UL 1419

STANDARD FOR SAFETY

Professional Video and Audio Equipment

UL Standard for Safety for Professional Video and Audio Equipment, UL 1419

Fourth Edition, Dated February 26, 2016

Summary of Topics

This revision of ANSI/UL 1419 dated July 30, 2021 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

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

The requirements are substantially in accordance with Proposal(s) on this subject dated May 14, 2021.

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UL 1419

Standard for Professional Video and Audio Equipment

First Edition – November, 1992
Second Edition – March, 1997
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Fourth Edition

February 26, 2016

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

The most recent designation of ANSI/UL 1419 as a Reaffirmed American National Standard (ANS) occurred on July 30, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover video and audio equipment operated and maintained by trained personnel under the conditions of controlled access.

1.2 These requirements cover such equipment as video tape recorders, audio/video editing equipment, audio/video receiving and processing equipment, signal transmission equipment, television cameras, video digitizers, video monitors, metering equipment and similar equipment.

1.3 This Standard also covers auxiliary equipment and accessories which by themselves may not perform the desired function of the equipment outlined in 1.2 but are used in addition to or as a supplement to the basic equipment (remote controls, convertors, stands, etc.).

1.4 These requirements cover equipment rated 600 volts or less for use in accordance with the National Electrical Code, ANSI/NFPA 70.

1.5 Equipment employing circuits that are intended to connect directly to a telecommunications network also comply with the applicable requirements in the following relevant standards:

a) Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1

b) Standard for Audio, Video, and Similar Electronic Apparatus-Safety Requirements, UL 60065

c) Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1

1.6 These requirements do not cover products that are intended for household or commercial use.

2 Glossary

2.1 For the purpose of this Standard the following definitions apply.

2.2 ACCESSIBLE PART – A part so located that it can be contacted by means of a probe (see Figure 31.1).

2.3 ADJUSTABLE CONTROL – A control provided for making adjustments necessary to render the equipment capable of performing its intended functions.

2.4 BRANCH CIRCUIT – A branch circuit is that portion of the building wiring system beyond the final overcurrent device on the power distribution panel protecting the circuit to the field wiring terminals in permanently connected equipment or to the receptacle outlet for cord connected equipment.

2.5 CART – A stand (see Personal Injury Tests, Section 58) provided with casters, wheels, or rollers to make it mobile.

2.6 CASTER – Any roller or swiveled wheel attached to a cart, stand, or equipment that makes the cart, stand, or equipment mobile.

2.7 CLEARANCE DISTANCE – The shortest distance measured through air between conductive parts.

2.8 CREEPAGE DISTANCE – The shortage distance measured over the surface of insulation between conductive parts.

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

2.10 FIBER – Where the term "fiber" is used in this standard to denote a material usually used as electrical insulation, vulcanized fiber is meant.

2.11 FIELD-WIRING TERMINAL – Any terminal to which a supply or other wire can be connected by an installer in the field is a field wiring terminal unless the wire is provided as part of the equipment and a connector, soldering lug, soldering loop, crimped eyelet, pressure terminal, or other means for making the connection is factory-assembled to the wire.

2.12 GROUND – Earth ground, unless otherwise specified.

2.13 HAND-HELD EQUIPMENT – Portable equipment that is held in one or both hands during normal use.

2.14 HANDLE – A part that is designed to be grasped by the hand or used by hand or machine for lifting or moving a product.

2.15 INTERLOCK – A mechanism that deenergizes parts involving a risk of electric shock or that stops moving parts before they become accessible to the user when the enclosure of the part is opened or a cover is removed.

2.16 LEAKAGE CURRENT – All currents, including capacitively coupled currents that flow through a person upon contact between accessible conductive surfaces of a product and ground or other accessible surfaces of a product.

2.17 MEASUREMENT INDICATION UNIT (MIU) – The output voltage across the meter in the measurement instrument in Figure 41.2, in millivolts RMS, divided by 500 ohms. MIUs are related to physiological effects when electric current flows through the human body. At low frequency, the number of MIUs that is obtained by dividing the output voltage, in millivolts, by 500 ohms, equals the current, in milliamperes, through the measuring instrument. The reading may not be a direct indication of the RMS or other common amplitude quantifier of leakage current when the leakage current is of a complex waveform or frequency other than 50 or 60 Hz. At high frequency, the meter indication of MIUs is less than the number of milliamperes through the measuring instrument. For example, at 100 Khz, 0.5 MIU occurs when the actual current through the measuring instrument, shown in Figure 41.2, is 70 mA. At any frequency, the acceptability of the leakage current can be determined by simply comparing the number of MIU's to the MIU limit.

2.18 MINOR DIMENSION OF OPENING – The minor dimension of an opening is the diameter of the largest sphere that can pass through the opening.

2.19 MULTIPLE (REDUNDANT) POWER SUPPLIES – Two or more power supplies, that are duplicates of each other, where one serves as a basic power source and the other(s) as back-up(s) should the basic power source become inoperative.

2.20 ORDINARY TOOLS – Flat-bladed and cross-head screwdrivers, nut drivers, and pliers.

2.21 PERMANENT OUTDOOR LOCATION – An unprotected location exposed to weather wherein the equipment is intended to be permanently installed and operated.

2.22 PORTABLE EQUIPMENT – Cord and plug connected equipment that weighs less than or equal to 18.2 kg (40 lb) and has no provision for permanent mounting and can be moved from one place to another without the use of carts or other assisting equipment.

2.23 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 speakers.

2.24 POWER-SUPPLY CORD – The cord provided to connect the equipment to the branch circuit.

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

2.26 PROBE – An instrument used to determine accessibility. See Figure 31.1.

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

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

2.29 UNINSULATED LIVE PART – A conductive part that involves a risk of fire or electric shock.

2.30 UNLIMITED POWER CIRCUIT – A circuit involving more than 240 W.

2.31 USER SERVICING – Servicing which can occur outside the enclosure in areas where uninsulated live parts are not accessible. See 33.1 for examples of user servicing.

3 Components

3.1 Except as indicated in 3.2 a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components used in the products covered by this standard.

3.2 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.

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

3.4 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.

4 Units of Measurement

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

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

5 References

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

CONSTRUCTION

6 General

6.1 Details

6.1.1 The construction of the equipment shall be such 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.

6.1.2 The materials and components referred to in 6.1.1 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.

6.1.3 The equipment shall comply with either Option A (Construction) or Option B (Performance) indicated in Table 6.1.

6.2 Systems

6.2.1 For a system that is comprised of two or more interconnected devices, each device may be evaluated to either Option A or Option B in Table 6.1.

Table 6.1
Product evaluation options

Option	240 W determination[a,b,c]	Component Tests > 240 W Circuitry[a,b,d]	Table 7.1[b]	7.3 – 7.7	Table 7.3[b]
A (Construction)					
Primary	Yes	Yes	Yes	Yes	No
Secondary	No	No	Yes	Yes	No
Enclosure and other parts	N/A	N/A	Yes	Yes	No
B (Performance)					
Primary	Yes	Yes	No	No	Yes
Secondary	Yes	Yes	No	No	Yes
Enclosure and other parts	N/A	N/A	No	No	Yes

Table 6.1 Continued on Next Page

Table 6.1 Continued

Option	240 W determination[a,b,c]	Component Tests > 240 W Circuitry[a,b,d]	Table 7.1[b]	7.3 – 7.7	Table 7.3[b]
[a] Does not apply to components and parts of Power Supplies that comply with applicable requirements in relevant UL Standards[i] such as UL 813, UL 1012, UL 1310, UL 60950-1, UL 60065, and UL 62368-1.					
[b] Does not apply to primary and secondary circuits supplied by a power supply as indicated in note (a) with a National Electrical Code Class 2 output.					
[c] Refer to Test for Limited-Power Circuit, Section 51, for 240 W determination.					
[d] Refer to Power Supply Test, Section 53 and Component Abnormal Operation Test, Section 54, for Component Testing.					
[i] Any power supply used shall be used in accordance with its Conditions of Acceptability.					

7 Frame and Enclosure

7.1 General

7.1.1 The enclosures, guards, and barriers of the equipment shall be complete, or completion of the enclosures, guards, and barriers shall be attained when the equipment is combined during installation.

7.1.2 Required enclosures, guards, and barriers shall be capable of being removed and replaced with a minimum of effort if removal is necessary for servicing the protected parts.

7.1.3 An enclosure, guard, and barrier shall have the strength and rigidity to resist the abuses likely to be encountered during intended use without increasing the risk of fire, electric shock, electrical energy-high current levels, or injury to persons due to total or partial collapse, with resulting reduction of spacings to less than required, or the loosening, displacement, or exposure of parts, or other serious defects.

7.1.4 The strength and rigidity of the enclosure is to be judged by the Strength of Enclosure Tests, Section 57.

7.1.5 A handle or handles intended to support hand carried or hand operated equipment shall be subjected to the Handle Strength Test as described in 58.4.

7.2 Doors or covers

7.2.1 If part of an enclosure consists of a door or cover leading to an operator access area, one of the following requirements shall apply:

a) Either the door or cover shall be interlocked to comply with the requirements in 32.1; or

b) The door or cover, although intended to be opened by the operator, shall comply with both the following conditions:

1) It shall not be removable by the operator from the enclosure;

2) It shall be provided with a means to keep it closed during normal operation.

7.3 External materials – Option A (Construction)

7.3.1 Materials such as steel, aluminum, glass, and other similar materials are to be used for the enclosure, guard, or cabinet of the equipment. Glass shall be heat resistant, tempered, wired, or laminated. Other materials may be used for part or all of an enclosure, if they comply with the requirements in the Standard for Polymeric Materials– Use in Electrical Equipment Evaluation, UL 746C.

The accessibility need not be investigated as part of the enclosure flammability – 130 mm (5-inch) Flame Test as required in UL 746C. See Table 7.1.

Exception: The enclosure materials of portable equipment may be rated minimum V-2. See Table 7.1

Table 7.1
Material requirements – Option A

Application	Flammability[c,d]	Properties of material
Section		
A. Nonportable enclosures	b	b
B. Portable enclosure	V-2	–
C. Internal parts[e,g]	V-2	–
D. External Parts[e,f,g]	HB	–

[a] These requirements do not apply to the internal insulating systems of components or where component requirements exist.

[b] Must comply with flammability and properties of materials requirements in UL 746C except accessibility after flame test.

[c] The flammability classifications V-0, V-1, V-2, and HB are to be determined by the tests described in the Standard for Tests for Flammability of Plastic Material for Parts in Devices and Appliances, UL 94. For enclosures, a material classified using 3.2 mm thick bar specimens can be accepted in lesser thicknesses in the end product. For other parts, a material classified using 1.6 mm thick bar specimens can be accepted in lesser thicknesses in the end product.

[d] For an assembly, the test parameters according to Table 7.1 can consist of the assembly and can be tested as finished parts, or test assemblies can be cut from finished parts. In the case of small parts that might be consumed before the test is completed, large pieces of the same material can be tested provided that they represent the same or lesser thickness than the part in question. None of the larger pieces are to be entirely consumed. Test assemblies or a section thereof that are not flat stock pieces are to be positioned in what is considered to be the worst position in the application.

[e] The requirements that materials possess certain flammability classifications do not apply to small parts. For the purpose of these requirements, a small part is one which:

1) The maximum dimension does not exceed 60 mm, and

2) The volume does not exceed 8000 mm^3, and

3) Is located where it could not act as a bridge between a source of arcing or ignition and other ignitable parts.

[f] Those parts outside required enclosure parts.

[g] Internal and external parts may consist of insulating materials, printed wiring boards, connectors, and the like.

7.4 Internal materials – Option A (Construction)

7.4.1 All combustible material used within a fire containment enclosure shall be rated in accordance with Table 7.1.

7.4.2 All materials located in circuits not involving a risk of fire and segregated from parts involving a risk of fire by a barrier with a minimum flammability rating of V-2 may be rated minimum HB.

Exception: All materials located in an enclosure constructed of steel or aluminum, or material with a minimum 5V flammability rating and containing no openings may be rated HB without the use of a barrier.

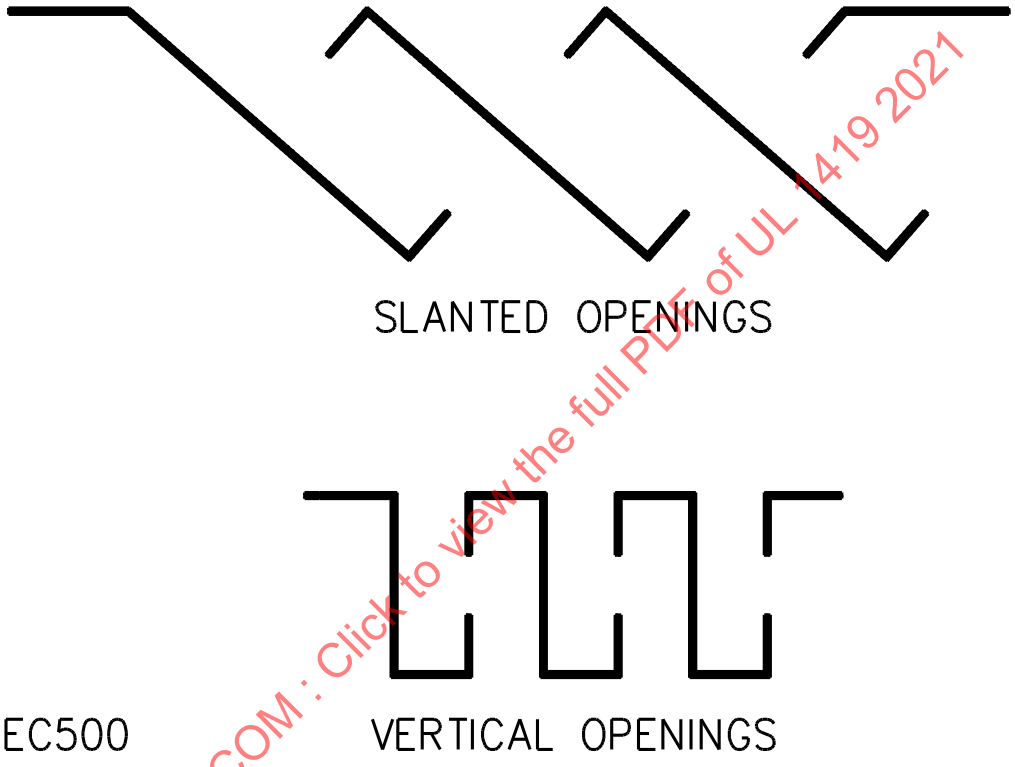
7.4.3 Flammability requirements do not apply to polymeric materials, printed wiring boards and wiring within an enclosure having a volume of 0.06 m^3 or less, consisting totally of metal and having no ventilation openings, or within a sealed unit containing an inert gas.

7.5 Enclosure openings

7.5.1 Enclosure openings over parts involving a risk of fire or electric shock or over parts not involving a risk of fire or electric shock that are not separated from such parts by a barrier complying with 7.3.1 and having openings only allowing for lead passage shall comply with the requirements in 7.6.1 – 7.8.1, and Figure 7.1.

Figure 7.1

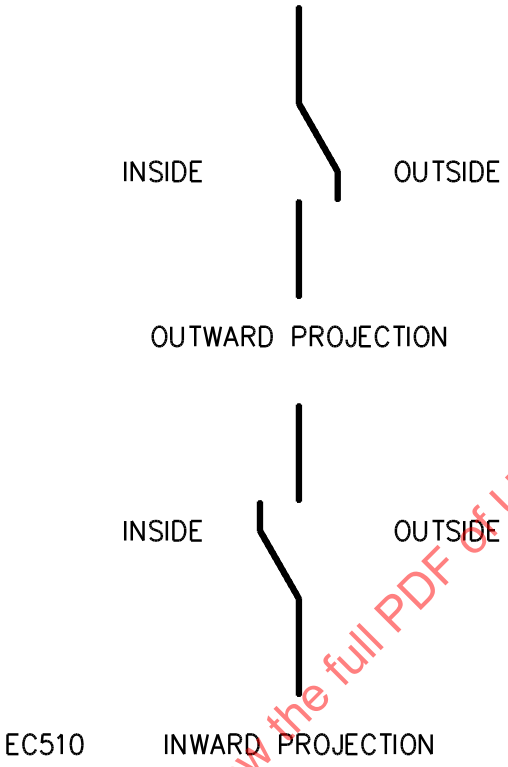
Cross sections of top-enclosure designs



7.6 Louvers

7.6.1 An opening in the front, back or sides of an enclosure shall be shaped and located so that a falling object cannot pass through the opening in a vertical direction. Louvers may be used if shaped to deflect an external falling object outward. See Figure 7.2.

Figure 7.2
Louvers



7.7 Enclosure bottom openings

7.7.1 Ventilation openings may be provided in the bottom of an enclosure under materials that are not rated V-1 or less flammable if the openings are constructed so that materials do not fall directly from the interior of the equipment onto the openings. Other bottom opening constructions that may be used are those that incorporate a perforated metal plate as described in Table 7.2, or a galvanized or stainless steel screen having a mesh not greater than 2 by 2 mm and a wire diameter of not less than 0.45 mm.

Table 7.2
Perforated metal plates

Minimum thickness		Maximum diameter of holes		Minimum spacings of holes center to center		
mm	(inch)	mm	(inch)	mm	(inch)	
0.66	(0.026)	1.14	(0.045)	1.70	(0.067)	233 holes per inch^2 (645 mm^2)
0.66	(0.026)	1.19	(0.047)	2.36	(0.093)	
0.81	(0.032)	1.91	(0.075)	3.18	(0.125)	72 holes per inch^2 (645 mm^2)
0.91	(0.036)	1.60	(0.063)	2.77	(0.109)	
0.91	(0.036)	1.98	(0.078)	3.18	(0.125)	
1.00	(0.039)	1.60	(0.063)	2.77	(0.109)	
1.00	(0.039)	2.00	(0.079)	3.00	(0.118)	

7.7.2 The bottom of the enclosure under areas containing only materials rated V-1 or less flammable may have openings no larger than 6.4 mm (1/4 inch) square. Openings that are not square may be provided if they do not have an area greater than 40 mm^2 (1/16 $inch^2$).

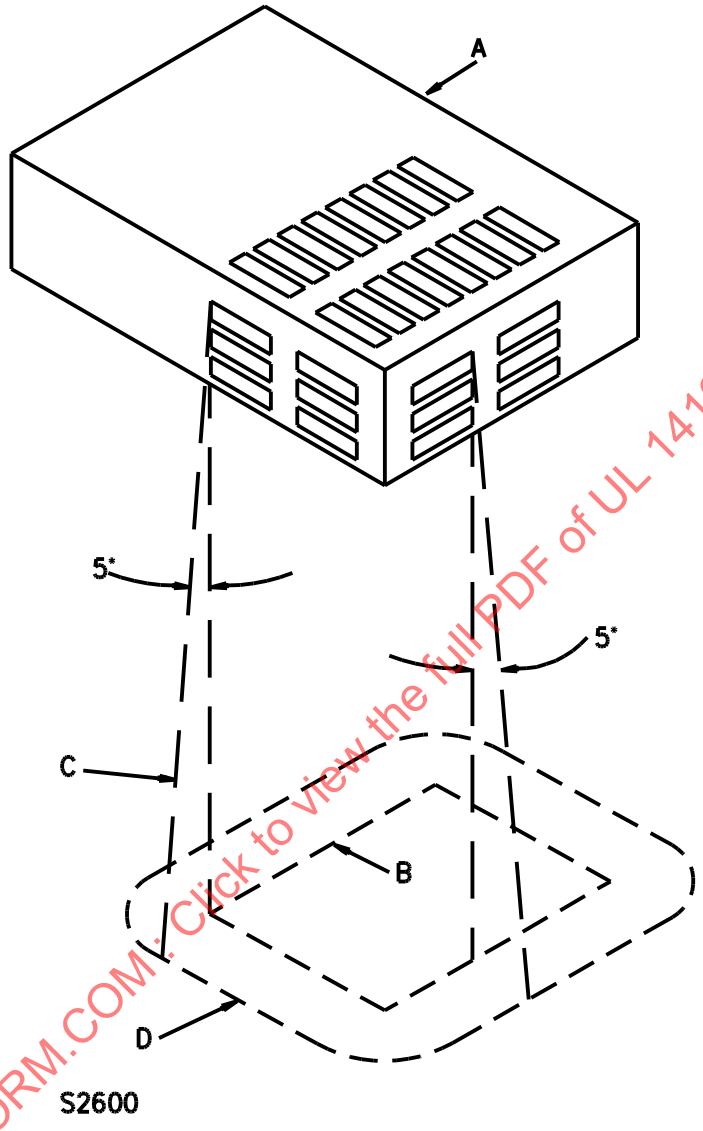
7.7.3 The bottom of an enclosure shall consist of a complete or partial bottom enclosure under a component, groups of components, or assemblies, as shown in Figure 7.3, that complies with the ventilation opening requirements in 7.7.1 and 7.7.2.

Exception No. 1: Units may have openings without limitation on their size and number in areas that contain only wires, cables, plugs, receptacles, and impedance-protected and thermally protected motors.

Exception No. 2: Equipment intended to be mounted on a concrete floor or other noncombustible surface need not be provided with a bottom enclosure if marked in accordance with 62.19.1.

Figure 7.3

Enclosure bottom



NOTES –

1) The entire component under which an enclosure (flat or dished with or without a lip or other raised edge) of noncombustible material is to be provided. The sketch is of an acceptably enclosed component with ventilation openings showing that the enclosure is required only for those openings through which flaming parts may be emitted. If the component or assembly does not have its own noncombustible enclosure, the area to be protected is the entire area occupied by the component or assembly.

2) Projection of the outline of the area of A that needs a bottom enclosure vertically downward onto the horizontal plane of the lowest point on the outer edge D of the enclosure.

3) Inclined line that traces out an area D on the horizontal plane of the enclosure. Moving around the perimeter of the area B that needs a bottom enclosure, this line projects at a 5 degree angle from the line extending vertically at every point around the perimeter of A and is oriented to trace out the largest area; except that the angle may be less than 5 degrees if the enclosure bottom contacts a vertical enclosure or side panel, or if the horizontal extension of the enclosure B to D exceeds 152 mm (6 inch).

4) Minimum outline of the enclosure, except that the extension B to D need not exceed 152 mm (6 inch), flat or dished with or without a lip or other raised edge. The bottom may be flat or formed in any manner provided that every point of area D is at or below the lowest point on the outer edge of the enclosure.

7.8 Top openings

7.8.1 Top openings shall not have a minor dimension of more than 4.8 mm (3/16 inch) unless the configuration is such that vertical entry to uninsulated live parts cannot occur.

Exception No. 1: An opening in the top of an overall enclosure and having a dimension larger than 4.8 mm (3/16 inch) is acceptable if it is protected by a knob, handle, louver, or similar part such that a falling object cannot pass directly through the opening in a vertical direction. Refer to Figure 7.1 for examples of acceptable designs.

Exception No. 2: If a falling object can pass through the opening in a vertical direction, it is acceptable if the object can only contact parts not involving a risk of fire or electric shock and is prevented by barriers or the like from moving into areas containing such parts.

7.9 Material requirements – Option B (Performance)

7.9.1 Polymeric materials used for an enclosure or internal parts, printed wiring boards, connectors, and the like shall be rated for flammability and ignition according to Table 7.3.

Table 7.3
Material requirements – Option B[a]

Application	Flammability classification[b,d]	Resistance to ignition from hot wire[c,d] PLC min
(A) Enclosures[e] or insulating materials[e], printed wiring boards and connectors[e] in contact with parts conductively connected to supply, unlimited power[f] or > 2500 V circuits (high voltage)	V-2 V-1 V-0 5V	–
(B) Enclosure materials used in all other applications[e]	HB	3
(C) Insulating materials, printed wiring boards and connectors used in applications other than those covered in (A) or (B) above	–	–

[a] These requirements do not apply to the internal insulating systems of components or where component requirements exist.

[b] The flammability classifications V-0, V-1, V-2, and HB 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 enclosures, a material classified using 3.2 mm thick bar specimens may be accepted in lesser thicknesses in the end product. For the parts, a material classified using 1.6 mm thick bar specimens may be accepted in lesser thicknesses in the end product.

[c] Hot-Wire Resistance to 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 specimens are to be used for this test. For enclosures, a material classified using 3.2 mm thick bar specimens may 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] For an assembly, specimens for the test parameters according to Table 7.3 may consist of the assembly and may be tested as finished parts, or test specimens may be cut from finished parts. In the same case of small parts that might be consumed before the test is completed, large specimens of the same material may be tested provided that they represent the same or lesser thickness than the part in question. None of the larger specimens are to be entirely consumed. Specimens that consist of an assembly or a section thereof that are not flat stock pieces are to be positioned in what is considered to be the worst position in the application.

[e] The requirements that materials used in applications covered by (A) and (B) of Table 7.3, possess certain flammability and ignition ratings do not apply to small parts. For the purpose of these requirements, a small part is one which:

1) the maximum dimension does not exceed 60 mm, and

2) the volume does not exceed 8000 mm^3, and

3) is located where it could not act as a bridge between a source of arcing or ignition and other ignitable parts

[f] An unlimited power circuit is one in which the maximum available power is not limited to 240 W or less in accordance with Risk of Fire, Section 30.

8 Equipment Intended to be Installed in Restricted Access Areas

8.1 Equipment may be provided without enclosures if it is intended solely for installation in restricted access areas such as dedicated equipment rooms, equipment closets and the like that limit access to the equipment to trained service personnel only. Such equipment shall comply with 8.2 – 8.8.

8.2 The bottom of equipment intended to be installed in restricted access areas shall comply with the requirements for enclosure bottom openings in 7.7.1 – 7.7.3.

8.3 Material utilized in the construction of the equipment, including insulating materials, and the like, shall comply with Table 7.1.

8.4 Printed wiring boards shall have a flammability rating of V-0.

8.5 All internal wiring and interconnecting cables provided with the equipment shall be rated minimum VW-1.

8.6 The equipment shall be constructed to provide for the protection of service personnel in accordance with Protection of Service Personnel for Equipment Not Provided with Complete Enclosures, Section 35.

8.7 The equipment shall be marked "To Be Installed Only in Restricted Access Areas (Dedicated Equipment Rooms, Equipment Closets, or the like) in Accordance with Articles 110-18, 110-26, and 110-27 of the National Electrical Code, ANSI/NFPA 70." The reference to the National Electrical Code Articles is not required in the marking if the information is included in the installation or instruction manual and the equipment marking includes the symbol as shown in Figure 8.1 or the words "See Instruction Manual", or the equivalent.

Figure 8.1

Instruction manual marking symbol

8.8 Air filters for use in cooling systems shall comply with the requirements in the Standard for Air Filter Units, UL 900, or shall be constructed of materials rated V-1 or HF-1 or less flammable.

9 Equipment Intended to be Installed in Permanent Outdoor Locations

9.1 Enclosures for equipment intended for permanent outdoor installation shall comply with the requirements for Type 3 enclosures of the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50. If the equipment is marked with a more severe outdoor enclosure type rating, then it shall comply with the requirements for that type rating.

10 Mechanical assembly

10.1 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 if all of the following conditions are met:

a) The switch is a plunger or other type that does not tend to rotate when operated. (A toggle switch is considered to be subject to forces that tend to turn the switch 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 non-removable jewel, need not be made resistant to turning if rotation cannot reduce spacings below the minimum accepted values or may place stress on lead connections.

10.2 The means for turn resistance mentioned in 10.1 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.

11 Supply Connections – Permanently Connected Equipment

11.1 General

11.1.1 Subsection 11.1 is only intended to serve as a reference for requirements that most commonly apply to permanently connected equipment and is not intended to provide a complete list of all of the applicable requirements. For complete requirements, see the National Electrical Code, ANSI/NFPA 70.

11.1.2 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 equipment or removal is necessary for maintenance and repair, in which case, the shortest feasible length of cord shall be used.

11.1.3 Equipment intended for permanent connection to the branch circuit shall have provision for the connection of one of the wiring methods that in accordance with the National Electrical Code, ANSI/NFPA 70 would be required for the purpose.

11.1.4 A sheet metal member to which a wiring system is to be connected in the field shall have a thickness not less than 0.8 mm (0.032 inch) if of uncoated sheet steel, not less than 0.9 mm (0.035 inch) if of galvanized sheet steel, not less than 1.1 mm (0.044 inch) if of sheet aluminum, and not less than 1.09 mm (0.043 inch) if of sheet copper or sheet brass.

11.1.5 A terminal box or compartment shall be provided in which branch circuit connections to permanently wired equipment are to be made and shall be such that these connections may be readily made and inspected without disturbing the wiring or the equipment after it is installed as intended.

11.1.6 The free length of a lead shall be no more than two wire sizes smaller than the copper supply conductor to which it will be connected. For example, if 2.1 mm^2 (14 AWG) supply conductors will be used, the leads provided shall be no smaller than 0.82 mm^2 (18 AWG).

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

11.2 Separation of circuits

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

a) From 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.

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

11.2.2 Separation of some field installed conductors from others and from uninsulated live parts connected to different circuits may be accomplished by arranging the location of openings in the enclosure for the various conductors (with respect to the terminals or other uninsulated live parts) so that there is no likelihood that the conductors or parts of different circuits may be intermingled. If no more openings are provided in the enclosure than are necessary for proper wiring of the equipment and each opening is opposite a set of terminals, it is to be assumed in determining compliance with 11.2.1 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 equipment, it is assumed in determining compliance with 11.2.1 that conductors:

a) Will enter the enclosure through openings not opposite the terminals to which they are intended to be connected, and

b) May touch insulated conductors and uninsulated live parts of circuits other than their own.

11.3 Wiring terminals

11.3.1 Permanently connected equipment shall be provided with wiring terminals or leads for the connection of conductors having an ampacity no less than 125 percent of the current input 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 5.3 mm^2 (10 AWG) 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.

11.3.2 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 equivalent method may be used.

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

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

11.3.4 It should be noted that 2.1 mm^2 (14 AWG) is the smallest conductor that is acceptable 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.

11.3.5 A terminal plate for a wire binding screw shall be of metal no less than 1.3 mm (0.050 inch) in thickness and shall have no less than two full threads in the metal.

11.3.6 A terminal plate formed from stock having the minimum required thickness as given in 11.3.5 may have the metal extruded at the tapped hole for the binding screw so as to provide two full threads.

11.3.7 An upturned lug or a cupped washer shall be capable of retaining a supply conductor as described in 11.3.1, but not smaller than 2.1 mm^2 (14 AWG), under the head of the screw or the washer.

11.3.8 The free length of a lead inside an outlet box or wiring compartment shall be 150 mm (6 inches) or more if the lead is intended for field connection to an external circuit.

11.3.9 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.

11.3.10 If a lampholder is provided, the identified terminal or lead mentioned in 11.3.9 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.

11.3.11 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.

12 Audio Output Connections

12.1 An amplifier or similar equipment having an audio output potential greater than 100 volts when tested as described in 59.2 shall be provided with one of the following to permit connection of the output circuit:

a) Means for connection of conduit complying with 11.1.2 – 11.1.6, and wire binding screws, 3.5 mm diameter (No. 6-32) or larger, quick connect terminals, or leads. If wire binding screws are provided, the terminals shall comply with the requirements in 11.1.4 and 11.1.5. If quick connect terminals are provided, the terminals shall comply with the requirements in 12.2.

b) A length of permanently attached Type SPT-2, SV, SVE, SVT, SJ, SJE, or SJT flexible cord, or the equivalent, and an acceptable equipment coupler complying with the requirements in 13.2. The cord shall be provided with strain relief and a bushing complying with the requirements in 13.3.1, 13.4.1 and 13.6.

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 (a). Such an opening shall be provided with an insulating bushing as described in 13.6.

d) A receptacle for a plug-in connection.

Exception: The constructions described in (b), (c), and (d) are not acceptable if the equipment is intended for supply connection by means of conduit.

12.2 If the following conditions are met, quick-connect terminals may be used for field connection as described in 12.1(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 equipment so that stress on the conductors will not be transmitted to the terminals.

Exception: Strain relief is not necessary if a separate wiring compartment or barrier is provided such that a disconnected terminal will not contact 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 acceptably when installed in accordance with the installation instructions and when tested in accordance with 46.1.1 – 46.1.4.

13 Cord-Connected Equipment

13.1 Cords and plugs

13.1.1 Equipment which is intended for cord connection to the supply source shall be provided with a power supply cord. The supply cord shall be attached permanently to the equipment or shall be in the form of a detachable power supply cord with a means for connection to male contacts affixed to the equipment.

Exception: A detachable power supply cord need not be provided if the equipment is marked in accordance with the provisions of 62.15.2.

13.1.2 A flexible supply cord shall have an ampacity as given in the National Electrical Code, ANSI/NFPA 70, not less than the current rating of the equipment.

13.1.3 A flexible cord not protected from continuous abuse shall be Type SJT. An equivalent or heavier type cord may be used.

13.1.4 A flexible cord protected from continuous abuse shall be Type SVT or SPT-2. An equivalent or heavier type cord may be used.

13.1.5 A flexible cord is considered protected from continuous abuse if:

a) The cord is contained in a protected enclosure, i.e. rack-mounted equipment,

b) During normal operation the entire cord or cable is 92 cm (3 feet) or more above the floor and is not mounted on wheels or intended for transport other than to the installation site, or

c) Less than 2.5 m (8 ft 3 in) in length.

13.1.6 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 detachable power supply cord is to be measured from the face of the attachment plug to the face of the equipment coupler.

13.1.7 Only one supply cord shall be provided to connect equipment to the branch circuit.

Exception: More than one power supply cord may be provided if one of the following is true:

a) More than 1 voltage or kind of power is necessary (for example, 3-phase and 1-phase, regulated and unregulated, alternating current and direct current).

b) The additional power supply cord

1) is provided as part of and

2) supplies power only for an optional component or group of components that may be installed at a later date in order to extend the function of the equipment.

c) Redundant power supply sources are necessary.

13.1.8 If more than one power supply cord is provided on the equipment, the construction shall be such that physical disconnection of any one power supply cord shall automatically cause de-energization of all circuits within the equipment supplied by other cords.

Exception No. 1: In the case of cords that remain connected, a terminal strip, any circuit breaker, and other parts of equipment on the line side of a disconnect device may remain energized if service personnel performing service functions not involving these parts are protected by an enclosure or other means from unintentional contact with these parts.

Exception No. 2: Automatic de-energization may be omitted if the equipment is provided with the marking specified in 62.15.1.

13.2 Equipment coupler

13.2.1 An equipment coupler employed as part of a detachable power supply cord set shall be so constructed that the equipment coupler cannot readily be used to defeat a conventional interlock device.

13.2.2 The conventional interlock device referred to in 13.2.1 has nominally 2.4 mm (3/32 inch) diameter pins, spaced 7.9 mm (5/16 inch) apart, measured between pin centers.

13.3 Cord strain relief

13.3.1 A non-detachable power supply cord or non-detachable interconnecting cable that involves fire or shock energy 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 internal wiring;

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

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

13.4 Cord and wire routing

13.4.1 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.

13.5 Attachment plug

13.5.1 The attachment plug shall conform with one of the configurations covered in Wiring Devices – Dimensional Specifications, ANSI/NEMA WD6, and in the Standard for Attachment Plugs and Receptacles, UL 498.

13.5.2 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.

13.5.3 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.

13.5.4 Equipment may incorporate an overcurrent protective device connected in the grounded (neutral) side of the line provided that all the following conditions are met:

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

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

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

13.6 Bushings

13.6.1 There shall be an insulating bushing that is secured in place:

a) Where the power supply cord emerges from the enclosure; and

b) Where the cord might be subjected to strain or motion.

Exception No. 1: A bushing of the same material as and molded integrally with the supply cord is acceptable on a Type SPT-2 or heavier cord if the built-up section is not less than 1.6 mm (1/16 inch) thick at the point at which the cord passes through the enclosure.

Exception No. 2: An insulated metal grommet may be acceptable in place of an insulating bushing if the insulating material used is not less than 0.8 mm (1/32 inch) thick and completely fills the space between the grommet and the metal in which the grommet is mounted.

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

13.6.3 Ceramic, porcelain, and phenolic materials and some molded compositions are acceptable for insulating bushings. Separate bushings of wood or rubber are not acceptable.

13.6.4 Fiber may be employed if the finished bushing is not less than 1.2 mm (3/64 inch) thick and is so formed and secured in place that it will not be affected adversely by ordinary moisture. Sheet fiber not less than 0.7 mm (0.028 inch) thick may be used under the same conditions.

14 Auxiliary Power Connections

14.1 An auxiliary input connection provided for operation of the equipment from an alternative source of power involving a risk of fire or electric shock, shall comply with the applicable portions in accordance with Supply Connections – Permanently Connected Equipment, Section 11 and Cord-Connected Equipment, Section 13.

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

14.3 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.

14.4 Auxiliary power output connections provided as a power source for other equipment, battery charging of external batteries, and the like, shall comply with 12.1 (a) – (d) if hazardous energy is involved.

14.5 Auxiliary input and output power connections shall be marked in accordance with 62.8.1.

15 Printed Wiring Boards

15.1 A printed wiring board containing circuits involving a risk of fire or electric shock or where separation of the bond between the printed wiring board foil and the base material might result in contact with circuits involving a risk of fire or electric shock, shall comply with the Standard for Printed Wiring Boards, UL 796.

16 Receptacles

16.1 An unused receptacle (such as one provided for the attachment of an accessory) that involves a risk of fire or electric shock shall not be of the type generally employed as a receptacle for signal interconnection of equipment (for example, a single-prong, shielded type phonograph plug) and shall involve line power only if of the conventional parallel-slot type (see 27.1.3 for details on an ac power grounding-type receptacle).

16.2 If the face of a receptacle is less than 16 mm (5/8 inch) wide or less than 22 mm (7/8 inch) long, the face of the receptacle shall project not more than 4.8 mm (3/16 inch) from the part of the mounting surface that is within a rectangle 16 mm (5/8 inch) wide and 22 mm (7/8 inch) long symmetrically located about the receptacle contacts. If the mounting surface is conductive, the face of the receptacle shall project not less than 2.4 mm (3/32 inch) from that part of the mounting surface.

16.3 The area surrounding an unused attachment plug receptacle shall be free of any projections that would prevent full insertion of the blades of a circular attachment plug having a face diameter of 30 mm (1-3/16 inches).

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.

17 Switches

17.1 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.

17.2 With respect to the requirement in 17.1, the current 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, intended operation mode. (The maximum steady state current is considered to occur at rated input power.)

18 Protective Devices

18.1 General

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

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

18.2 Fuses

18.2.1 A fuse that is user serviceable 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.

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

18.3 Battery circuit protection

18.3.1 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.

18.3.2 When an external battery is used and the battery supply cord is provided by the manufacturer, the fuse or protective device shall be located not more than 130 mm (5 inches) from the battery connecting means.

Exception: Equipment intended to be connected to a multiple storage battery source in stationary installations shall be provided with installation instructions that state that the equipment is to be connected to a battery supply that is in accordance with the National Electrical Code, ANSI/NFPA 70.

19 Across-the-Line and Isolating Components

19.1 A component such as a capacitor, a combination capacitor and resistor, a varistor, a suppressor or an electromagnetic interference (EMI) filter connected across the supply circuit; or used for antenna blocking, line-by-pass, or metal cabinet isolation; or between supply-circuit (line) connected parts and exposed metal parts shall comply with the requirements in the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and connection to the Supply Mains, UL 60384-14; or the Standard for Electromagnetic Interference Filters, UL 1283; or the Standard for Surge Protective Devices, UL 1449, as appropriate. A component is considered to be across the primary circuit, if in a shorted condition, a current of greater than 1 A passes through it when the equipment is in a heated condition (after a minimum of 15 minutes of operation). Limiting the current to 1 A or less by a fixed impedance or a protective device rated 1 A or less meets the intent of the requirement.

19.2 An electrolytic capacitor located in unlimited power circuitry and that is greater than 10 mm (0.4 inches) in diameter shall be provided with a means for relieving internal pressure.

20 Batteries

20.1 General

20.1.1 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.

20.2 Batteries containing liquids or gases

20.2.1 Batteries, liquid containers containing or involving hazardous gases or liquids that constitute a risk of fire, electric shock or injury to persons shall not leak in any position of intended use and shall be so located that it is unlikely that persons may inadvertently contact the liquids or gas. There shall be no accumulation of flammable concentrations of gases or vapors emanating from batteries, liquid containers, or the like within the equipment.

20.3 Lithium batteries

20.3.1 Lithium batteries provided with or indicated for use with equipment covered by this Standard shall comply with the requirements in the Standard for Lithium Batteries, UL 1642.

21 Motors

21.1 A motor provided as a part of the equipment in a primary circuit shall comply with the requirements in the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1.

22 Lasers and X- Radiation

22.1 Equipment that employs a laser shall comply with the current requirements of the Code of Federal Regulations, Title 21, Chapter I, Subchapter J, Sections 1010.2 and 1010.3 and Sections 1040.10 and 1040.11.

22.2 Equipment capable of emitting ionizing radiation shall comply with the current requirements of the Code of Federal Regulations, Title 21, Chapter I, Subchapter J, Sections 1010.2 and 1010.3 and Section 1020.10.

23 Sleeving, Tape, Tubing, and Wire Insulation

23.1 General

23.1.1 Sleeving, tape, tubing, and wire insulation shall be rated for the voltage involved and the temperature attained under any condition of use.

Exception: Sleeving, tape, tubing and wire insulation that does not involve the risk of fire or electric shock and are segregated (such as by routing) from wiring and parts involving a risk of fire or electric shock.

23.2 Mechanical protection

23.2.1 The wiring and connections between parts within the equipment shall be protected or enclosed to reduce the risk of mechanical damage that could result in a risk of fire or electric shock.

23.2.2 Internal wiring shall be so routed and secured that neither it nor related electrical connections are likely to be subjected to stress or mechanical damage if such damage could result in a risk of fire or electric shock.

23.2.3 Any wiring or wiring connections:

a) Involving a risk of fire or electric shock, and

b) Subject to handling by the user,

shall have supplementary insulation consisting of two thicknesses of insulating tape or a length of equivalent tubing or shall have a minimum insulation thickness of 0.8 mm (1/32 inch).

23.2.4 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 0.8 mm (1/32 inch) thick and no overall braid.

23.2.5 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 subject to stress or motion resulting from a servicing procedure shall be provided with bushings and strain relief in accordance with 13.3.1 and 13.6.1 – 13.6.4.

23.2.6 A hook up wire employing thermoplastic insulation with wall thickness less than 0.8 mm (1/32 inch) shall be located entirely within a chassis or be such that it will not be subject to mechanical damage, flexing during intended operation, or handling during user servicing.

23.2.7 Wire smaller than 0.21 mm^2 (24 AWG) 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 servicing.

23.2.8 Wiring not involving a risk of fire or electric shock (such as a video 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 as described in 13.3.1.

24 Remote Control and Interconnecting Cables

24.1 A cable involving a risk of fire or electric shock used as an interconnecting cable or for the connection of a remote control or the like shall be rated for the application and, if subject to motion:

a) Be Type SJ flexible cord, or

b) Complete the tests in accordance with Tests for Remote Control and Interconnecting Cables, Section 45, with acceptable results.

24.2 If the cable is permanently attached to the equipment, it shall be provided with a cord exit and strain relief in accordance with Cord-Connected Equipment, Section 13.

24.3 Cords and wires involving a risk of fire or electric shock used for internal interconnection between sections of the equipment within the overall enclosure 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 the equivalent or are so located that they will not be subject to handling during user servicing need not be provided with strain relief means.

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

25 Splices and Connections

25.1 General

25.1.1 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 so as to cause a risk of fire or electric shock, or a reduction of spacings below the minimum required for the application. Consideration shall be given to vibration and the like when judging the acceptability of electrical connections.

25.1.2 A lead is considered to be mechanically secure if 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.

25.1.3 The placing of a lead along a flat surface and soldering (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 detached.

25.1.4 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.

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

Exception: Connectors that are additionally taped to the conductors.

25.2 Wire wrapped connections

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

25.2.2 Wiring used for solderless wire wrapped connections shall be solid, copper wire in 0.21, 0.32, or 0.52 mm^2 (24, 22, or 20 AWG). Other sizes and types of wire may be used if they provide an equivalent connection.

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

25.2.4 The wrap shall have at least 20 points on the corners of the terminal in contact with the wire with at least 16 points closely wrapped with no overlapping. 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 25.1. A lesser number of wraps may be subjected to an investigation to determine equivalence.

Table 25.1
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

26 Spacings

26.1 The spacings between field wiring terminals of opposite polarity and the spacings between a field wiring terminal and any other uninsulated metal part (dead or live) of the opposite polarity shall be no less than indicated in Table 26.1.

Table 26.1
Minimum spacings at field wiring terminals

Potential involved Volts	Between field wiring terminals (through air or over surface)		Between field wiring terminals and other uninsulated parts not always of the same polarity			
			Over surface		Through air	
	mm	(inch)	mm	(inch)	mm	(inch)
0 – 50	3.2	(1/8)	3.2[a]	(1/8[a])	3.2	(1/8)
51 – 250	6.4	(1/4)	6.4[a]	(1/4[a])	6.4	(1/4)
251 – 600	12.7[b]	(1/2)[b]	12.7[a,b]	(1/2[a,b])	9.5	(3/8)

[a] These spacings apply to the sum of the spacings involved wherever an isolated dead metal part is interposed.

[b] A spacing of not less than 9.5 mm (3/8 inch) over surface or through air may be provided at wiring terminals in a wiring compartment or terminal box that is integral with a motor.

26.2 In primary circuits where hand-soldering is involved, other than at field wiring terminals, the spacings between an uninsulated live part and any other uninsulated metal part (dead or live) of the opposite polarity shall be no less than indicated in Table 26.2. If an uninsulated live part is not rigidly fixed in position (by means other than friction between surfaces) or if a moveable dead metal part is located near an uninsulated live part, the construction shall be such that at least the minimum spacings shall be maintained regardless of the position of the moveable part.

Table 26.2
Minimum primary circuit spacings where hand-soldering is involved, other than at field-wiring terminals[a,b]

Potential involved volts	Over surface		Through air	
	mm	(inches)	mm	(inches)
51 – 125	1.6[c]	(1/16[c])	1.6[c]	(1/16[c])
126 – 250	2.4[c]	(3/32[c])	2.4[c]	(3/32[c])
251 – 600	12.7[d]	(1/2[d])	9.5[d]	(3/8[d])

[a] Film coated wire is to be considered an uninsulated live part.

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

Table 26.2 Continued on Next Page

Table 26.2 Continued

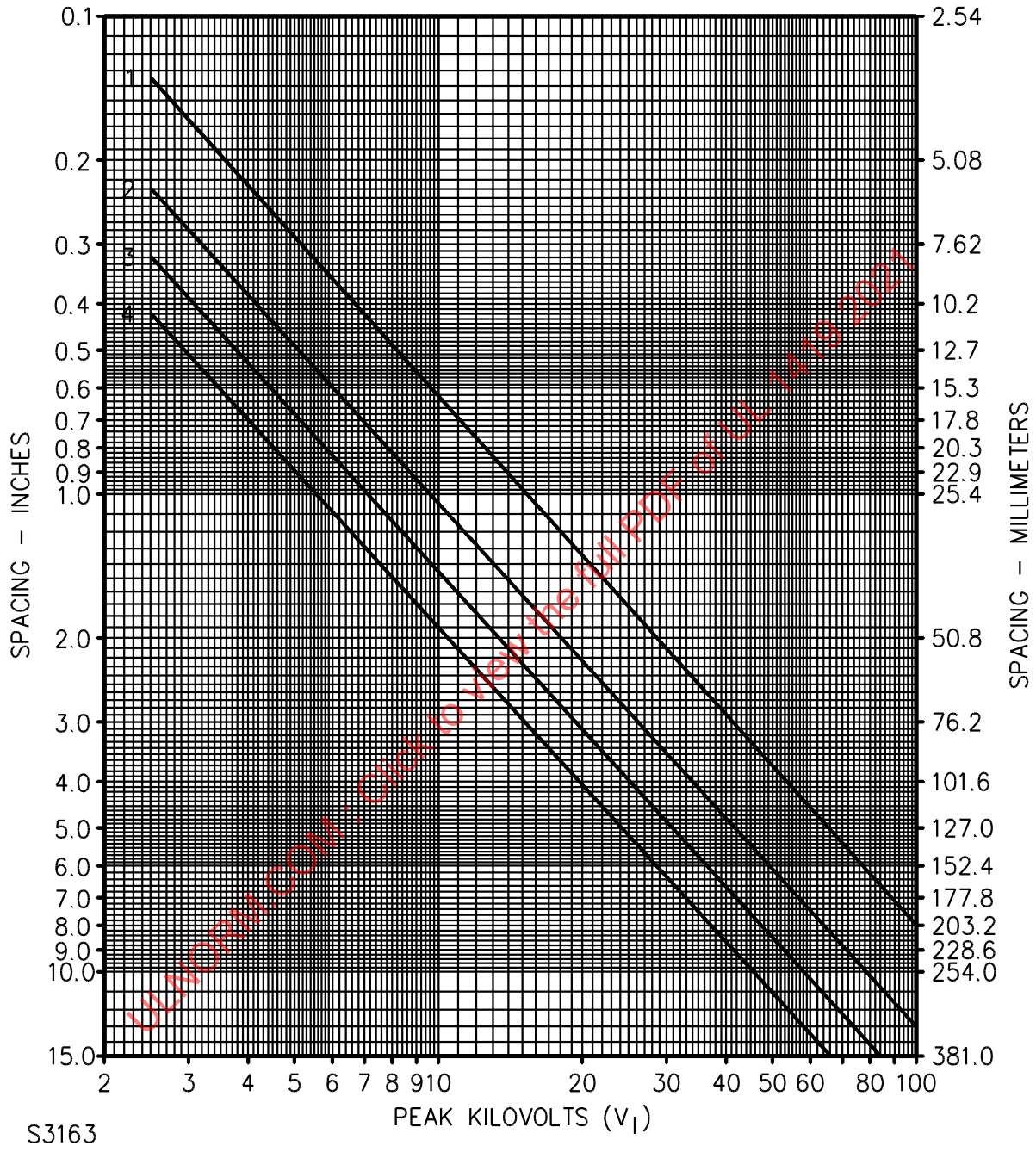
Potential involved volts	Over surface		Through air	
	mm	(inches)	mm	(inches)
[c] At closed in points only, such as a screw and washer construction of an insulated stud mounted in metal, a spacing of 1.2 mm (3/64 inch) is acceptable.				
[d] A spacing of not less than 2.4 mm (3/32 inch) over surface and through air may be provided between a dead metal part and film coated wire that is rigidly supported and held in place on a coil.				

26.3 For circuits operating at greater than 2500 V, spacings from those parts to accessible conductive parts or conductive enclosure, shall be in accordance with Figure 26.1 where peak kilovolts (V_1) = 2E + 1000 or be in accordance with the Dielectric Voltage-Withstand Test for high voltage circuits specified in the Dielectric Voltage-Withstand Test, Section 43.

26.4 The spacings in all circuits of equipment where machine soldering is involved are to be investigated on the basis of the Dielectric Voltage-Withstand Test specified in Section 43.

Figure 26.1

Spacings



V_1 – Measured between parts operating at greater than 2500 V and accessible conductive parts or conductive enclosure

Curve 1 – Through air spacings.

Curve 2 – Over surface spacings – insulating materials having an arc-tracking (D-495) PLC of 0,1,2,3 or 4.

Curve 3 – Over surface spacings – insulating materials having an arc-tracking (D-495) PLC of 5.

Curve 4 – Over surface spacings – insulating materials having an arc-tracking (D-495) PLC of 6 or 7.

27 Grounding

27.1 General

27.1.1 All equipment with accessible conductive parts or parts within the enclosure that are exposed to contact during any operation and are likely to become energized shall be grounded. All of these parts shall be connected to the grounding means. For compliance with this requirement, see 40.1.

Exception No. 1: This requirement does not apply to a direct plug-in type ac adapter complying with the requirements in the Standard for Class 2 Power Units, UL 1310.

Exception No. 2: This requirement does not apply to equipment complying with the additional requirements in the Reference Standard for Double Insulation Systems for Use in Electronic Equipment, UL 2097, and marked in accordance with 62.22.

27.1.2 With reference to the requirement in 27.1.1 the following accessible conductive 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 0.8 mm (1/32 inch) 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 the like.

e) Accessible conductive parts marked in accordance with 62.11.1.

f) Antennas, antenna terminals, control shafts, mounting screws, and the like that are not practical to connect to the grounding means.

27.1.3 An ac receptacle that is provided on equipment shall be of a grounding type. The grounding contact of the receptacle shall be electrically connected to the grounding means of the equipment.

27.1.4 The resistance between the point of connection of the equipment grounding means, at or within the equipment, and any other point in the grounding circuit shall be no more than 0.1 ohm. Determination of the resistance is in accordance with the test in 40.1.

27.2 Cord-connected equipment

27.2.1 An equipment grounding conductor 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 to the frame or enclosure. The screw 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 or star washer shall be employed to prevent the screw from becoming loosened by vibration.

27.2.2 If a portion of the main ground is provided on the printed wiring board (PWB) trace, then compliance of the printed wiring board trace as a reliable means for main grounding shall be determined by the Ground Printed Wiring Board (PWB) Trace Test in Section 56. The ground trace shall terminate as described in 27.2.1(c).

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

27.2.4 If equipment is provided with a detachable power supply cord, and has conductive parts that are connected to the grounding conductor that might be contacted during the connection or disconnection of the equipment coupler at the equipment end of the cord, the construction shall be such that the grounding connection is made first and broken last with respect to the power supply conductors.

27.3 Permanently connected equipment

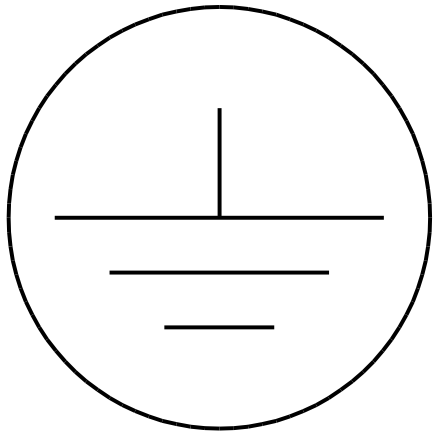
27.3.1 A field wiring terminal or lead for the connection of an equipment grounding conductor shall be provided.

27.3.2 A field wiring terminal 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 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", the symbol shown in Figure 27.1, or the like, or by marking on a diagram provided on the equipment. The wire binding screw or screw type wire connector shall be so located 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.

Figure 27.1

Grounding symbol



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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 separated or segregated from primary field wiring connections by barriers.

28 Risk of Electric Shock

28.1 Accessible live parts

28.1.1 Uninsulated parts that are accessible to the user constitute a risk of electric shock if they:

a) Do not comply with the leakage current requirements in Leakage Current, Section 29, and the open circuit voltage between these parts and earth ground or other accessible conductive parts is more than 30 Vrms, 42.4 Vpeak or 60 Vdc (or 15 Vrms, 21.2 Vpeak or 30 Vdc where wet contact is likely to occur), or

b) Are not grounded and do not meet the criteria of the ungrounded dead metal parts requirements in Grounding, Section 27.

29 Leakage Current

29.1 For cord connected equipment, when tested in accordance with Equipment Leakage Current Test, Section 41, the leakage current at any accessible part shall not be more than:

a) 0.75 MIU for hand held equipment; and

b) 3.5 MIU for all other equipment, or

c) 5.0 MIU for all other equipment that complies with the following:

1) The cross sectional area of the internal protective conductor shall not be less than 1.0 mm^2 in the path of high leakage current, and

2) The equipment is provided with the marking specified in 62.14.1, and

3) The equipment is provided with installation instructions as specified in Installation Instructions, Section 64, or

d) 5% of the maximum input current for equipment that complies with (c) (1), (2), and (3) above, and is provided with an industrial (twist lock) type attachment plug and socket, or an attachment plug other than a standard type parallel blade or T-blade configuration.

30 Risk of Fire

30.1 A risk of fire is considered to exist if the source of power to a circuit or part is capable of delivering a power of more than 240 W for five seconds into an external resistor connected singly between each such circuit or part and any return to the power supply.

30.2 To determine compliance with 30.1, the source of supply for a power limited circuit shall be subjected to the tests described in Test for Limited-Power Circuit, Section 51.

31 Accessibility

31.1 General

31.1.1 During normal operation or user servicing, parts of equipment shall be located, enclosed, or guarded so that persons will not contact parts that involve a risk of electric shock.

31.1.2 An opening in an enclosure, guard, or barrier may be provided if the probe illustrated in Figure 31.1 cannot be made to bridge two uninsulated parts, one of which may be a live part, nor to touch any uninsulated live part that involves a risk of electric shock or any moving part that involves a risk of injury to persons when inserted into the opening through which a 25 mm (1 inch) diameter sphere cannot pass. The probe is to be rotated with the movable sections straight or in any possible position resulting from bending one or more sections in the same direction.

Exception No. 1: Moving parts that are exposed to perform a work function shall be investigated based on consideration of the following factors with respect to intended operation or likely misuse of the equipment:

a) Degree of exposure necessary to perform the intended function;

b) Sharpness of the moving part;

c) Likelihood of unintentional contact with the moving part;

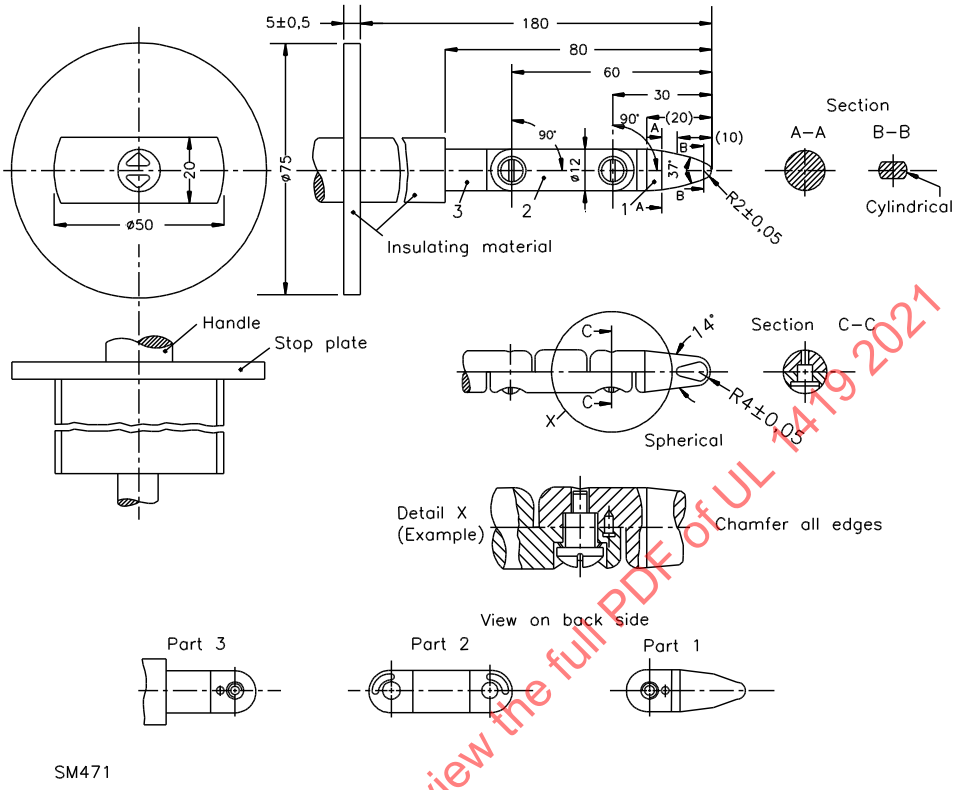
d) Speed of the moving part; and

e) Likelihood that a part of the body would be endangered or that clothing could be entangled by the moving part, resulting in an injury.

Exception No. 2: For floor standing equipment, the probe is to be inserted into all openings in the bottom that are accessible without tipping, turning over, or otherwise moving the equipment from its intended installed position.

Figure 31.1

Accessibility probe



Note: All dimensions in millimeters

31.1.3 The minimum recessing behind an enclosure opening through which a 25 mm (1 inch) diameter sphere can pass, of parts involving the risk of electric shock shall be at least that shown in Table 31.1.

Table 31.1
Minimum recessing of parts involving electric shock

Maximum width of slot[c] mm (inches)	Diameter of round holes[c] mm (inches)	Minimum distance between opening and part[a,b]
	More than 25.4 (1) but not more than 50.8 (2)	5D + X
More than 25.4 (1) but not more than 50.8 (2)	More than 50.8 (2) but not more than 76.2 (3)	6D + X
More than 50.8 (2) but not more than 76.2 (3)		7D + X

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

[b] X is 3.2 mm (1/8 inch) for each 1000 V peak or fraction when operated under the conditions of the Power Input Test, Section 37.

[c] Over 76.2 mm is not acceptable.

31.2 Guard and barrier insulating material

31.2.1 A guard or barrier of insulating material employed to render live parts inaccessible or used in lieu of spacings shall:

a) Be no less than 0.71 mm (0.028 inch) thick or, when used in lieu of spacings, may be 0.33 mm (0.013 inch) thick if used in conjunction with an air space, and

b) Have a flammability classification in accordance with Table 7.1 if the equipment is evaluated to Option A or Table 7.3 if the equipment is evaluated to Option B.

Exception: Fiber or the equivalent that is at least 0.33 mm (0.013 inch) thick may be used to cover a splice within the overall enclosure. If it is no less than 0.33 mm (0.013 inch) thick, a covering of paper, waxed or otherwise treated to resist the absorption of moisture, may 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 no less than 0.71 mm (0.028 inch) thick may 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 0.51 mm (0.020 inch).

32 Interlocks

32.1 An interlock shall:

a) Not be defeatable without the use of a tool,

b) Render parts that become accessible to the user free from electric shock, emanation, excessive temperature, or driven movement (that could result in injury to persons), and

c) Be constructed such that two interlock devices are not simultaneously accessible (to the user) by one hand.

33 Servicing

33.1 User servicing includes but is not limited to the following:

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

b) Fuse – Replacement of a fuse.

Exception No. 1: One intended to be soldered in place.

Exception No. 2: One not readily perceptible by the user. A fuse is not readily perceptible if located within a chassis, compartment, or enclosure of the equipment and located such that it is not readily visible through an opening in the enclosure. If the enclosure has a cover, it is to be one that:

1) does not need to be opened or removed during intended operation or user servicing,

2) can be opened or removed only with a tool, and

3) 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 No. 3: The literature mentioned in Exception No. 2 does not include schematic circuit diagrams or instructions for service personnel as described in 63.2.

c) User Adjustment – Adjustment of a marked adjustable control or an adjustable component if the adjustment may be accomplished with ordinary tools, with the equipment in operation, the adjustment does not involve a risk of electric shock, and without defeating the interlock.

d) Unmarked Adjustment – Adjustment of an unmarked adjustable control if the adjustment may be accomplished without a tool, with the equipment in operation, the adjustment does not involve a risk of electric shock, and without defeating the interlock.

e) 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.

33.2 Servicing by qualified service personnel includes but is not limited to:

a) Servicing components soldered in place, and not readily perceptible during user servicing.

b) Servicing in compartments with accessible uninsulated live parts.

c) Servicing procedures accomplished after the removal of enclosure covers, barriers, and the like, relied on to maintain inaccessibility to uninsulated live parts.

d) Servicing accomplished by defeating the interlock.

34 Protection During User Servicing

34.1 Uninsulated parts that involve a risk of fire or electric shock shall be so located or protected that unintentional contact with the parts is not likely during user servicing.

34.2 Uninsulated parts that involve unlimited power levels shall be so located or protected that they are not likely to be unintentionally bridged by conductive materials that might be present during operator service operations not involving those parts, or instructions be provided as to precautions to be taken when performing these operator servicing operations.

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

34.4 A risk of injury to persons is considered to exist if one or more of the following conditions is present:

a) Power operated moving parts such as gears and linkages are accessible during intended operation and may cause a cut or laceration.

b) Sharp edges, burrs, or projections are present that may cause injury during operation or user servicing.

c) The stability of the equipment is such that it may cause injury to persons, in accordance with Personal Injury Tests, Section 58.

d) It is likely that a part of the body would be endangered or that clothing would be entangled by the moving part, resulting in an injury.

34.5 With reference to 34.4, unintended contact with power operated moving parts is to be investigated by applying applicable accessibility requirements.

34.6 A part or portion of a part that is necessarily exposed to perform the work function need not be enclosed but, when necessary, guarding shall be provided.

35 Protection of Service Personnel For Equipment Not Provided With Complete Enclosures

35.1 The requirements of Section 35 apply only to equipment intended to be installed in restricted access areas that are not provided with complete enclosures which may require service personnel to reach over, under, across or around uninsulated electrical parts or moving parts to make adjustments or measurements with the equipment energized.

35.2 Uninsulated parts that exceed the limits of 28.1.1 shall be so located or guarded that unintentional contact with the parts is not likely during service operations involving other parts of the equipment and shall be provided with a marking as specified in 62.20.1 to warn service personnel of the potential risk of electric shock.

35.3 Uninsulated parts that involve a risk of fire shall be so located or guarded that they are not likely to be unintentionally bridged by conductive materials that might be present during service operations not involving those parts.

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

35.5 Required guards or barriers shall be capable of being removed and replaced with a minimum of effort if removal is necessary for servicing the protected parts.

36 Implosion Protection

36.1 General

36.1.1 Equipment containing cathode-ray tubes with a minimum 76 mm (3 inch) diameter face area, shall have integral implosion protection in accordance with the Standard for Mechanical Safety for Cathode-Ray Tubes, UL 61965.

Exception: This requirement does not apply to a CRT that is not directly viewed and is totally enclosed, including the face, as described in 36.3.1.

36.2 Mechanical protection

36.2.1 Equipment containing CRTs shall be provided with a cabinet or equivalent enclosure that shall house all live or current carrying parts, other than cords or cables. The enclosure shall be substantial and shall reduce the likelihood of mechanical damage to the various parts of the equipment.

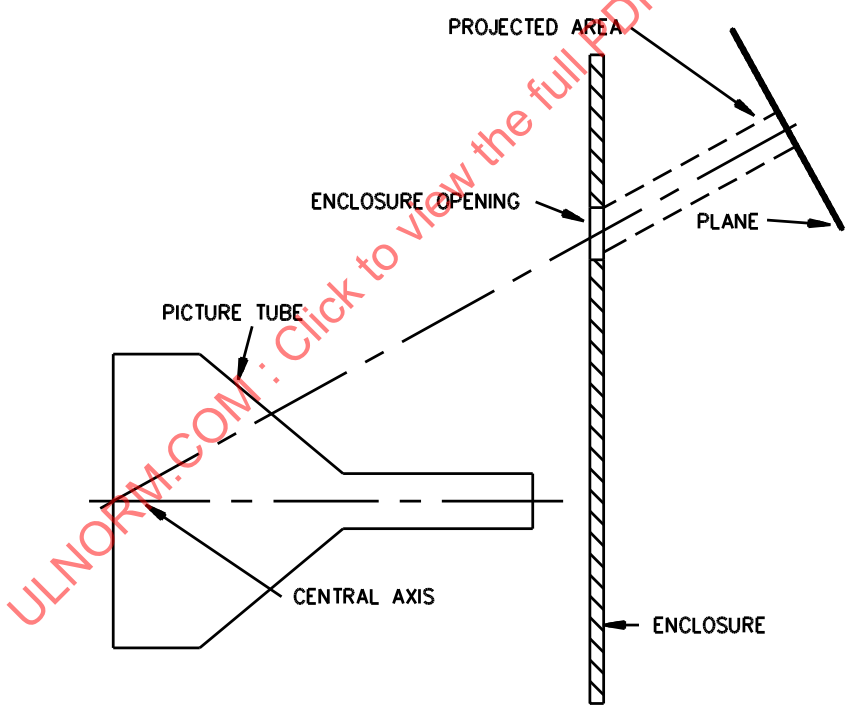
36.2.2 The use of a metal cone picture tube and the presence of barriers are to be given consideration in applying 36.2.1.

36.3 Cathode-ray tube (CRT) enclosure opening

36.3.1 To reduce the risk of injury that may result from implosion of a CRT having a minimum diameter of 76 mm (3 inches), the projected area of any opening in the top, back, sides or front of the enclosure onto a plane perpendicular to a line passing through the center of the opening and any point on the central axis of the bulb section of the picture tube, shall not exceed 129 mm^2 (0.20 square inch) unless the minor dimension of the projected area is not more than 9.5 mm (3/8 inch). See Figure 36.1.

Figure 36.1

Cathode-ray tube enclosure opening



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36.4 CRT neck protection

36.4.1 A CRT neck, socket and leads shall have an enclosure or the equivalent that protects them from mechanical damage from the top and sides.

36.4.2 When a guard is used to comply with 36.4.1 the projections of the guard onto horizontal and vertical planes parallel to the axis of the CRT shall encompass the projections of the CRT neck, socket,

and leads onto these planes; and an opening in the top or sides of the guard, having a minor dimension of more than 13 mm (1/2 inch), shall have a maximum area of 645 mm^2 (1 square inch).

PERFORMANCE

37 General

37.1 Details

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

37.1.2 Equipment having both ac and dc ratings is to be tested with the equipment connected to an ac supply and again to a dc supply.

Exception: When it can be established that one type of supply connection results in the maximum operating conditions.

37.2 Voltmeters

37.2.1 Unless indicated otherwise, voltage measurements shall be made with a voltmeter having a resistance of 2000 ohms per volt minimum for potentials of 1000 V or less and 20,000 ohms per volt minimum for potentials of more than 1000 V.

37.2.2 The open-circuit voltage measurement used in conjunction with a leakage current determination shall 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 shall be used.

37.3 Leads, connectors, and components

37.3.1 When testing the complete equipment, a lead, connector, or component that is accessible during operation or user servicing of the equipment is to be:

a) In its intended position, and

b) In any position likely after user servicing

37.4 Cheesecloth indicators

37.4.1 Cheesecloth used for tests shall be untreated cotton running 26 – 28 m^2/kg (14– 15 yd^2/lb) and having what is known to the trade as a count of 13 by 11 – that is, for any square centimeter, 13 threads in one direction and 11 threads in the other direction (for any square inch, 32 threads in one direction and 28 threads in the other direction).

37.4.2 Tests involving cheesecloth shall be made in a room free of drafts.

37.5 Supply circuit voltage and frequency

37.5.1 All operational tests shall be conducted with the equipment connected to a supply circuit of rated frequency and a voltage as indicated in Table 37.1.

Table 37.1
Operational test voltages

Section	Test	Marked voltage rating	Test voltage
	Normal operation tests		
38	Power Input	105 – 130	Maximum marked voltage, but not less than 120 V
40	Grounding Impedance	or	
41	Equipment Leakage Current		
60	Audio Output Maximum Voltage	210 – 260	Maximum rated voltage, but not less than 240 V
39	X-Radiation	105 – 130	130[a,b]
		210 – 260	260[a,b]
	Abnormal operation tests		
45	Interconnecting cable	105 – 130	130[a,b]
47	Battery and Battery Circuit		
49	Battery Supply		
50	Vacuum tube filament short circuit	or	
51	Limited Power Circuit		
52	Transformer Short Circuit/Overload		
53	Power Supply		
54	Component Abnormal Operation	210 – 260	260[a,b]

[a] For equipment intended to be operated at more than one given voltage (for example – 120V/230V), the test voltage is to be 130 V for the lower voltage, and 110% of the higher voltage, and 110% of the higher voltage, but not less than 240 V nor more than 260 V, except when it may be established that one voltage represents the most severe operating conditions.

[b] The test voltage may be reduced to a lower value, but not less than 105 or 210 V, respectively. The lower test voltage value may be used for abnormal operation tests where the lower value represents a more severe condition or a higher voltage might cause a protective device to clear the circuit.

37.5.2 Equipment with one supply circuit frequency rating shall be tested at that frequency. Equipment with a multiple-frequency rating shall be tested at 60 Hz, if 60 Hz is included in the rating, and may also be tested at any of the other frequency ratings unless it may be established that testing at 60 Hz results in the maximum operating conditions.

38 Power Input Test

38.1 The measured power input shall not exceed the marked input rating by more than 10 percent when the equipment is operated with controls and signal input adjusted within its intended range of operation to produce maximum power input.

38.2 A television receiver is to be operated on-channel with an off-the-air signal of sufficient strength to eliminate snow. A television monitor is to be operated using a signal source with a color bar pattern. Video and audio equipment shall be tested in accordance with 38.3.

38.3 The power input measurements are to be made under the following conditions:

a) Positions and Use – The equipment is to be connected, operated, and mounted according to the manufacturer's instructions.

b) Operating Controls – User controls are to be adjusted within the range of intended operation. For equipment with amplification circuits, all controls such as volume, bass, treble, loudness, and the like are to be adjusted so as to produce maximum amplifier output [see (g) and (h)]. If there is more than one amplifier circuit and a single balance control is provided, it is to be set so that each

amplifier simultaneously produces output, even if not equal, so as to result in maximum input. If separate volume and other operating controls are provided, then each amplifier is to be adjusted to produce maximum output simultaneously even if not equal. Supply circuit voltage setting devices are to be set according to the manufacturer's instructions.

c) Factory Controls – Factory set controls that are not intended to be user adjustable are not to be readjusted from their factory setting.

d) Motors and Motor Drive Parts – Motors and motor driven parts of the equipment are to be loaded according to the intended purpose. When testing involves motor driven parts, other parts of the equipment that are intended to be operated at the same time are to remain connected.

e) Accessories – Equipment with an output connection intended to supply voltage and current to an accessory is to have the intended accessory:

1) Connected according to the manufacturer's instructions unless power consumption is greater with the accessory not connected, and

2) Operated in such a way as to produce maximum power input on the equipment. A simulated load consuming power equivalent to the accessory may be used in place of the accessory.

f) Audio Output Circuit Loading – An audio amplifying circuit intended to supply audio signal voltage and current to a speaker is to have its output load adjusted according to one of the following:

1) If the equipment is provided with either internally connected speakers or externally connected speakers, an audio load of equal impedance may be substituted for each speaker or assembly of speakers provided.

2) If the equipment is not provided with speakers but the speaker impedance rating is marked on the equipment, an audio load of impedance equal to that marked on the equipment is to be connected to the equipment output terminals according to the manufacturer's instructions, or

3) If the equipment is not provided with speakers and there isn't a speaker impedance rating marked on the equipment, an audio load that results in the highest audio output power per channel of amplification is to be connected to the equipment output terminals according to the manufacturer's instructions.

The audio load connected to each piece of equipment is to be essentially resistive with not more than a 10-percent reactive component at any frequency up to 5 Khz. The audio load is to be capable of continuously dissipating the full output of the equipment while maintaining the resistance within 1 percent of its rated value. See Figure 38.1 for a typical input-power and input-current test circuit for an audio amplifier.

g) Signal Input Not Affecting Power Input – Equipment provided with signal input circuits need not be connected to an input signal if:

1) The signal input circuits do not amplify the signal in the equipment and

2) The supply circuit input power or current is not noticeably affected by a signal input.

h) Signal Input Affecting Power Input– Equipment provided with signal input circuits in which supply circuit input power or current is noticeably affected by a signal input is to be tested as follows:

1) A 1000-Hz sinusoidal signal is to be applied to the first audio stage of each preamplifier or amplifier circuit.

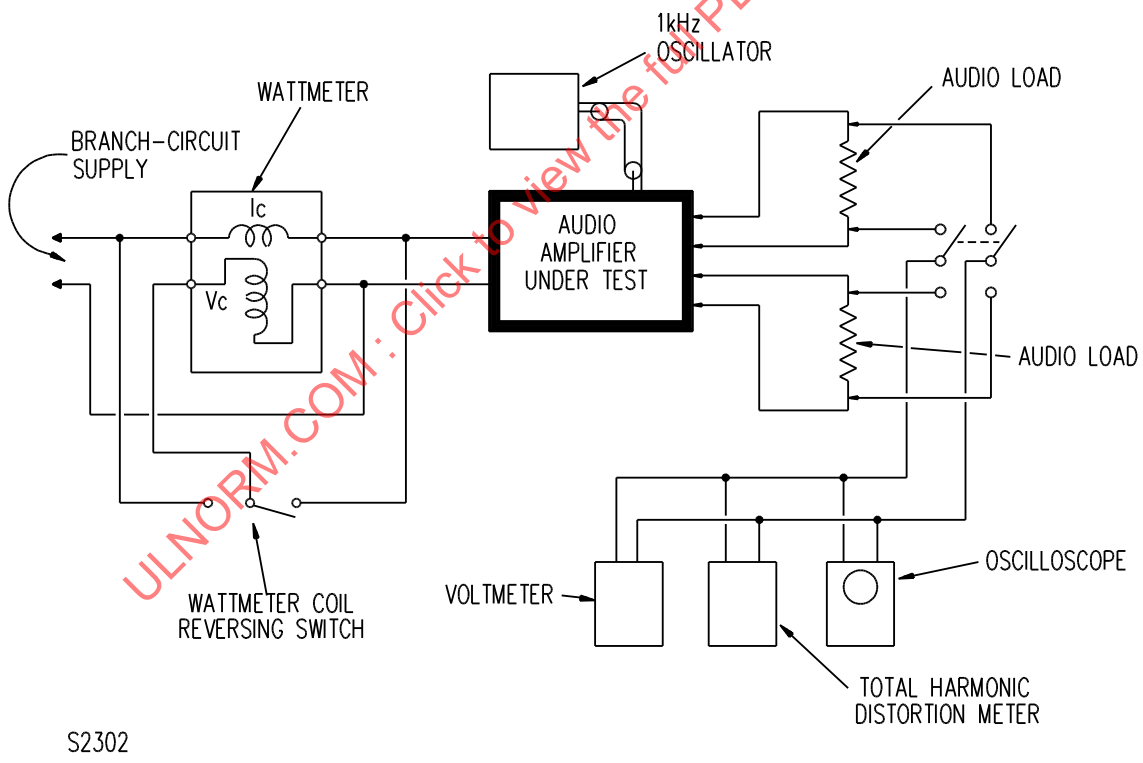
Exception: A sinusoidal signal of the geometric mean frequency of the upper and lower frequency limits of the circuit under test may be used if the amplifier has a limited bandwidth (for example, less than nominal 20 Hz-20 Khz). The geometric mean frequency is equal to the square root of the product of the low frequency limit and the high frequency limit. The frequency limits may be specified by the manufacturer.

2) After a 15-minute warmup period, the signal input level and the equipment operating controls are to be adjusted to produce 1/10 of the maximum available undistorted sine wave output power or 0.5 W, whichever is greater. The maximum available undistorted sine wave output power is considered to be the maximum attainable with no evidence of clipping or flattening of the sine wave as determined by viewing the waveform on an oscilloscope. If there is a question about clipping or flattening of the output sine wave, a distortion analyzer may be used to measure the total harmonic distortion (THD) present in the waveform. The THD is not to be greater than 1 percent.

38.4 While measuring the power input, increases in power having a duration of 5 seconds or less are to be discounted if the power increase does not occur more often than once a minute.

Figure 38.1

Typical input-power and input-current test circuit for an audio amplifier



39 X-Radiation Test

39.1 General

39.1.1 Equipment incorporating a CRT or other possible X-radiation source shall not produce X-radiation exceeding a dose rate, averaged over an area of 10 cm^2, of 0.5 milliroentgen per hour above background at any external location 5 cm from the outer surface of the overall enclosure when measured as described in 39.1.2.

39.1.2 X-radiation measurements are to be made with instruments under the following conditions:

a) The enclosure is to be complete except that any parts that may be opened or removed for any operator servicing are to be opened or removed unless the parts are interlocked.

b) The voltage of the supply circuit is to be 130 volts if the rating of the equipment is within the range 105– 130 volts and 260 volts if the rating of the equipment is within the range 210 – 260 volts. For equipment rated at any other voltage rating, the supply circuit voltage is to be set at the marked voltage rating of the equipment.

c) After measurements have been made with the supply voltage specified in (b), the supply voltage is to be adjusted to any other voltage within the mentioned ranges that results in greater X-radiation.

d) All controls, regardless of location, are to be adjusted for maximum X-radiation during equipment operation without impairing the performance of the equipment. Impaired performance is that condition under which the basic function of the equipment has deteriorated to the point where outputs are not usable (nonusable visual information on a graphic display tube, and so forth).

e) For multiple-function equipment, measurements are to be made with the equipment in any mode of intended operation that produces usable visible information.

f) If equipment is intended to display information received from an outside source, X-radiation is to be measured with and without such a signal input.

Exception: If it is possible to display maximum information without an external signal input source, X-radiation measurements are to be made in this operating mode.

39.1.3 Unless marked as indicated in 62.7.1, equipment shall comply with 39.1.1 under all conditions of servicing. Service conditions include the removal of shields, windows, cages, and covers, with or without the chassis removed from the overall enclosure.

40 Grounding Impedance Test

40.1 Accessible conductive parts likely to render an electric shock in the event of a fault shall be tested to verify that they are bonded to the grounding terminal of the equipment. Compliance is to be checked by measuring the resistance between a grounded accessible conductive part and the point of connection to the protective grounding means, excluding the protective grounding conductor of the power supply cord. The resistance shall not be more than 0.1 ohm. The resistance shall be determined by a resistance measuring instrument or the resistance shall be determined by measuring the voltage when a current of 25 A at supply circuit frequency with a no-load voltage not exceeding 12 V is passed between the equipment grounding means and the grounded conductive part. The resistance is to be determined by dividing the drop in potential, in volts, by the current, in amperes, passing between the two points.

41 Equipment Leakage Current Test

41.1 General

41.1.1 All accessible conductive parts shall be tested for leakage current. The currents from these parts shall be measured to the grounded supply conductor individually as well as collectively where simultaneously accessible.

41.1.2 Parts are considered to be simultaneously accessible if they can be contacted by one or both hands of a person at the same time. For the purpose of these requirements, one hand is considered to be able to simultaneously contact parts that are within a 100 by 200 mm (4 by 8 inch) rectangle. Parts that

can be contacted simultaneously by a person having a reach of 1.83 m (6 ft) are considered to be touchable by both hands.

41.1.3 Leakage current refers to all currents, including capacitively coupled currents.

41.1.4 Insulation, such as that used:

a) Between the voice coil and the frame of a speaker,

b) Between the plates of an adjustable or variable air dielectric capacitor,

c) Between any two adjacent elements of an electrolytic capacitor, or

d) Between the elements of a solid state component (diode, transistor, integrated circuit, and the like) shall be short circuited or open circuited during leakage current measurements.

41.1.5 The leakage current shall not be more than that specified in 29.1.

41.1.6 The measurement circuit for the equipment leakage current test shall be as shown in Figure 41.1. The measurement instrument is defined in Figure 41.2. The meter that is actually to be used for a measurement need only indicate the same numerical value for the particular measurement as would the defined instrument. The meter used need not have all of the attributes of the specified instrument.

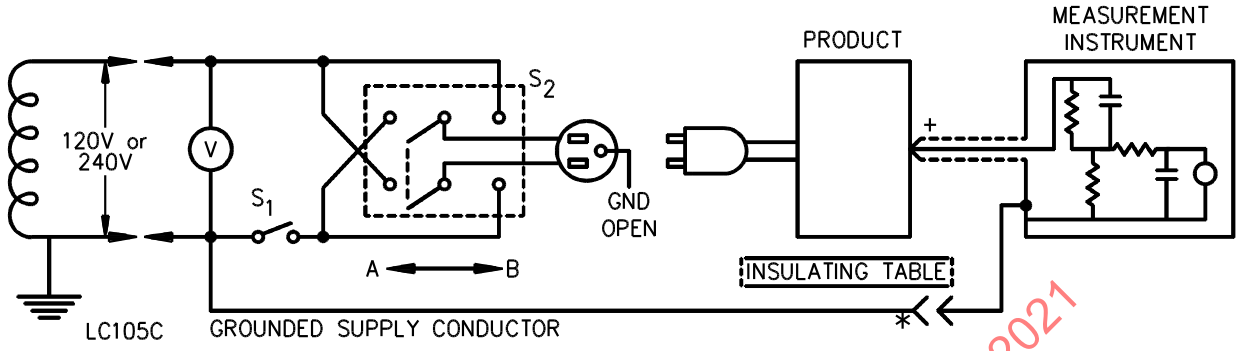
Over the frequency range 20 Hz to 1 MHz with sinusoidal currents, the performance of the instrument is to be as follows:

a) The measured ratio V_1/I_1 with sinusoidal voltages is to be as close as feasible to the ratio V_1/I_1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 41.2.

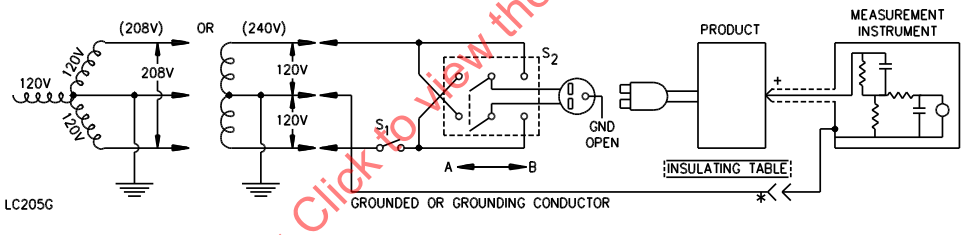
b) The measured ratio V_3/I_1 with sinusoidal voltages is to be as close as feasible to the ratio V_3/I_1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 41.2. V_3 is to be measured by the meter M in the measuring instrument. The reading of meter M in RMS volts can be converted to MIU by dividing the reading by 500 Ω and then multiplying the quotient by 1,000. The mathematic equivalent is to simply multiply the RMS voltage reading by 2.

Figure 41.1

Typical leakage-current measurement circuits



Product intended for connection to a 120-volt or an end-grounded 2-wire, 240-volt power supply.



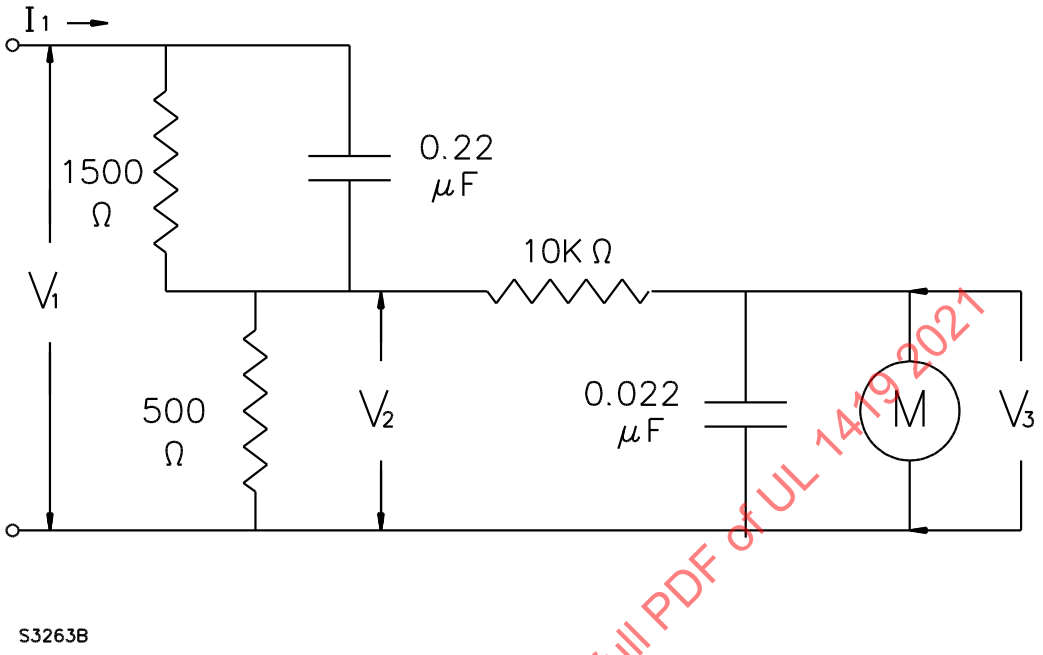
Product intended for connection to a 3-wire 208-volt or a 3-wire 240-volt grounded neutral power supply.

+ – Probe with shielded lead.

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

Figure 41.2

Measurement instrument for reaction (leakage) current



Note – Detailed specifications and guidance for the calibration of this instrument are given in the American National Standard for Leakage Current for Appliances, ANSI C101.

41.1.7 Unless the instrument is being used to measure leakage current from one part of the equipment to another, it is to be connected between the accessible parts and the grounded supply conductor.

41.1.8 For products with direct plug in power supplies where there is no grounded supply conductor, the instrument return lead may be connected to either the grounded or grounding conductor of the supply depending on the other electrical loads connected to the branch circuit and operating at the time the test is conducted. Use the conductor introducing the least electrical signals (noise), as indicated by the lowest leakage current reading. In environments having considerable electrical signals (noise) an isolating transformer can reduce the effects of extraneous signals.

41.1.9 A sample of the equipment shall be tested in the as-received condition with all of its switches closed, but with its grounding conductor open and with the equipment at room temperature. The supply voltage is to be the maximum voltage marked on the equipment, but not less than 120 (or 240) V. See Table 37.1. The test sequence, with reference to the measuring circuit in Figure 41.1, shall be as follows:

a) With the branch circuit connected power switch (if provided) in the "off" position, the equipment shall be connected to the measuring circuit. Immediately after connection, the leakage current shall be measured using both positions of switch S2 in Figure 41.1, and with other switching devices in the equipment in all of their operating positions.

b) The power switch (if provided) shall then be in the "on" position, energizing the equipment, and immediately after closing the switch, the leakage current shall be measured using both positions of switch S2 in Figure 41.1, and with other switching devices in the equipment in all of their operating positions.

c) Switch S1 as shown in Figure 41.1 is used only for direct plug-in power supply products that do not employ an equipment grounding conductor. For such products, steps (a) and (b) are to be conducted taking measurements with the S1 switch in both positions.

41.1.10 Should the leakage current measured exceed the limits specified in 29.1, when tested in the as-received condition described in 41.1.9, the test may be repeated with preconditioning consisting of the equipment not being energized for a minimum of 48 hours prior to the test.

41.2 Leakage current measurements for equipment with multiple (redundant) power supplies

41.2.1 Equipment designed for multiple (redundant) supplies, where only one primary circuit is energized at a time, shall be tested with only one supply connected.

41.2.2 For equipment with multiple (redundant) power supplies, including multiple (redundant) power supply cords, where all power supplies are energized at the same time, equipment may also be tested with one supply cord at a time if the instruction manual is marked in accordance with 62.18.

42 Temperature Test

42.1 General

42.1.1 Equipment, when tested according to the applicable conditions and procedures described in this Section, shall not attain a temperature that results in one or more of the following conditions:

a) The likelihood of ignition of materials or components.

b) An adverse effect upon materials or components.

c) The temperature limits of materials or components being exceeded.

d) Temperatures at specific points greater than the limits specified in Table 42.1.

e) A protective device opening.

Table 42.1
Maximum acceptable temperatures

Parts of the equipment	Temperature	
	°F	°C
1. Accessible parts[e]		
A. Surfaces of an enclosure	194	90
B. Small areas and easily discernible heat sinks	194	90
2. Operating devices and handles[f]		
A. Grasped for lifting, carrying, or holding		
1. Metallic	122	50
2. Nonmetallic	140	60
3. Surfaces other than handles and knobs that are subject to contact[f]		
A. Metallic[g]	140	60
B. Nonmetallic	185	85
4. Enclosure interior surfaces		

Table 42.1 Continued on Next Page

Table 42.1 Continued

Parts of the equipment	Temperature	
	°F	°C
A. Wood	194	90
B. Insulating material	d	d
5. Insulating materials		
A. Polymeric	d	d
B. Varnished cloth	185	85
C. Fiber	194	90
D. Wood and similar material	194	90
E. Laminated phenolic composition[a]	257	125
F. Phenolic	302	150
6. Softening point of any sealing compound	e	e
7. Coil winding surfaces employing impregnated organic insulation or film-coated wire[a,c]	194	90
8. Capacitors[b]		
A. Electrolytic	149	65
B. Other types	194	90
9. Fuses[a]	194	90
10. Conductors with rubber, thermoplastic or similar insulation[a]	140	60

[a] Does not apply if investigated and accepted for a higher temperature.

[b] An electrolytic capacitor operating at a temperature higher than 65°C (149°F) is to be evaluated on the basis of its marked temperature rating, or if not marked with a temperature rating, may be investigated to determine its acceptability at the higher temperature.

[c] A hot-spot temperature not higher than 105°C (221°F) on the surface of a coil winding is acceptable, provided the temperature of the winding, as measured by the resistance method, does not exceed 100°C (212°F).

[d] Polymeric material shall be acceptable for the application when evaluated with respect to temperature.

[e] The maximum sealing compound temperature, when corrected to 25°C (77°F) ambient temperature, is 15°C (27°F) less than the softening point of the compound as determined by the Standards Test Methods for Softening Point of Resins Derived from Naval Stores by Ring-and-Ball Apparatus, ASTM E28.

[f] Item 1 is concerned with ignition of materials that may contact the enclosure. Items 2 and 3 are concerned with skin burn if contacted by the user. The lowest temperature limit on a given surface is the maximum acceptable for that surface or part.

[g] A heat sink may exceed the specified temperature if a marking is affixed adjacent to the heat sink as specified in 62.17.1.

42.2 Thermal equilibrium

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

42.3 Equipment test conditions

42.3.1 The equipment shall be tested with the maximum projection on the back in contact with a flat vertical wall constructed of heat insulating material and painted flat black.

Exception: The spacing between the wall and the main surface of the back of the equipment shall not be less than 25 mm (1 inch).

42.3.2 Covers and doors likely to be closed during operation shall be closed for the duration of the test.

42.3.3 Consideration is to be given to the actual conditions of intended operation.

42.3.4 Rubber-like and felt materials shall be removed from supporting feet to the extent that they are likely to be worn off in service.

42.3.5 Horizontal ventilating screens subject to the accumulation of dust and having holes less than 1.2 mm (3/64 inch) in diameter shall be covered with loose cotton.

42.4 Equipment operating conditions

42.4.1 The equipment shall be operated:

a) At the power input as described in accordance with Power Input Test, Section 38, with the equipment connected as described in 37.5.1 and 37.5.2.

Exception: Pink noise as described in 42.4.2 may be used as an alternate signal if the sine wave does not represent loading of the amplifier. Each amplifier circuit shall be adjusted to deliver one-tenth maximum undistorted output as determined in the Power Input Test, Section 38. If the acceptability of a component or part is in question, sinusoidal signals at one-tenth maximum undistorted output shall be used.

b) With all unused receptacles connected to loads at their maximum marked rating, and

c) As described in 42.3.1 – 42.3.5 to represent expected usage of the equipment.

42.4.2 Equipment intended to be operated with a pink noise input as specified in the Exception to 42.4.1(a) shall 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 equipment, coupled through a filter circuit with a frequency roll-off of minimum 12 decibels per octave as follows. The amplitude-probability distribution shall be three standard deviations. The low and high frequency figures of the amplifier mentioned in 42.4.2(a) and 42.4.2(b) are those given by the manufacturer. The signal amplitude is to be adjusted to cause the equipment to deliver power equal to one-tenth of measured maximum undistorted output power as described in the Power Input Test, Section 38, or one-tenth 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 38.3. 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 audio signal is down 3 decibels) of 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 low pass filter set at 20 Khz or as close as practicable to one half the high frequency response limit figure, whichever is lower.

42.5 Thermocouples

42.5.1 When thermocouples are used in the determination of temperatures, it is common practice to employ thermocouples consisting of 30 AWG iron and constantan wires and a potentiometer-type instrument. When it is not practical to use iron and constantan thermocouples, some other type as described in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M, may be used.

42.6 Winding temperature measurement

42.6.1 The temperature on a winding shall be measured by applying a thermocouple to the hottest part of the surface of the coil winding. If the winding is enclosed, a hole shall be made in the case; and, if the

winding is potted, a heated wire may be used to provide a hole in the compound before the thermocouple is placed in contact with the coil surface.

42.6.2 The temperature of a copper or aluminum winding shall be calculated by Equation 42.1. Windings shall be at room temperature at the start of the test.

Equation 42.1
Calculation of temperatures of windings

$$T = \frac{R}{r}(K + t) - K$$

In which:

T = Temperature in °C

R is the resistance of the coil at the end of the test.

r is the resistance of the coil at the beginning of the test.

t is the room ambient temperature in degrees Celsius at the beginning of the test.

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

42.7 Ambient temperatures

42.7.1 The values in Table 42.1 are based on an ambient temperature of 25°C (77°F). However, a test may be conducted at any ambient temperature within the range 10 – 40°C (50 – 104°F). Each observed temperature of a coil winding shall satisfy Equation 42.2.

Equation 42.2
Correction of measured temperatures

$$T_m + (K - T_o) \leq T$$

In which:

T_m *is the measured temperature of the material or component.*

T_a *is the room ambient temperature.*

T is the temperature according to Table 42.1.

K is 25 if temperatures are measured in degrees Celsius, and 77 if measured in degrees Fahrenheit.

42.7.2 If the ambient temperature is not 25°C (77°F), and the corrected temperature exceeds the value appearing in Table 42.1, the test may be repeated at an ambient temperature closer to 25°C.

42.8 Rack mounted equipment

42.8.1 A large rack or console involving several pieces of equipment grouped in a single large enclosure is to be placed against a vertical wall constructed of heat insulating material and painted flat black.

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 460 mm (18 inches) 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, require 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 25 mm (1 inch) from the wall surface, or the equipment is to be placed as close to the wall as its construction will permit.

42.8.2 An individual piece of equipment that may 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, as specified in 42.8.1, or for portable equipment, whichever is more severe.

43 Dielectric Voltage-Withstand Test

43.1 General

43.1.1 The insulation and spacings between conductors and parts shall withstand without breakdown the application of the test potentials shown in Table 43.1 for 1 minute.

Exception: If an investigation shows that a breakdown does not result in a risk of electric shock or fire.

Table 43.1
Dielectric Voltage-Withstand Test – potentials and applications

Circuit or component	Points of application[a]	Test potentials[b]
Primary circuits		
Printed wiring portions	c, d	(2E + 1000) V dc
All parts	c, d	1000 V, 60 Hz; or 1400 V dc
Power transformers	e	1000 V, 60 Hz
Other circuits		
Power transformer supplied secondary	f	(2E + 1000) V dc
Load side of rectifier of direct connected supply	d, f	(2E + 1000) V dc
High Voltage Circuits (over 2500 V dc or peak ac)	g	(1.25E + 1750) V dc or peak ac
High voltage circuits	h	(2E + 1000) V dc

[a] Power dissipating component parts, electronic devices, and electrolytic capacitors located between the circuits under test shall be removed or disconnected so that the spacings and insulations, rather than such component parts, are subjected to the full dielectric voltage-withstand test potential. Switches and other controls, whether accessible or not, shall be set or adjusted so that all conductors and parts intended to be tested are connected to the circuit under test.

[b] E equals the maximum peak potential in volts under normal operation between the conductor or part to be tested and earth, an accessible conductive part, or other conductive part.

[c] The insulations and spacings shall be tested between primary circuit parts and the following parts all connected together:

1) The grounding terminal.

2) The enclosure, with a conductive foil wrapped around insulating portions of the enclosure.

3) Accessible conductive parts.

Table 43.1 Continued on Next Page

Table 43.1 Continued

Circuit or component	Points of application[a]	Test potentials[b]
Care should be taken to make sure that each capacitor, winding separation, or other separation (such as spacing between conductors) that isolates accessible conductive parts from the primary circuit shall be tested. [d] The insulations and spacings between parts of opposite polarity shall be tested. [e] The insulations and spacings between windings and parts of a transformer conductively connected to the supply circuit, and not complying with the Exception to 52.1 shall be tested. The windings and parts to be tested shall include each of the following: 1) Primary to shield or guard (if employed). 2) Primary to core. 3) Primary to each secondary (or all secondaries connected together). [f] Other than secondary circuits in Option A (Construction) evaluations and in primary circuits where hand soldering is involved, the insulations and spacings between parts of circuits involving the risk of electric shock or fire and each of the following shall be tested: 1) The protective grounding terminal (if provided). 2) The enclosure, with a conductive foil wrapped around insulating portions of the enclosure. 3) Accessible conductive parts. 4) All other circuits. [g] Shall operate at this potential without breakdown for 1 minute. [h] The insulation and spacings between the high voltage circuit and accessible conductive parts shall be tested unless the spacings between these parts comply with Figure 26.1 where peak kilovolts (V_1) = 2E + 1000.		

43.1.2 A d-c test voltage shall not have more than 3 percent ripple.

43.1.3 The indicated test voltage shall be measured directly across the points of application of the test potential with a high resistance voltmeter.

43.1.4 The test voltage shall be raised gradually and smoothly to the specified value so that there are no transients that may cause the instantaneous test potential applied to exceed the peak value specified.

43.1.5 If the Production-Line Dielectric Voltage-Withstand Test potential, in accordance with Tests by the Manufacturer, Section 60, exceeds 1300 V, 50 or 60 Hz, or 1840 V dc, or a time duration of more than 2 seconds, the equipment shall be subjected to the continuous application of the voltage potential that the manufacturer intends to use on the production line for a duration that is 100 times the factory-test time. There shall be no breakdown of insulation or spacings in the equipment that would result in a risk of fire or electric shock.

43.2 Breakdown

43.2.1 Breakdown is often indicated by:

a) An abrupt decrease or nonlinear advance of voltage as the test voltage is increased, or by

b) An abrupt increase in current.

44 Abnormal Operation Test

44.1 General

44.1.1 For abnormal operation tests, the equipment shall be operated according to applicable paragraphs contained in this Section.

44.2 Supply circuit fuse rating

44.2.1 The equipment shall be connected to a supply circuit fused at 30 A.

44.3 Equipment supporting surface

44.3.1 The equipment shall be placed on a white tissue paper covered softwood surface.

44.4 Cheesecloth indicator

44.4.1 A single layer of cheesecloth shall be draped loosely over the entire piece of equipment.

44.5 Fuse indicator

44.5.1 Accessible conductive parts are to be connected to earth ground through a 1-A nontime-delay type fuse.

44.6 User-removable parts

44.6.1 Parts of the equipment that are subject to removal during user servicing may be omitted if all of the following conditions apply:

a) The parts are not necessary for the functioning of the equipment.

b) The parts are not exposed to view during the operation of the equipment.

c) The parts are not captivated.

44.7 Polarization

44.7.1 The supply circuit connection shall be such that the maximum potential exists between the protective device of the equipment, if any, and the chassis.

44.8 Test duration

44.8.1 An abnormal operation test is to be conducted for 4 hours or until one or more of the following results are observed:

a) A risk of fire develops. See 44.9.1.

b) A risk of electric shock develops. See 44.9.1.

c) The branch circuit protector opens.

d) The circuit being tested opens or reacts in some manner to terminate the abnormal condition.

e) A predictable shut-down circuit terminates the abnormal condition before overheating of parts occurs.

f) A minimum of 1 hour has elapsed, circuit conditions have stabilized, and there is no further evidence of any overheating of parts.

44.8.2 Overheating of parts may be detected by such indicators as: odor, smoke, discoloration, cracking of material, charring, flaming, glowing, arcing, changes in circuit current through the applied fault, or similar phenomenon.

44.8.3 A printed wiring conductor opening cannot terminate a test. The test is to be repeated with a minimum 0.82 mm^2 (18 AWG) wire jumper across the open conductor.

44.9 Unacceptable conditions

44.9.1 An unacceptable condition is considered to exist if the test results in one or more of the following conditions:

a) The single layer of cheesecloth glows or flames.

b) The tissue paper glows or flames.

c) The 1-A fuse connected to earth ground opens.

d) An opening develops in the overall enclosure (cabinet) that does not meet the accessibility requirements in this Standard.

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

f) A dielectric breakdown as a result of the test conducted as described in Dielectric Voltage-Withstand Test, Section 43.

44.10 Circuit interruption

44.10.1 An abnormal operation test is to be conducted once. If there is evidence of overheating of parts, the test is to be repeated using new components, when necessary, and the equipment repaired to its intended operating condition.

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

45 Tests for Remote Control and Interconnecting Cables

45.1 Cable flexing test

45.1.1 A single or multiple conductor cable as described in 24.1 shall be subjected to 15000 cycles of the Flexing Test described in Section 1582 in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. This is to be followed by the 2E + 1000 V Dielectric Voltage-Withstand Test described in accordance with Dielectric Voltage-Withstand Test, Section 43, between conductors involving the risk of fire or electric shock and all other conductors, and between conductors involving the risk of fire or electric shock and foil wrapped around the cable. The results are considered acceptable if there is no dielectric breakdown.

45.2 Cable crush test

45.2.1 Three pieces of cable, each one meter in length, are to be placed between two flat, parallel, 150 mm long, steel plates of a tensile-compression tester. One plate is to close on the other at a rate of 10 ±2.5 mm per minute until a force of 454 Kgf (1000 lbf) is obtained. After removal of the force, the Dielectric

Voltage-Withstand Tests described in 45.1.1 are to be conducted. The results are considered acceptable if there is no dielectric breakdown.

46 Strain Relief Test

46.1 Power supply cord and interconnecting cable

46.1.1 The attachment of a non detachable power supply cord or non detachable interconnecting cable to the equipment that involves fire or shock energy shall be capable of withstanding a weight applied to the cord as described in 46.1.2.

46.1.2 The force shall be applied by a weight that exerts 156 N (35 lbf) or a steady pull of 16 kgf (35 lbf). With the chassis in the cabinet in the intended manner, the force shall be applied from any angle possible. One sample shall be tested with the pull applied for 60 seconds.

46.1.3 The results of the test are not acceptable if one or more of the following conditions occur:

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

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

c) Cemented-on bushings slide on the cord.

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

e) Strain is placed on internal conductors.

46.1.4 If the integrity of the strain relief means is dependent upon a polymeric material, the test shall be conducted before and after either of the temperature stability tests described in 57.5.2.1.

47 Battery and Battery Circuit Tests – Electrical

47.1 Battery overcharge test

47.1.1 A rechargeable battery provided with equipment shall be overcharged:

a) With the equipment charging circuit adjusted for the maximum charging rate, and again

b) With any single junction or part of an electronic device or electrolytic capacitor in the charging circuit either short circuited or open circuited.

47.1.2 The test conditions shall be as described in the applicable clauses of Abnormal Operation, Section 44, and, in addition, shall not result in any of the unacceptable conditions described in 48.3.1.

47.2 Battery discharge test

47.2.1 Short circuiting of the terminals of a fully charged rechargeable battery provided with the equipment shall not result in any of the unacceptable conditions described in 48.3.1.

48 Battery Tests – Mechanical

48.1 Battery drop test

48.1.1 Each of three samples of a fully charged external rechargeable battery shall be dropped three times from a height of 92 cm (3 ft) onto a hardwood floor in the position most likely to produce adverse results without producing any of the unacceptable conditions described in 48.3.1.

48.2 Battery oven test

48.2.1 A fully charged rechargeable battery that employs a polymeric case shall withstand either of the temperature stability tests described in 57.5.2.1 without producing any of the unacceptable conditions described in 48.3.1.

48.3 Battery test results

48.3.1 The tests results are considered unacceptable if one or more of the following occurs:

a) The battery case cracks.

b) Battery electrolyte leaks from the case.

c) The battery explodes.

49 Battery Supply Test

49.1 To determine the acceptability of the rating of the fuse or protective device described in 18.3.1, Battery Circuit Protection, the equipment shall be connected to the storage battery (if provided with the equipment) or a test supply of rated voltage that has a 30 A minimum capability. Using the intended connecting means provided, the equipment shall be evaluated in accordance with Test for Limited-Power Circuit, Section 51, and Power Supply Test, Section 53.

50 Vacuum Tube Filament Short Circuit Test

50.1 Any likely conditions of an internal short circuit of a vacuum tube as described in 50.2 shall not result in the risk of electric shock or fire.

50.2 Short circuits that are considered likely to occur shall be simulated by a connection between a heater terminal and a terminal of any other element of the tube such that at least one heater or a portion thereof remains in the test circuit.

50.3 The test conditions shall be as described in the applicable clauses of Abnormal Operation Test, Section 44.

51 Test for Limited-Power Circuit

51.1 A limited-power circuit is one in which the power capable of being delivered to an external resistor connected in parallel to the circuit load is not more than 240 W.

51.2 To determine circuit power capabilities as described in 51.1, the power measurement shall be made between the conductor or part in question and its associated circuit common with:

a) The equipment connected to a supply circuit of maximum rated voltage, but not less than 130 V (or 260 V), and

b) The equipment operating under reference test conditions, and

c) An external resistive load and wattmeter connected in parallel with the circuit load.

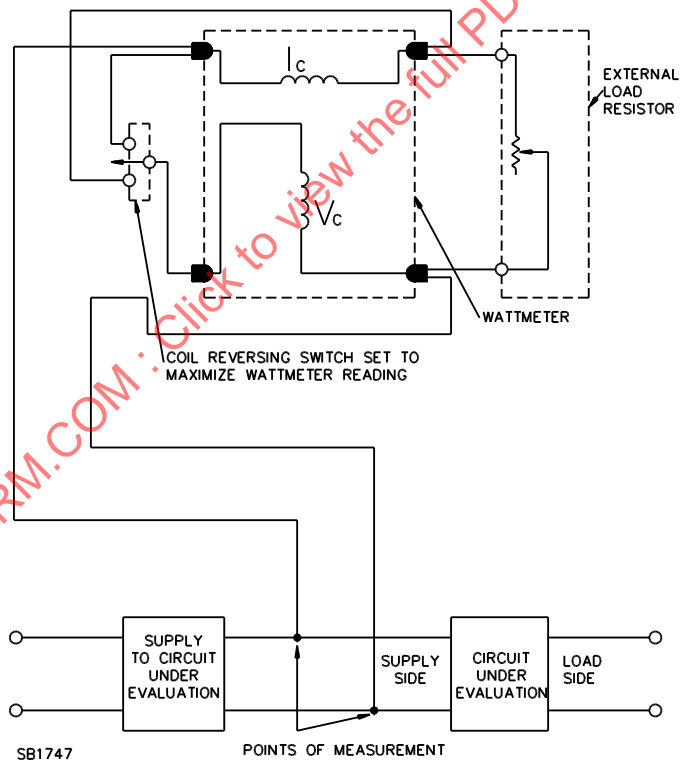
The combination of the resistive load and wattmeter is connected according to Figure 51.1. The first power measurement is to be made at the power source; subsequent measurements, if necessary, are to be made at additional points between the power source and the load(s) until the power-limited point is identified. Before energizing the equipment, the external resistor is adjusted for maximum resistance. The equipment is then to be energized and the resistor adjusted for 240 W dissipation indicated by the wattmeter. The supply side of the circuit under evaluation, at the point of measurement, is considered to be connected to a source of limited power if:

d) The supply to the circuit under evaluation cannot deliver 240 W to the external resistor; or

e) An overload protector or circuit component opens to interrupt the delivery of power to the external resistor from the supply to the circuit under evaluation prior to reaching 240 W or within 5 seconds after reaching 240 W.

Figure 51.1

Connection of wattmeter for determining a limited-power circuit



52 Transformer Short Circuit and Overload Tests

52.1 An isolating transformer connected to an unlimited-power circuit, in accordance with Test for Limited-Power Circuit, Section 51, or one conductively connected to the supply circuit shall be subjected to tests according to this Section. The other secondary windings may be connected, or not connected, as may occur in the equipment.

a) Short circuit – Each secondary winding shall be separately short circuited.

b) Overload – Each secondary winding shall be separately overloaded to maximum power. If overcurrent protection is provided, the loading shall be 110 percent of the rating of the overcurrent protective device. The overcurrent protective device shall remain in circuit for the duration of the test.

Exception No. 1: A transformer in compliance with the construction and performance requirements of the Standard for Transformer and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411 or the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1 and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

Exception No. 2: A transformer provided as part of a power supply in compliance with UL 813, UL 1012, UL 1310, UL 60950-1, UL 60065, and UL 62368-1. See also Table 6.1 note a.

52.2 The test conditions shall be as described in the applicable clauses of Abnormal Operation Test, Section 44.

53 Power Supply Test

53.1 The acceptability of the power supply circuitry of the equipment and associated component parts shall be evaluated as indicated in Table 6.1

53.2 If required by Table 6.1 the power supply of the equipment is to be investigated to determine that a risk of fire or electric shock is not produced under the conditions of short or open circuiting, singly, of any unreliable component such as a rectifier, transistor, IC, or electrolytic capacitor in a circuit that is determined not to be limited power as described in Test for Limited Power Circuit, Section 51.

53.3 In conducting the tests required in 53.2, the following connections are to be short circuited for the components:

a) Solid state rectifier – any two terminals.

b) Electrolytic capacitor – any two terminals.

c) Transistor, IC, Microprocessor– any two terminals.

53.4 To determine if the equipment complies with the test in 53.2, the test shall be conducted under the conditions described in the applicable clauses of Abnormal Operation Test, Section 44.

53.5 The Dielectric Voltage-Withstand Test described in 44.9.1 shall be conducted only after the last test on the power supply is completed.

Exception: The Dielectric Voltage-Withstand Test should also be conducted earlier if it is necessary to replace components after conducting the other tests.

54 Component Abnormal Operation Test

54.1 Equipment shall not result in a risk of fire or electric shock when operated under abnormal conditions that are possible to occur during operation of the equipment.

54.2 The test conditions are to be as described in Abnormal Operation Test, Section 44.

54.3 Malfunction of components and possible misuse of the equipment that might occur are to be simulated during the abnormal tests mentioned in 54.1. Only one fault is to be assumed at a time. Examples are:

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

b) Malfunction of fans or blowers that provide ventilation. During this test the fan or blower located in limited power circuits is to be disconnected. Fans or blowers located in unlimited power circuits shall be stalled.

c) Solenoid with plunger blocked in the deenergized (at rest) position.

55 Multiple Voltage Equipment Test

55.1 Equipment having a user adjustable supply circuit voltage selector shall have its voltage selector set in any marked supply circuit voltage position with the equipment connected to any one of the rated supply circuits. The combinations of selector settings and supply circuit to which the equipment is intended to be connected are to be that which develop the most severe operating conditions.

55.2 To determine if the equipment complies with the test in 55.1, the test is to be conducted under the conditions described in the applicable clauses of Abnormal Operation Test, Section 44.

56 Ground Printed Wiring Board (PWB) Trace Test

56.1 One sample of the product shall be subjected to the following short circuit test. The power source for the test circuit shall be calibrated to supply 200 A under short circuit conditions for a product with an input rating up to 9.8 A at 120 V, or 4.9 A at 240 V, or 1000 A under short circuit conditions for a product with an input rating more than 9.8 A at 120 V or 4.9A at 240 V. The voltage of the test circuit shall be either 130 or 260 V depending on the nominal voltage marked on the equipment. A circuit breaker with a minimum rating suitable for the product involved but no less than 20 A shall be connected in series with the grounding circuit being tested. For equipment with a detachable power supply cord, the test circuit is to be connected between the ground pin of the motor attachment cap and the PWB trace being tested. For equipment with a non-detachable power supply cord, the test circuit is to be connected in series between the ground pin of the power supply cord attachment plug cap and the PWB trace being tested. The test circuit wire size shall be equal to the power supply cord wire size and have a length of 1.5 m (60 in). Surgical cotton is to be placed outside the openings in the enclosure of the equipment. The test is concluded when the short circuit test current is interrupted.

56.2 The test results are considered unacceptable if:

a) The ground trace becomes broken or otherwise separated from the PWB,

b) There is contact between the grounding circuit and a bare live part,

c) The surgical cotton ignites, or

d) There is a dielectric breakdown as a result of the test conducted as described in Dielectric Voltage Withstand Test, Section 43.

57 Strength of Enclosure Tests

57.1 Mechanical tests – general

57.1.1 The overall enclosure and back cover of equipment shall withstand the mechanical abuse tests described in this section without resulting in any of the following: