A spring-mounted or suspended motor board is to be captive so it cannot be easily removed or lifted from the mounting surface.

37.3 Enclosures and guards

37.3.1 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 34.1 to contact the part when inserted as described in 34.1.3.

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

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 interlocks to protect against access to the source of injury.

37.3.3 An enclosure or guard shall be subjected to the tests described in 56.4.1 – 56.4.3.

37.3.4 The requirement in 37.3.3 applies to that portion of a guard adjacent to a moving part that is considered a possible source of injury to persons.

37.4 Sharp edges and projections

37.4.1 An edge, projection, or corner of an enclosure, opening, frame, guard, knob, or handle, of the equipment shall be smooth and round and not sufficiently sharp to cause cuts when contacted during intended use or user servicing of the equipment.

PERFORMANCE

38 General

38.1 Alternating-current and direct-current equipment

38.1.1 Equipment having both alternating current and direct current ratings is to be tested with the equipment connected to an alternating current supply and again to a direct current supply.

Exception: There is no need to conduct both tests if it can be established that one test results in the maximum operating conditions.

38.2 Voltmeters

38.2.1 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.

38.2.2 The open circuit voltage measurement in conjunction with a leakage or electric 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 can be used.

38.3 Cheesecloth indicators

38.3.1 Cheesecloth used for tests shall be untreated cotton cloth running 14–15 square yards per pound (26–28 square meters per kilogram) and having what is known to the trade as a count of 32 by 28.

38.3.2 Tests involving cheesecloth are to be made in a room free of drafts.

38.4 Supply circuit voltage and frequency

38.4.1 All operational tests shall be conducted with the equipment connected to a supply circuit of rated frequency and of the voltage indicated in Table 38.1.

Exception: Equipment with a dual frequency rating is to be tested at 60 Hz, if 60 Hz is included in the rating and may also be tested at the second frequency if such testing is warranted.

Table 38.1
Operation test voltages

Marked voltage rating between[a]	Test voltage for intended operation	Test voltage for abnormal operation
105 – 130	Maximum marked voltage, but no less than 120	130[b]
210 – 260	Maximum marked voltage, but no less than 240	110 percent of maximum marked voltage, but no 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 no less than 105 volts or 210 volts, respectively. The lower test voltage value may be used for abnormal operation tests where the lower value will represent a more severe condition or where a higher voltage would cause a protective device to open the circuit.

39 Operation Test

39.1 Operation of the equipment as described in 39.2 shall not increase the risk of fire, electric shock, or injury to persons.

39.2 A sample of the equipment in the as-received condition is to be set up or installed and operated in accordance with the manufacturer's instructions regarding the intended uses of the equipment, including intended maintenance and cleaning, with all accessories supplied by the manufacturer for use with the equipment in place. The equipment 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 such that all reasonably foreseeable complications are revealed.

40 Leakage Current and Shock Current Tests

40.1 Leakage current

40.1.1 The leakage current of cord connected equipment when tested in accordance with 40.1.2 – 40.1.7 shall not be more than specified in 30.2.1.

40.1.2 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.

40.1.3 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 protect against electric shock. Surfaces that can be readily contacted by one or both hands of a person at the same time are considered to be simultaneously accessible. These measurements do not apply to terminals operating at voltages that are less than 30 volts.

40.1.4 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 dimensions 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.

40.1.5 The measurement circuit for the leakage current test is to be as illustrated in Figure 40.1. The measurement instrument is defined in 40.1.5(a) – (d). 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 Hz.

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

40.1.6 A sample of the equipment 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. Equipment 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 40.1) is to be as follows:

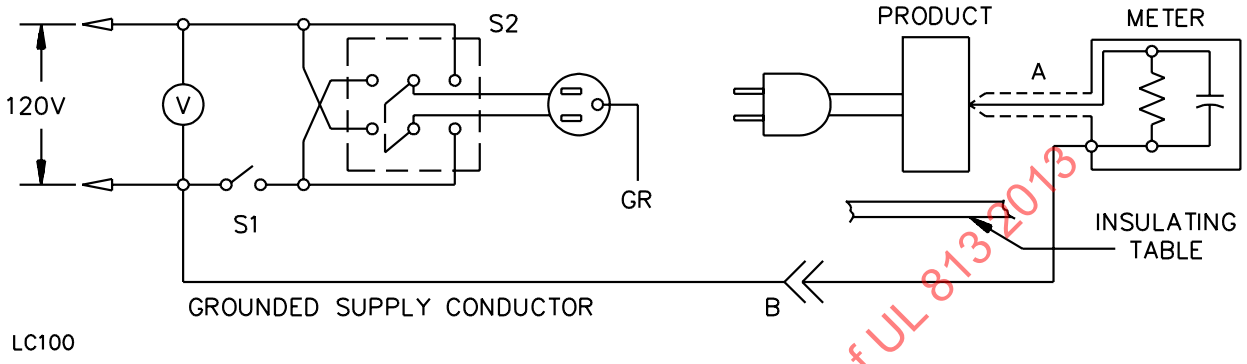
a) With switch S1 open, the equipment is to be connected to the measuring circuit. Leakage current is to be measured using both positions of switch S2, and with the equipment switching devices in all of their intended operating positions.

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

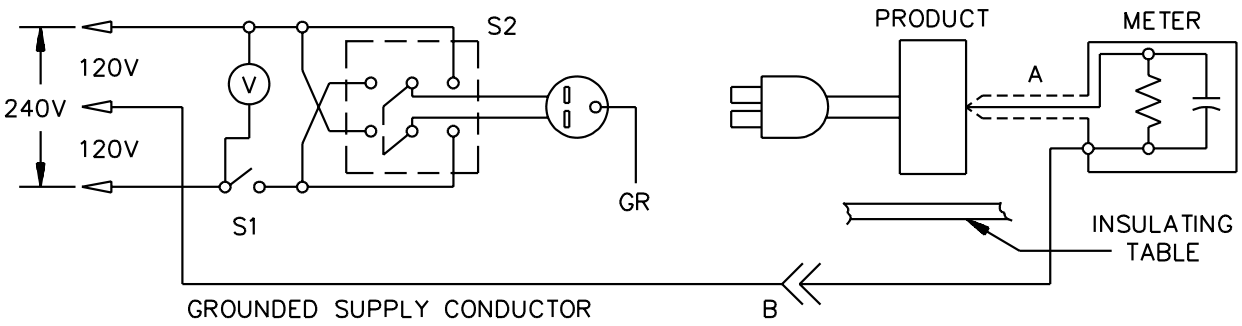
c) Leakage current is to be monitored until thermal stabilization. Both positions of S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation of the equipment as in the Temperature Test, Section 42.

Figure 40.1
Leakage current measurement circuits

Figure 40.1 revised February 6, 1998

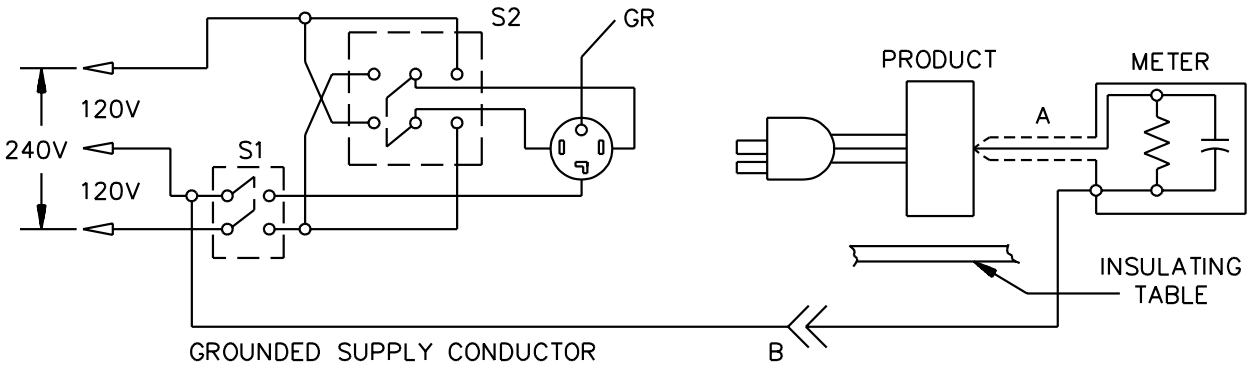


Equipment intended for connection to a 120-volt power supply.



LC200

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



LC300

Equipment 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.

40.1.7 Usually the complete leakage current test described in 40.1.6 is to be conducted without interruption for other tests. With the concurrence of those concerned, the leakage current tests may be interrupted for the purpose of conducting other nondestructive tests.

40.2 Electric shock current

40.2.1 All parts accessible during user servicing are to be tested for electric shock current. The currents from these parts are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible and from one part or group of parts to another part or group of parts if simultaneously accessible. Parts are considered to be simultaneously accessible when they can be contacted by one or both hands of a person at the same time. For this measurement, one hand is considered to be able simultaneously to contact parts that are within a 4 by 8 inch (102 by 203 mm) rectangle; and two hands of a person are considered to be able simultaneously to contact parts that are not more than 6 feet (1.8 m) apart.

40.2.2 Electric shock current refers to all currents, including capacitively coupled currents.

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

40.2.4 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 phonograph pickup cartridge, and between the plates of an adjustable or variable air dielectric capacitor, may be short-circuited during the test.

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

40.2.6 Current measurements are to be 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.

40.3 Electric shock at audio output under fault conditions

40.3.1 In an amplifier audio output circuit tested in accordance with 40.3.2 – 40.3.5, the voltage between any accessible part as described in 34.1.2, and any other accessible part including earth ground or another accessible part of the audio output circuit, is not to 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 duration of current through a 500-ohm noninductive resistor connected between the parts satisfies the following equation:

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

in which:

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

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.

Added 40.3.1 effective December 13, 1996

40.3.2 A variable resistor is to be connected between any two terminals of a discrete unreliable component (for example; vacuum tube, diode, electrolytic capacitor, transistor, 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.

40.3.3 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 magnitudes of current.

40.3.4 With the equipment connected to a supply circuit according to 38.2.1 and Table 38.1 and operating as intended under no-load conditions, the variable resistor is to be slowly reduced in value and the voltage at the audio output is to be monitored. If the equipment ceases to function before the voltage at the audio output exceeds the values specified in 40.3.1, 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 is reached, or the voltage is reduced or interrupted by the opening of a fuse or overload protector or limiter.

40.3.5 Following the test procedure specified in 40.3.4, the new equipment, or one repaired to original operating order, is to be additionally tested by suddenly applying a short circuit across the same two terminals. The output voltage waveform is to be recorded on a storage oscilloscope or by similar means.

40.3.6 When the maximum value of output voltage measured according to either 40.3.4 or 40.3.5 exceeds the values specified in 40.3.1, a 500-ohm noninductive resistor is to be connected between the parts. The tests specified in 40.3.4 or 40.3.5 (or both if the maximum value of output voltage exceeded the specified values when the equipment was tested according to both paragraphs) are to be repeated; however, the current through the 500-ohm resistor (rather than the open-circuit voltage) is to be monitored.

40.3.7 The results comply when the duration of the current through the resistor satisfies the equation for transient electric shock specified in 30.3.1.

40.3.8 When a fuse, other circuit protective element, protector, limiter, or similar device is relied upon to open the circuit, then the equipment is to be marked in accordance with 64.8.1 and 65.3.1.

40.3.9 When the protective or limiting function is accomplished through the use of solid-state circuitry to provide sensing, cut-off, or limiting the equipment with protective or limiting, circuitry shall complete 100,000 cycles of operation, simulating the fault(s) that it is intended to interrupt or clear, to reduce the risk of hazardous potentials appearing at the speaker terminals.

40.3.10 To determine compliance with 40.3.9, three samples of the equipment are to be subjected to the cycling test. Upon completion of the required number of cycles, the test specified in 40.3.4 or 40.3.5 is to be repeated.

41 Power Output and Power Input Tests

41.1 Power output

41.1.1 The audio input connections of the equipment or system to be tested are to be connected to a sine wave oscillator, the frequency of which is adjusted to 1000 Hz or the geometric mean frequency of the upper and lower frequency limits of the equipment or system under test. (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 Hz or the manufacturer's rated value, whichever is higher; the upper frequency limit is to be 20 kHz or the manufacturer's rated value, whichever is lower.

41.1.2 The geometric mean frequency corresponding to the rated frequency response of each channel is to be applied as the input signal for the channel(s) of equipment intended only to cover a limited portion of the audio frequency range, such as a bass amplifier, biamplifier, and the like.

41.1.3 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 equipment are to be electrically replaced with an equivalent resistive load.

41.1.4 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 so 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 a clearly delineated clipping is not visible, the maximum undistorted output power is defined as the power reading after the amplifier transconductance (the output current divided by the input signal voltage) or the voltage gain (the output voltage divided by the input voltage) has changed 10.0 percent. 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.

41.1.5 During the measurement of the maximum undistorted output power, fuses, circuit breakers, limit switches, or other safety devices or circuits are actuated and prevent determination of maximum undistorted output power, the protective device or protective circuit is to be defeated. If the measurement is still unattainable, the maximum undistorted output power is to be taken as the manufacturer's rated output power.

41.2 Power input

41.2.1 The current or wattage consumption of the sound equipment or system shall not exceed the marked input rating by more than 5 percent when the equipment is operated under intended conditions as described in 41.2.2 – 41.2.8 while connected to a supply circuit of rated frequency and voltage as specified in Table 38.1.

41.2.2 All controls are to be adjusted to cause the amplifier to deliver measured maximum undistorted output power or manufacturer's rated output power, whichever is greater, into matched resistive loads when operated as described in 41.1.1 and 41.2.3 – 41.2.5. The test is to be repeated throughout the range of audio load impedance taps provided, and in each case the resistive load is to match closely the rated output load of the amplifier taps. The input power is then to be determined when the amplifier is delivering one-eighth output power (considered to be intended operation) as tested above. The power consumption shall comply with the requirements specified in 41.2.1.

41.2.3 Each input and corresponding output of a biamplifier, multichannel amplifier, or other unit that has an effect on the total power consumption of the unit is to be operated simultaneously under the conditions specified in 41.2.2. A biamplifier and similar equipment is to have the 1000 Hz sine wave or sine wave geometric mean frequency of the rated frequency response for an individual input/output pair applied to the respective inputs simultaneously.

41.2.4 A signal processing unit is to be operated as in 41.1.1 with an input sine wave signal frequency of 1000 Hz or the geometric mean frequency of the unit, as appropriate, adjusted to provide the maximum undistorted output signal, into a resistive load matching the output impedance specified by the manufacturer. For a unit whose power consumption is not affected by an audio signal, it is not necessary to provide an audio signal during the input test. A unit containing any motor, solenoid, or other load as found in tape machines, turntables, and the like is to be operated under conditions approximating those of intended use.

41.2.5 Other types of products not covered by 41.2.3 and 41.2.4 are to be tested under conditions closely approximating intended operating conditions. Equipment incorporating combinations or features of power amplifiers, signal processing units, signal generators, and similar devices to have those pieces of the equipment tested as described for the appropriate equipment.

41.2.6 Equipment not having separate audio input terminals shall be operated with an appropriate input signal, as described in 40.1.2, 40.1.6, and 40.1.7 (as appropriate), applied to the first audio stage of the equipment.

41.2.7 Equipment that has provision for charging a self-contained storage battery is also to be operated while charging the battery from a discharged (but not short-circuited) state.

41.2.8 An unused receptacle or connector shall be loaded to its maximum rating and shall be marked in accordance with 64.5.1 and 64.6.2.

Exception: A conventional, parallel-slot type that is used to supply power to other equipment or to an accessory need not be loaded for the input test.

42 Temperature Test

42.1 General

42.1.1 Equipment shall be subjected to the test conditions described in 42.1.2 – 42.3.6. The results comply when:

a) There is no temperature at any part sufficiently high to constitute a risk of fire or damage to any materials employed and

b) There is no temperature at specific points higher than those indicated in Table 42.1.

Table 42.1
Maximum temperature rises

Materials and components		°C	°F
1.	Varnished cloth insulation	60	108
2.	Fuses	65	117
3.	Fiber used as electrical insulation	65	117
4.	Wood and other combustible material	65	117
5.	Conductors with rubber or thermoplastic insulation	35[a]	63[a]
6.	At any point within a terminal box or wiring compartment of a permanently connected appliance in which power supply conductors are to be connected, including such conductors themselves, unless the appliance is marked in accordance with64.12.1.	35	63
7.	An electrolytic capacitor	40[b]	72[b]
8.	A cabinet of thermoplastic material on a portable, cord-connected appliance	40[a]	72[a]
9.	A selenium rectifier	50[a,c]	90[a,c]
10.	A silicon rectifier	75[a,c]	135[a,c]
11.	Exterior surface of an overall enclosure	65[d]	117[d]
12.	Handles and knobs	See Table 42.2	
13.	Laminated phenolic composition	100[a]	180[a]
14.	Phenolic composition	125[a]	225[a]
15.	Transformers with class 105 insulation systems:		
	Thermocouple method	65	117
	Resistance method	75	135
16.	Class 105 insulation systems on coil windings of AC motors (other than universal motors) having a frame diameter no larger than 7 inches (178 mm)[e]		
	a) In open motors (thermocouple or resistance method)	75	135
	b) In totally enclosed motors (thermocouple or resistance method)	80	144
17.	Class 105 insulation systems on windings of relays, solenoids, magnets, and the like		
	Thermocouple method	65	117
	Resistance method	75	135

NOTE – Tests can be made at any room temperature between 10°C (50°F) and 40°C (104°F).

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

Table 42.1 Continued on Next Page

Table 42.1 Continued

Materials and components	°C	°F
[b] A capacitor operating with a temperature rise greater than 40°C (72°F) may be evaluated on the basis of its marked temperature rating or, if not marked with a temperature rating, may be investigated to determine its use at the higher temperature.		
[c] A rectifier operating with a temperature rise greater than 75°C (135°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).		
[d] This limitation does not apply to that portion of semiconductors (including their heat sinks) on the rear surface of amplifiers and the like that cannot touch a vertical wall surface placed immediately behind the equipment, nor to vacuum tubes and semiconductors (including their heat sinks) of amplifiers and the like that are intended for protected installations.		
[e] 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, boxes, and the like used solely for motor mounting, assembly, and connection are to be excluded.		

42.1.2 Equipment when subjected to the test conditions described in 42.1.3 – 42.3.6, is to be operated until constant temperatures are reached with all unused receptacles loaded to their maximum rating, and with the equipment mounted, positioned, closed, or enclosed to represent intended use when use conditions are not described.

42.1.3 Operation of an amplifier under the conditions described in 42.1.2 is not to cause a thermal or overcurrent protective device of the single operation (nonresettable) type to function.

42.1.4 If operation of an amplifier under the conditions described in 42.1.2 causes a resettable thermal or overcurrent protective device to function (including those that limit power supply output), the unit is to be tested as described in 42.1.5 and 48.5.1.

42.1.5 Optional cooling or ventilating equipment, as recommended in an installation and use manual provided by the manufacturer, is to be installed. The temperature test is to be repeated under the conditions described in 42.1.2. The resettable overcurrent, overtemperature, or other protective device shall not function under these conditions.

42.1.6 Ordinarily, the temperature of a coil or winding is to be measured by means of thermocouples mounted on the outside of the coil wrap. When the coil is inaccessible for mounting thermocouples [for instance, a coil immersed in sealing compound or a coil wrap that includes thermal insulation such as asbestos, 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 described by item 16 of Table 42.1, the thermocouple is to be mounted on the integrally applied insulation of the conductor. At a point on the surface of a coil where the temperature is affected by an external source of heat, a ″hot spot″ temperature no 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 no more than that specified in Table 42.1.

42.1.7 When using the resistance method, the windings are to be at room temperature at the start of the test. The temperature rise of a winding is to be calculated from the formula:

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

in which:

ΔT is the temperature rise of the winding in °C;

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

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

t_1 is the room temperature at the beginning of the test in °C;

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

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.

42.1.8 All values in Table 42.1 are based on an assumed ambient (room) temperature of 25°C (77°F), but a test may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F).

42.1.9 It is standard practice to use thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wire and a potentiometer-type instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary. When it is not practical to use iron and constantan thermocouples, other types of thermocouples as described in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M, may be used.

42.1.9 revised October 4, 2013

42.1.10 Thermal equilibrium is considered attained when three successive readings taken at 15 minute intervals indicate that there is no temperature change of the part.

42.1.11 The equipment is to be set up or mounted as in actual service and connected to a supply circuit as described in Table 38.1.

42.1.12 The equipment is to be operated with a pink noise audio input signal (band-limited at 12 decibels per octave, 20 Hz to 20 kHz, 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 specified in 42.1.12 (a) and (b) are those given by the manufacturer. 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 Power Output and Power Input Tests, Section 41, 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 when tested in accordance with 41.2.1. The output power is to be calculated using the relation $P = E^2/R$ in which E is the voltage measured by a true rms indicating voltmeter across the noninductive resistive output load R.

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

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

Exception: At the manufacturer's request, the temperature test may be conducted using a 1 kHz 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.

42.2 Rack-mounted equipment

42.2.1 A large rack or console involving several units grouped in a single large enclosure is to be placed against a vertical wall of wood or comparable material.

Exception No. 1: This requirement does not apply to equipment obviously intended for installation in the open.

Exception No. 2: If the back of the equipment is provided with covers or doors for servicing, a minimum spacing of 18 inches (457 mm) is to be maintained between the back of the enclosure and the wall (unless other factors, such as the space needed for the swinging of hinged doors, requires a greater spacing).

Exception No. 3: Equipment intended for installation against a wall, and provided with ventilation openings on the rear surface, is to be spaced 1 inch (25.4 mm) from the wall surface, or the equipment is to be placed as close to the wall as its construction will permit.

42.2.2 An individual appliance that can be used as rack-mounted equipment or portable equipment when provided with a complete enclosure by the manufacturer is to be tested under the conditions for rack-mounted equipment, or for portable equipment, whichever is more severe.

42.2.3 An individual amplifier, signal processing unit, or similar device having provision for rack mounting is to be installed in a test rack constructed of metal, as described in 42.2.4. The unit is to be mounted at the top of the rack, and a standard 1-3/4 inch (44.5 mm) high blank panel is to be mounted directly below the unit. A resistor panel as described in 42.2.5 is then to be mounted below the blank panel, and the remaining front panel area is to be filled with blank panels. The resistor panel is to be connected to a source of supply adjusted to cause the resistors to dissipate power equal to the power dissipated by the unit under test. The rack is to be positioned as described in 42.2.1, taking into consideration recommendations that can be carried out with materials supplied as part of the basic equipment, as described in the manufacturer's instruction manual.

Exception: A second sample of the unit under test may be used in place of a resistor panel. The second unit is to be operated with the same input signal and output power of the unit under test.

42.2.4 The metal rack for mounting equipment with standard 19-inch (483-mm) front panels is to be constructed of metal no thinner than 0.053 inch (1.34 mm), having approximate overall dimensions of 32 inches (0.81 m) high by 22 inches (0.56 m) wide, with a clearance depth of 16 inches (406 mm) or greater, if needed to contain the equipment under test. Clearance depth of greater than 16 inches is not to exceed the product depth by more than 3 inches (76.2 mm). The panel space is to accommodate standard 19 inch panels. The left and right sides are to be provided with louvers. The louver area is not to exceed 30 percent of the side area, and the total opening area is not to exceed 5 percent of the side area. The top is to be solid and the rear door is to have an opening for ventilation across the bottom 2-1/2 inches (63.5 mm) high, or louver openings may be located in the rear door to provide an equivalent open area for ventilation.

42.2.5 The resistor panel referred to in 42.2.3 is to use a standard 19-inch (483-mm) rack panel, 5-1/4 inches (133 mm) high, and a metal top panel with dimensions the same as the bottom of the unit under test. The top panel is to support the resistive loads, mounted underneath, that will dissipate energy as described in 42.2.3, simulating the heat contribution of similar equipment mounted below.

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42.3 Portable equipment

42.3.1 Portable equipment 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 1-inch spacing requirement may be waived if the arrangement of ventilation and similar cooling factors is such that operation against a wall (as compared with operation in the open) will not increase operating temperatures.

Exception No. 2: This requirement does not apply when of the device is constructed so that a spacing greater than 1 inch is maintained.

42.3.2 Doors and covers that may be closed during operation of the equipment are to be closed during the test.

Exception: Consideration may be given to the actual conditions of intended operation of the equipment, including the changing of records.

42.3.3 A portable amplifier without a cover is to be tested in any optional enclosure that may be provided by the manufacturer or shall be provided with a built-up wood cover simulating installation in a cabinet. The cover is to be constructed of wood nominally 3/4 inch (19.1 mm) in thickness and is to consist of a top, sides, and front, arranged so as to expose user controls. The cover is to provide a clearance of 2 inches (50.8 mm) from each side of the chassis and is to clear the top of the tallest component part mounted above the chassis by 2 inches. In determining the chassis dimensions, extended flanges and feet are to be disregarded.

42.3.4 A turntable, record changer, or tape deck without an enclosure intended for a protected installation is to be mounted in a built-up enclosure simulating installation in a cabinet. The enclosure is to be constructed of wood nominally 3/4 inch (19.1 mm) thick and is to consist of four sides and a bottom. The enclosure is to provide a clearance of 1 inch (25.4 mm) from the bottom of the lowest component.

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

42.3.6 During the temperature test, temperature rises on surfaces that may be contacted by the user are to be measured. The results comply if the temperature rises do not exceed the values given in Table 42.2.

Table 42.2
Maximum surface temperature rises

Location	Composition of surface[a]	
	Metal	Nonmetallic
Handles or knobs that are grasped for lifting, carrying, or holding	25°C (45°F)	35°C (63°F)
Handles or knobs that are contacted but do not involve lifting, carrying, or holding, and other surfaces subject to contact and user maintenance[b]	35°C (63°F)	60°C (108°F)

NOTE– Tests can be made at any room temperature between 10°C (50°F) and 40°C (104°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.

[b] A heat sink may exceed the specified temperature if a marking, which is permanently affixed or adjacent to the heat sink, reads: ″CAUTION – HOT SURFACE, AVOID CONTACT,″ or the equivalent.

43 Audio Output Maximum Voltage Test

43.1 Deleted effective April 1, 2001

43.2 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 thereto, the test impedance is to be adjusted to have a value equal to the rated output load impedance of the amplifier. 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 ($R = E^2/W$). The input signal voltage is to be adjusted to a value so that the appliance delivers rated power or maximum available undistorted sine wave power to the load, whichever is greater. After the adjustments described are made, in accordance with the method of marking the output terminals, the output circuit is to be opened and the potential across the output terminals measured. The test is to be conducted with the variable-frequency generator set at 1000 Hz or geometric mean frequency. Throughout these tests, the supply circuit is to be adjusted as described in 42.1.11.

Revised 43.2 effective April 1, 2001

44 Maximum Voltage Test

44.1 The maximum voltage used as a basis for the calculation of the dielectric voltage-withstand potentials specified in 45.6.1, 45.7.1, 45.8.1, and 45.8.2 shall be determined in accordance with 44.2 – 44.5.

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

44.3 An automatic voltage-regulating device is to be rendered inoperative. The investigation is to take into consideration any possible failures in either the regulating device or the equipment and possible disconnection of the device, when it is not permanently connected in the circuit.

Exception: The investigation need not be conducted if it has been previously determined that the device or tube can be relied upon to prevent an increase in voltage.

44.4 A connector or comparable part that is likely to be disconnected during intended operation or user servicing is to be both connected and disconnected during the test in order that the maximum voltage may be obtained.

44.5 When a complex voltage is present, the peak value of the voltage is to be measured.

44.6 If the maximum voltage across an electrolytic capacitor is more than its marked operating voltage rating when measured under the conditions described in 44.2 – 44.4, the capacitor shall not short-circuit when subjected to the test specified in 44.7.

44.7 The equipment 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 then to be 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 electrolytic capacitor is acceptable if all three samples operate for 15 minutes without short-circuiting.

45 Dielectric Voltage-Withstand Test

45.1 General

45.1.1 The insulation and spacings of the equipment shall be capable of withstanding without breakdown for 1 minute the application of the test potentials described in 45.1.2 – 45.8.2.

Exception: The test may be waived when an investigation shows that such breakdown will not result in a source of fire or electric shock.

45.1.2 When conducting the dielectric voltage-withstand test, the applied 60 Hz voltage is to be monitored with a voltmeter having a minimum resistance of 2000 ohms per volt. Breakdown, not leakage, is to be the criteria for compliance. Leakage is the intended flow of current due to imperfect insulating materials and can vary with the applied voltage.

45.1.3 Breakdown is defined as actual insulation or spacing failure and is indicated by an abrupt decrease or retarded advance of the voltmeter reading.

45.1.4 The test potentials specified in 45.2.1 – 45.4.1 are to be obtained from a testing transformer, the output 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. The dielectric voltage-withstand tests are to be conducted with the equipment at its intended operating temperature.

45.2 Primary circuits

45.2.1 A 1000-volt, 60 Hz potential is to be applied between any live part conductively connected to the supply circuit and any dead metal part or user terminal such as an antenna or ground lead.

45.2.2 If an isolating power transformer is not a part of the equipment, the test described in 45.2.1 is to be conducted with tubes removed, filament circuits short-circuited, and electrolytic capacitors and plate cathode rectifier terminals short-circuited.

45.3 Isolating power transformer

45.3.1 When an isolating type of power transformer is employed, a 1000 volt, 60 Hz potential is to be applied between any live or current carrying part of the primary or power supply circuit and any live part or current carrying part of the secondary circuit.

45.4 Primary insulation

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

Exception: This test need not be conducted in the secondary circuit of an isolating type power transformer.

45.5 Output circuit

45.5.1 When the equipment 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 (but in no case less than 1270 volts) is to be applied across a blocking capacitor (other than an electrolytic type) and between the primary and secondary windings of an isolating type output transformer, the output circuit of which is isolated from the chassis used for speaker coupling.

45.5.2 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.

45.6 Power transformer secondary

45.6.1 When a power transformer is employed, the secondary circuit of which involves a possible risk of fire or electric shock, a direct-current potential of three times the maximum voltage determined in accordance with 44.2 – 44.4, but not less than 500 volts, is to 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 in 44.6.

45.6.2 An electrolytic capacitor, tube, transistor, or similar device 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.

45.6.3 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.

45.6.4 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.

45.6.5 The test potential can 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.

45.6.6 The equipment is to be connected to the variable source of supply. Starting at zero, the supply potential is to be increased gradually until the lowest of the several secondary test voltages is reached or until breakdown occurs. Upon completion of the test of the lowest voltage circuit, that circuit is to be disconnected from the remaining higher voltage secondary circuits. The same procedure is then to be followed in testing the successive higher voltage secondary circuits, disconnecting each circuit after it has been tested.

45.7 Direct-connected power supply

45.7.1 When a direct-connected power supply is used, a direct-current potential of three times the maximum voltage determined in accordance with 44.2 – 44.5, but no less than 1270 volts, is to be applied between live parts of opposite polarity on the load side of the rectifier.

45.7.2 An electrolytic capacitor, tube, transistor, or lamp 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.

45.7.3 The test potential is to 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.

45.8 Printed wiring assembly

45.8.1 A printed wiring assembly is to withstand for 1 minute without breakdown the application of a direct potential of 2E (see 45.8.2) plus 1000 volts between:

a) Printed wiring parts and

b) Printed wiring parts and other parts where electrical breakdown over the surface of the printed wiring board insulating material would result in a possible source of electric shock.

45.8.2 The potential E is the maximum peak between the parts when measured with the equipment operated under the conditions described in 44.2 – 44.5.

46 Test For Low-Voltage, Limited-Energy Circuits

46.1 A transformer, transformer-resistor combination, or a transformer and regulating circuit intended to comply with 32.2 and Table 32.1 shall be tested as described in 46.2 – 46.5.

46.2 The maximum volt-ampere output capacity of the secondary winding is to be determined as follows. The primary winding of the transformer, at room temperature, is to be connected as intended in the equipment. The secondary winding in question is to be connected to a variable resistance load. When 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. 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 are to be recorded, plotted, and drawn as a smooth curve. The peak value obtained from the curve is not to exceed 250 volt-amperes and, if two or more secondary windings supply interconnected circuits, the sum of the outputs of the windings in question is not to exceed 250 volt-amperes.

46.3 The following are to be subjected to continuous operation at short-circuit conditions and maximum power to the externally connected resistor:

a) The secondary of a transformer,

b) The output of a transformer-resistor combination, or

c) A transformer regulating circuit that limits the current to 8 amperes or less or the output to 250 volt-amperes or less as described in 32.2.

The measurements are to be repeated, and the results comply when conditions are maintained in accordance with Low-Voltage, Limited-Energy Circuits, Section 32.

Exception: When the short-circuit test runs continuously for 7 hours, the maximum power test need not be done.

46.4 When 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 (electrolytic capacitor, transistor junction, diode, or vacuum tube) in that circuit shall not exceed the limits specified in 32.2.

46.5 Three complete tests are to be made under the conditions described in 46.3, using new components for each test.

47 Test For Nonhazardous Secondary Circuits

47.1 A source of power for a component part of assembly intended to comply with 33.2 is to be investigated to determine the points nearest the power supply not capable of:

a) Producing an open-circuit voltage exceeding the applicable limits specified in Table 30.1 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.

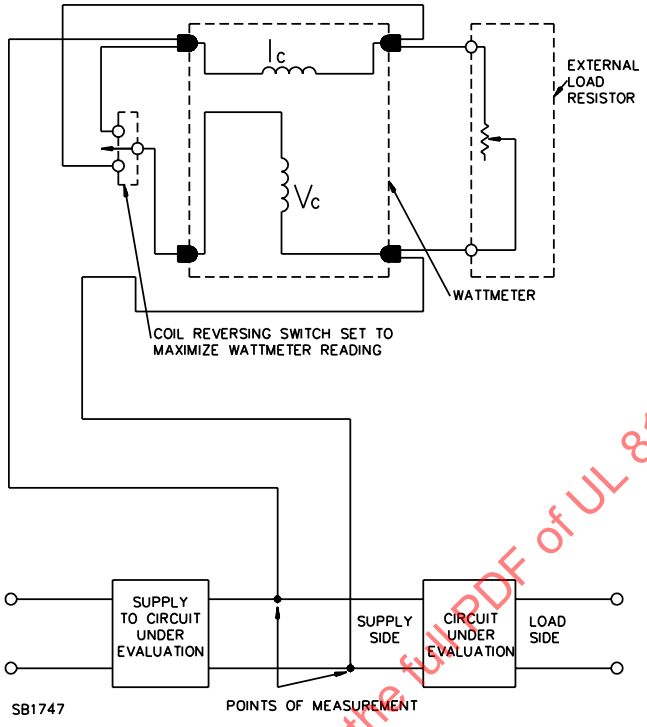
The measurements in 47.1(a) and (b) are to be made with the equipment operating as intended (with no signal input for amplifier circuits) and with all load circuit components that are beyond the two points disconnected.

47.2 In determining the points not capable of delivering a power of more than 15 watts that are specified in 47.1(b), the external resistor is to be set for maximum resistance before being connected to the circuit under investigation. The external resistor is to be adjusted until the maximum wattage is consumed by it as indicated by a peak reading of the wattmeter connected in the circuit as shown in Figure 47.1. If the reading is more than 15 watts, the desired point has not been located and then it will be necessary to move the external resistor to other points toward the load side of the circuit. When a protective device is used in the equipment, 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 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.

47.3 When 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 (electrolytic capacitor, transistor junction, diode, or vacuum tube) in that circuit shall not exceed the limits specified in 47.1.

47.4 As a result of the tests described in 47.5, no components located between the tested points and the power supply shall be affected to such a degree (as by a change in value or characteristics) to cause the limits in 47.1 to be exceeded.

Figure 47.1
Connection of wattmeter



47.5 The points determined by the measurements described in 47.1 – 47.3 are to be investigated to determine the following:

a) 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;

b) That a risk of fire or electric shock is not produced under the conditions of short-circuiting (singly) any unreliable component (electrolytic capacitor, transistor junction, diode, or vacuum tube) between the points and the power supply; and

c) Following the tests described in 47.5(a) and (b), that the circuit tested is capable of withstanding without breakdown for 1 minute, a 1000-volt alternating potential having a frequency of 60 Hz between:

1) Any live part conductively connected to the supply circuit and any dead metal part, and

2) Any live part of the primary or power supply circuit and any live part of the secondary circuit.

47.6 To determine if the equipment complies with 47.5, the equipment is to be tested as described in 48.1.1 – 48.1.9.

47.7 If the short-circuit tests required in 47.5(a) continue for 7 hours, it is not necessary that the maximum power test be conducted.

48 Abnormal Operation Test

48.1 General

48.1.1 For abnormal operation tests, the equipment is to be connected to a supply circuit fused at 30 amperes and placed on a white tissue-paper-covered softwood surface.

48.1.2 A single layer of cheesecloth is to be draped loosely over the equipment.

48.1.3 A part of the equipment subject to removal during user servicing can be omitted if it is:

a) Not necessary for the functioning of the equipment,

b) Not exposed to view during normal operation, and

c) Not captivated.

48.1.4 Exposed dead metal parts are to be connected to earth ground through a 1-ampere, nontime delay-type fuse. The supply circuit connection is to be such that the maximum potential exists between the protective device of the equipment, if any, and the chassis.

48.1.5 The equipment is to be operated both with and without a signal input, as described in 41.2.2 – 41.2.8, unless it can be established that one test condition will produce the most severe results. The supply circuit voltage is to be in accordance with the abnormal operation requirements in Table 38.1.

48.1.6 When provided inherent overheating protection, shall be investigated.

48.1.7 An abnormal operation test that involves stalling a motor or short-circuiting or overloading a component or circuit to maximum power is to be conducted until:

a) A risk of fire develops,

b) The circuit under test burns open, or

c) No further change is likely to take place.

However, the test shall not be conducted for longer than 7 hours.

48.1.8 The term maximum power referred to in 48.1.7 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.

48.1.9 A risk of fire or electric shock is considered to exist if any of the following occur:

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 that is larger than those permitted by accessibility requirements as covered in 34.1.2 and 34.1.3; or

f) Dielectric breakdown during the dielectric voltage-withstand test described in 45.2.1 and 45.3.1.

48.1.10 When 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.

48.1.11 A manual reset type overload protective device is to perform acceptably for 50 cycles of operation under the most unfavorable of the overload conditions.

48.1.12 Equipment shall not develop a risk of fire or electric shock when operated under abnormal conditions that are likely to occur during intended use.

48.1.13 The test conditions are to be as described in 48.1.1 – 48.1.9.

48.1.14 Malfunction of a component and likely misuse of the equipment that might result in a fire or electric shock are to be simulated during the abnormal tests. Only one fault is to be assumed at a time. Examples are given in 48.1.14(a) – (f):

a) Jamming of tape that is likely to stall or overload a drive or similar type motor.

b) Breakdown 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 or loss of lubrication, or the like).

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

e) Incorrect setting of an input voltage selector.

f) Attempting to charge a short-circuited battery.

48.2 Power supply tests

48.2.1 The power supply of the equipment is to be investigated to determine each of the following:

a) That a risk of fire or electric shock is not produced under the conditions of short-circuiting (singly) any rectifier, vacuum tube, transistor, or electrolytic capacitor in a circuit that is determined not to be low-voltage, limited-energy as described in Test for Low-Voltage, Limited-Energy Circuits, Section 46, or nonhazardous as described in Test for Nonhazardous Secondary Circuits, Section 47.

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 as determined in 48.2.4.

b) That, while in a heated condition from the test described in 48.2.1(a), the power supply is capable of withstanding without breakdown the dielectric voltage-withstand test described in 45.2.1 and 45.3.1.

48.2.2 The dielectric voltage-withstand test described in 48.2.1(b) need be conducted only after the last test on the power supply is completed.

Exception: The dielectric voltage-withstand test should be conducted earlier if it is necessary to replace components after conducting the other tests.

48.2.3 In conducting the short-circuit tests required in 48.2.1(a), the following connections are to be short-circuited:

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.

48.2.4 To locate the points not capable of delivering more than 50 watts of power (as specified in the Exception to 48.2.1(a)), an adjustable resistor is to be set for maximum resistance and then connected to a wattmeter and the circuit under investigation as shown in Figure 47.1. The external resistor is to be adjusted until it consumes the maximum power as indicated by a peak reading of the wattmeter. When the reading is more than 50 watts, the desired point has not been located and it is necessary to move the input to the wattmeter to other points away from the supply side of the circuit. When a 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 open and the time required for the protective device to open is to be recorded. When 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.

48.2.5 To determine if the equipment complies with the test in 48.2.2, the test is to be conducted under the conditions described in 48.1.1 – 48.1.5, 48.1.9, and 48.1.10.

48.3 Short-circuit test

48.3.1 The following test is to be conducted when spacings on a printed-wiring board are investigated in accordance with Exception No. 3 to 26.2.1. Printed-wiring board traces of different potentials are to be short-circuited and the test is to be conducted as described in 48.1.1 – 48.1.6 and 48.1.9.

The overcurrent protection associated with the branch circuit to which the unit is connected shall not open as a result of this test. Additionally, a wire or a printed-wiring board trace shall not open during this test.

Exception: This test is not required to be conducted if previously conducted in accordance with the power supply tests specified in 48.2.1 – 48.2.5.

48.4 Abnormal temperature test

48.4.1 Each channel of a power amplifier is to be loaded with a resistive value as specified in 42.1.12. Each channel is to be driven with a 1 kHz 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 41.1.4. The supply circuit voltage is to be the test voltage for intended operation as specified in Table 38.1. The amplifier is to operate under these conditions for a period of 7 hours, until thermal equilibrium as specified in 42.1.10 is established, or until a protective circuit or a protective device operates.

48.4.2 If a protective circuit or a protective device operates before temperatures stabilize or 7 hours have elapsed at the one-third level, the test described in 48.4.1 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.

48.4.3 The test specified in 48.4.1 is to be repeated at the one-third level only (set while the equipment is loaded with the resistive value specified in 42.1.12) with the resistive loads replaced with:

a) A resistive load equal to one-half the value used in 48.4.1 and

b) 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 42.1.10 is established, or until a protective circuit or a protective device operates.

48.4.4 As a result of the test described in 48.4.1 – 48.4.3, there shall be no risk of fire or electric shock as described in 48.1.9. Transformers used in the equipment shall comply with the temperature limits specified in Table 48.1.

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.

48.5 Protective devices

48.5.1 To determine if a protective device or circuit used in an amplifier tested as described in 42.1.4 is to be relied upon to reduce the risk of fire, the unit is to be prepared in accordance with 48.1.1 and 48.1.2 – 48.1.4 and tested with the protective device or circuit bypassed and an input signal applied as described in 42.1.12 until ultimate results are observed, or no longer than 7 hours. The test results shall be evaluated in accordance with 48.1.9.

Table 48.1
Maximum temperature rises under abnormal temperature conditions

Condition	Type of protection	Maximum temperature rises				
		Class 105	Class 130	Class 155	Class 180	Class 220
1	Integral, non-replaceable, non-resettable protector, including open primary winding, resulting in the replacement of the transformer	130°C (234°F)	155°C (279°F)	180°C (324°F)	205°C (369°F)	245°C (441°F)
2	None or any other form of protection	110°C (198°F)	135°C (243°F)	160°C (288°F)	185°C (333°F)	225°C (405°F)

49 Battery Test

49.1 Battery supply test

49.1.1 To determine the acceptability of the fuse or protective device described in 14.4.1, the equipment is to be connected to the storage battery (if provided with the equipment) or to a test supply of rated voltage with a 30-ampere minimum capability, or to both. Using the connecting means provided, the equipment is to be investigated for a risk of fire in accordance with 48.2.1 – 48.2.5.

49.1.2 In addition, a battery supply cord is to be short-circuited at any point on the cord but not within 5 inches (127 mm) of the battery connecting means.

49.2 Battery overcharge test

49.2.1 A fully-charged rechargeable, nonautomotive-type battery, provided or specifically recommended for use with the equipment, shall not create any of the conditions described in 49.6.1 when overcharged for 7 hours with the equipment charging circuit adjusted for the maximum charging rate. Additional tests are also to be conducted with any single junction or part of an unreliable component in a charging circuit short-circuited or open-circuited.

49.3 Battery discharge test

49.3.1 Short-circuiting of the terminals of the type battery described in 49.2.1 shall not result in any of the conditions described in 49.6.1.

49.4 Battery drop test

49.4.1 Each of three samples of the type battery described in 49.2.1 are to be dropped three times from a height of 3 feet (0.92 m) onto a hardwood floor in the position most likely to produce adverse results without producing any of the conditions described in 49.6.1.

49.5 Battery oven test

49.5.1 A battery of the type described in 49.2.1 provided with a polymeric case is to withstand one of the temperature stability conditions described in 49.5.2 without producing any of the conditions described in 49.6.1.

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

49.6 Test results

49.6.1 The results of the tests described in 49.2.1 – 49.5.2 are considered unacceptable if any of the following conditions occur:

a) The battery case cracks;

b) Battery electrolyte leaks from the case; or

c) The battery explodes.

50 Switching Device Test

50.1 Switches and other current-rupturing devices are to be tested in accordance with the requirements for that component. The actual load controlled in the equipment 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 where the controlled load is limited to 100 volt-amperes or less.

50.2 A switch or other device that controls a motor of the equipment shall be capable of performing acceptably when subjected to an overload test consisting of 50 cycles of operation, making and breaking the locked rotor current of the equipment. Dielectric or mechanical breakdown of the device or undue pitting or burning of the contacts is considered unacceptable.

Exception No. 1: The test need not be conducted if the switch or other device is so interlocked that it will never have to break the locked rotor motor current.

Exception No. 2: If the switch or device has previously been determined acceptable for the intended use, the test need not be conducted.

50.3 To determine if the switch or other control device is capable of performing acceptably in the overload test specified in 50.2, the equipment 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 equipment 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 equipment is intended for use on direct current, the exposed dead metal parts of the equipment are to be connected so as to be positive with regard to a single-pole, current-rupturing, control device. The device is to be operated at a rate of more than 10 cycles per minute. The results are considered acceptable if the fuse in the grounding connection has not opened during the test.

Exception: A faster rate of operation may be used if agreeable to all concerned.

51 Solid State Switch Test

51.1 Abnormal operation test

51.1.1 Equipment containing any solid state component or device that functions as a switch in a hazardous energy circuit is to be subjected to the following abnormal operation, voltage surge, and reduced voltage tests in the order given. Results are acceptable in each case if the equipment operates as intended throughout.

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

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

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

d) Ten random applications of a 3-kilovolt surge impulse at 60-second intervals as described in 51.2.1. Results comply if there is no tripping of circuit protection, if the equipment remains operable after the test, and if there has been no fire or development of a source of electric shock, as described in 48.1.1 – 48.1.5 and 48.1.9.

51.2 Voltage surge test

51.2.1 The sample is to be connected to a supply of rated voltage. The grounding lead or terminal of the sample 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-Hz supply to the unit under test. Each of the ten applications is to be random with regard to the phase of the 60 Hz supply voltage.

51.2.2 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;

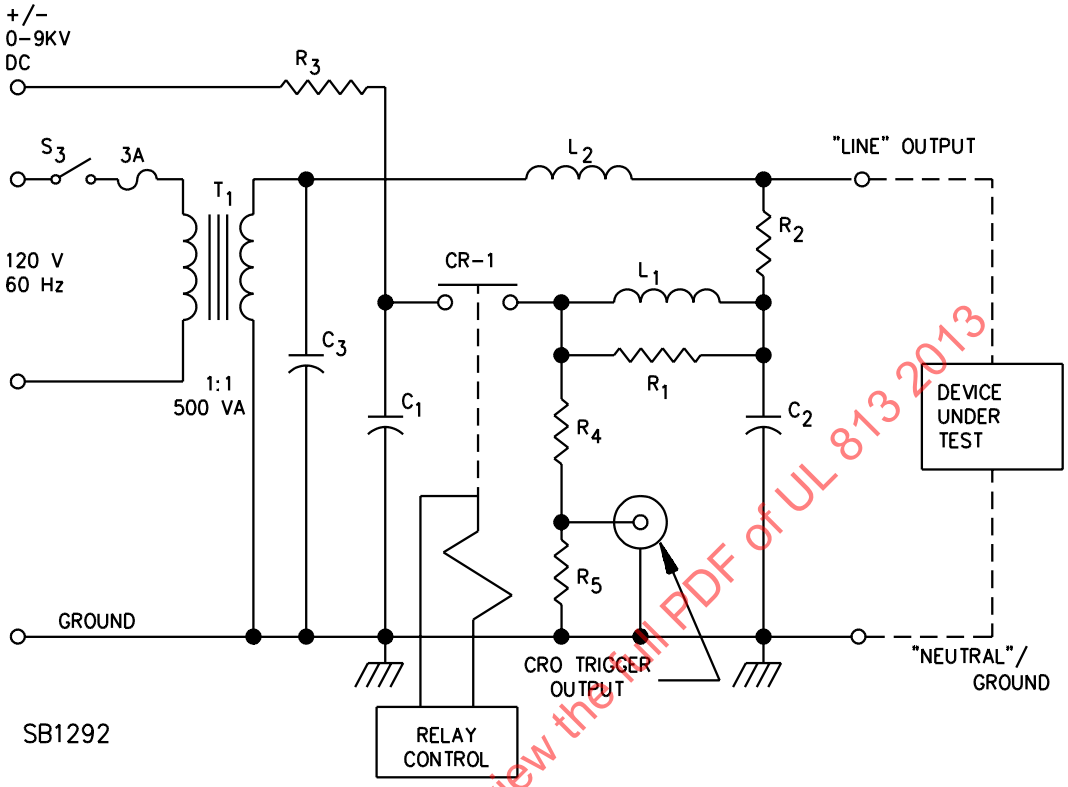
b) The period of the following oscillatory wave, 10 microseconds; and

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

Figures 51.1 and 51.2 show a typical surge generator and control relay.

Figure 51.1
Surge generator circuit

Figure 51.1 revised May 7, 2010



C_1 – 0.025 µF, 10kV

C_2 – 0.01 µF, 10kV

C_3 – 4 µF, 400V

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

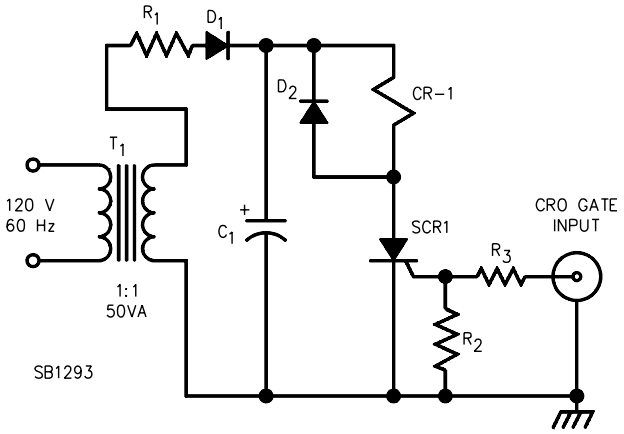
R_3 – 1.3M ohms (12 by 110K ohms, 1/2 W)

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

R_5 – 200 ohms, 1/2 W

CR-1 – Relay

Figure 51.2
Relay control circuit for surge generator



R_1 – 10K ohms, 1 W
R_2 – 1K ohms, 1/2 W
R_3 – 1K ohms, 1/2 W

C_1 – 32 µF, 250 V
D_1 – IN5060 or equivalent
D_2 – IN5060 or equivalent
SCR1 – GE C122B or equivalent
CR-1 – Relay GE CR 2790 E 100 A2 or equivalent
T_1 – Triad N4S X or equivalent

52 Tests For Remote Control and Interconnecting Cables

52.1 Cable short circuit

52.1.1 Equipment provided with a single or multiple conductor cable as described in 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. Results comply if a risk of fire or electric shock does not develop.

52.1.2 The test conditions for compliance with 52.1.1 are described in 48.1.1 – 48.1.7 and 48.1.9 – 48.1.11.

52.2 Cable arcing test

52.2.1 A single-wire or a multiple-conductor cable as described in 20.1 is considered to involve a risk of fire if the arc caused by short-circuiting or grounding the conductors will ignite combustible material.

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