UL 1711

ISBN 0-7629-1282-0

Amplifiers for Fire Protective Signaling Systems

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062-2096

UL Standard for Safety for Amplifiers for Fire Protective Signaling Systems, UL 1711

Fourth Edition, Dated December 28, 2006

Summary of Topics

This new edition of UL 1711 is being issued through UL's electronic publishing system to ensure format uniformity between the PDF and HTML versions of the document. While numbering and figure placement, where appropriate, may have been updated, no substantive changes have been incorporated in the document.

The UL Foreword is no longer located within the UL Standard. For information concerning the use and application of the requirements contained in this Standard, the current version of the UL Foreword is located on ULStandardsInfoNet at: http://ulstandardsinfonet.ul.com/ulforeword.html

The master for this Standard at UL's Northbrook Office is the official document insofar as it relates to a UL service and the compliance of a product with respect to the requirements for that product and service, or if there are questions regarding the accuracy of this Standard.

Revisions of UL Standards for Safety are issued from time to time. A UL Standard for Safety is current only if it incorporates the most recently adopted revisions.

UL will attempt to answer support requests concerning electronic versions of its Standards. However, this support service is offered on a reasonable efforts basis only, and UL may not be able to resolve every support request. UL supports the electronic versions of its Standards only if they are used under the conditions and operating systems for which it is intended. UL's support policies may change from time-to-time without notification.

UL reserves the right to change the format, presentation, file types and formats, delivery methods and formats, and the like of both its printed and electronic Standards without prior notice.

Purchasers of the electronic versions of UL's Standards for Safety agree to defend, indemnify, and hold UL harmless from and against any loss, expense, liability, damage, claim, or judgement (including reasonable attorney's fees) resulting from any error or deviation introduced while purchaser is storing an electronic Standard on the purchaser's computer system.

If a single-user version electronic Standard was purchased, one copy of this Standard may be stored on the hard disk of a single personal computer, or on a single LAN file-server or the permanent storage device of a multiple-user computer in such a manner that this Standard may only be accessed by one user at a time and for which there is no possibility of multiple concurrent access.

If a multiple-user version electronic Standard was purchased, one copy of the Standard may be stored on a single LAN file-server, or on the permanent storage device of a multiple-user computer, or on an Intranet server. The number of concurrent users shall not exceed the number of users authorized.

Electronic Standards are intended for on-line use, such as for viewing the requirements of a Standard, conducting a word search, and the like. Only one copy of the Standard may be printed from each single-user version of an electronic Standard. Only one copy of the Standard may be printed for each authorized user of a multiple-user version of an electronic Standard. Because of differences in the computer/software/printer setup used by UL and those of electronic Standards purchasers, the printed copy obtained by a purchaser may not look exactly like the on-line screen view or the printed Standard.

An employee of an organization purchasing a UL Standard can make a copy of the page or pages being viewed for their own fair and/or practical internal use.

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

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing, Recognition and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

This Standard consists of pages dated as shown in the following checklist:

Page	Date
1-64	December 28, 2006
A1-A2	December 28, 2006

UL 1711

Standard for Amplifiers for Fire Protective Signaling Systems

First Edition – January, 1987
Second Edition – August, 1994
Third Edition – February, 1999

Fourth Edition

December 28, 2006

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at http://csds.ul.com.

ISBN 0-7629-1282-0

No Text on This Page

CONTENTS

INTRODUCTION

1 Scope 6
2 General 7
2.1 Components 7
2.2 Units of measurement 7
2.3 Undated references 7
3 Glossary 8

INSTRUCTIONS AND DRAWINGS

4 General 8

CONSTRUCTION

ASSEMBLY

5 General 9
6 Protection of Service Personnel 9
7 Electrical Supervision 10
8 Enclosures 10
8.1 General 10
8.2 Openings 11
8.3 Cast metal 14
8.4 Sheet metal 15
8.5 Nonmetallic 17
8.6 Doors and covers 18
8.7 Screens and expanded metal 19
9 Electric Shock 19
9.1 Shock current 19
9.2 Antenna terminals 19
9.3 Circuit element replacement 20
10 Protection Against Corrosion 20

FIELD-WIRING CONNECTIONS

11 General 21
12 Field-Wiring Compartment 21
13 Power-Limited Circuits 21
14 Field-Wiring Terminals 22
14.1 General 22
14.2 General application 22
15 Leads 24
16 Cords and Plugs 24
17 Grounding 25

INTERNAL WIRING AND ASSEMBLY

18 General 26
19 Separation of Circuits 27
20 Bonding for Grounding 27

COMPONENTS – ELECTRICAL

21 General 29
21.1 Mounting of components 29
21.2 Insulating materials 29
21.3 Current-carrying parts 30
21.4 Bushings 30
22 Overcurrent Protection 31
23 Semiconductors 31
24 Switches 31
25 Transformers and Relays 32
26 Printed-Wiring Boards 32
27 Spacings 32

OPERATING COMPONENTS

28 General 34

PERFORMANCE

29 Test Samples 34
30 Test Voltages 35
31 Waveform Analysis Test 35
32 Power Input/Output Characteristics Tests 36
33 Variable Voltage Operation Test 36
34 Electrical Supervision Tests 36
35 Harmonic Distortion Test 37
35.1 Crossover 37
35.2 Total harmonic 37
36 Variable Ambient Temperature Test 37
37 Humidity Test 38
38 Electric Shock Current Test 38
39 Leakage Current Test 42
40 Temperature Test 45
41 Overload Test 48
42 Endurance Test 48
43 Burnout Test 48
44 Component Failure Test 49
45 Abnormal Operation Test 49
46 Transient Tests 50
46.1 General 50
46.2 Supply line transients 50
47 Mechanical Strength Tests 52
47.1 Jarring test – complete product 52
47.2 Impact test – glass parts 53
48 Strain Relief Tests 54
48.1 Flexible cords 54

48.2 Field-wiring leads 54
49 Radio-Frequency Rejection Test 54
50 Power-Limited Circuits 55
50.1 General 55
50.2 Maximum voltage 57
50.3 Maximum current 57
50.4 VA_{max} (not inherently limited circuits only) 58
51 Polymeric Materials Tests 58
52 Dielectric Voltage-Withstand Test 58

MANUFACTURING AND PRODUCTION TESTS

53 General 59
54 Production-Line Dielectric Voltage-Withstand Test 59
55 Production-Line Grounding Continuity Test 60

MARKING

56 General 61
57 Permanence of Marking 63

ACCESSORY EQUIPMENT

58 General 63
59 Construction 63
60 Performance (Installation) Test 64
61 Marking 64

APPENDIX A

Standards for Components A1

INTRODUCTION

1 Scope

1.1 These requirements cover electrically- and electronically-operated amplifiers that provide speech communication and distinctive sounds in conjunction with fire protective signaling systems for indoor location in accordance with the following standards:

a) National Electrical Code, NFPA 70.

b) National Fire Alarm Code, NFPA 72.

1.2 These requirements do not cover amplifiers for use in hazardous locations, as defined in the National Electrical Code, NFPA 70.

1.3 These requirements do not cover commercial equipment for institutional and industrial use or theater equipment. Commercial sound equipment is covered by the Standard for Commercial Audio Equipment, UL 813.

1.4 These requirements do not cover signal generating or processing equipment, such as tone generators, tape decks, microphones, and the like.

1.5 These requirements do not include determination of compliance with regulations of the Federal Communications Commission (FCC). Should products covered by these requirements be required to comply with FCC regulations, a report of verification from the manufacturer is required as evidence of such compliance.

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

2 General

2.1 Components

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

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

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

b) Is superseded by a requirement in this standard.

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

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

2.2 Units of measurement

2.2.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

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

2.3 Undated references

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

3 Glossary

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

3.2 CIRCUITS, ELECTRICAL:

a) High-Voltage – A circuit involving a potential of not more than 300 volts and having circuit characteristics in excess of those of a low-voltage circuit.

b) Low-Voltage – A circuit involving a potential of not more than 30 volts alternating current (AC) rms, 42.4 volts direct current (DC) or AC peak.

c) Power-Limited Circuit – A circuit wherein the power is limited in accordance with Power-Limited Circuits, Section 50.

3.3 FIELD-WIRING TERMINALS – Those terminals to which power supply (including equipment grounding) or control connections will be made in the field when the product is installed as intended.

3.4 OPERATOR – A person who may manipulate the control or amplification functions of a product but does not have access to portions of the product required for servicing and maintenance.

3.5 POWER, EVACUATE – Rated output power for a square wave signal used for evacuation purposes.

3.6 POWER, SPEECH – Rated output power while delivering audio frequency signals over the rated frequency band within the constraints of the distortion limits specified in this standard. Audio frequency signals are considered to be within the 15-hertz to 15-kilohertz frequency range.

3.7 PRODUCT – Any type of amplifier covered by these requirements.

3.8 RADIO FREQUENCY – All frequencies above 20 kilohertz.

INSTRUCTIONS AND DRAWINGS

4 General

4.1 Each product shall be provided with installation instructions and drawings that shall include the following information:

a) Typical installation drawing layouts and complete representative installation wiring diagram for the product indicating recommended locations and wiring methods. The recommended locations and methods shall be in accordance with the National Electrical Code, ANSI/NFPA 70.

b) A concise description of the operation, testing, and proper maintenance procedures for the product. The frequency of testing shall be in accordance with the requirements of the authorities having jurisdiction.

c) Identification of replacement parts, such as lamps or batteries, by a part number, manufacturer's model number, or the equivalent.

d) Typical installation wiring diagrams showing the interconnection of the product in a manner verifying electrical supervision in a complete system. See 4.3 for interconnection diagram specifications.

4.2 The instructions may be incorporated on the inside of the product, on a separate sheet, or as part of a manual. If not included directly on the product, the instructions or manual shall be referenced in the marking information on the product.

4.3 With reference to 7.1, the interconnection diagram that includes speakers and amplifiers interconnected as part of a fire protective signaling system is to be reviewed to verify that electrical supervision is provided for the amplifier and speaker circuits. The interconnection diagram shall be included with the installation wiring diagram or operating instructions, or both, furnished by the manufacturer, and shall indicate connections required for supervision.

CONSTRUCTION

ASSEMBLY

5 General

5.1 Unless specifically indicated otherwise, the construction requirements specified for a product also apply to any remote accessories with which it is to be used.

5.2 If provision is made for testing the operability of a product, the means provided shall not involve a risk of electric shock or injury to persons.

5.3 A test means shall be constructed and located so as to reduce the likelihood of tampering by unauthorized personnel.

6 Protection of Service Personnel

6.1 An uninsulated live part of a high-voltage circuit within the enclosure shall be located, guarded, or enclosed to reduce the likelihood of unintentional contact by persons performing service functions that may be performed while the equipment is energized.

6.2 During the examination of a product in connection with the requirements of 6.1, a part of the outer enclosure that may be removed without the use of tools, or part of the outer enclosure that may be removed by the user to allow access for making intended operating adjustments, is to be disregarded; it will not be assumed that the part in question affords protection against electric shock.

6.3 An electrical component requiring examination, replacement, adjustment, servicing, or maintenance while the product is energized shall be located and mounted with regard to other components and grounded metal so that it is accessible for such service without subjecting the service person to a risk of electric shock from adjacent uninsulated high-voltage live parts.

6.4 The following are not considered to be uninsulated live parts:

a) Coils of relays and solenoids, and transformer windings, if the coils and windings are provided with insulating overwraps rated for the potentials involved;

b) Terminals and splices having insulation rated for the potential involved; and

c) Insulated wire.

6.5 If the linear distance from a component requiring servicing to an uninsulated high-voltage live part is less than 6 inches (152 mm), the part shall be protected by insulating tape, barriers, or the equivalent.

Exception: A product need not comply with this requirement if either:

a) An interlock is provided on the cover that de-energizes all live parts in the enclosure when the cover is removed or

b) The cover is marked in accordance with 56.9.

7 Electrical Supervision

7.1 An amplifier shall be provided with means for interconnection into a system of electrical supervision that will provide an audible trouble signal in the event of an open circuit in the input or output circuits of the amplifier or other malfunction (including internal malfunction of tone generators, preamplifiers, and amplifiers resulting in loss of their intended output or reduction of performance below the level required by this standard) that will impair intended signaling operation. See 4.3 for interconnection diagram specifications.

8 Enclosures

8.1 General

8.1.1 The frame and enclosure of a product shall have the strength and rigidity to resist total or partial collapse with attendant reduction of spacings, loosening or displacement of parts, and development of other conditions that could impair operation of the product and result in a risk of fire, electric shock, or injury to persons.

8.1.2 Uninsulated high-voltage live parts of a product shall be located or enclosed to provide protection from unintentional contact.

8.1.3 An operating part, such as a gear mechanism, a light-duty relay, or similar device, shall be enclosed to protect against malfunction from dust or other foreign material that may impair the intended operation.

8.1.4 The mounting means of an enclosure shall be accessible without disassembly of any operating part of the product. Removal of a completely assembled panel to mount the enclosure is not considered to be disassembly of an operating part.

8.1.5 A material used within an enclosure shall be classified V-2 or HF-2, or less flammable, in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception No. 1: A motor, relay, capacitor, semiconductor, transformer, switch, insulating tubing or tape, or other electrical element need not comply with this requirement if it complies with the flame test applicable to the component.

Exception No. 2: A meter face and case (if intended for mounting live parts) and indicator lamp or jewel need not comply with this requirement.

Exception No. 3: The material used to form a gear, cam, belt, bearing, strain-relief bushing applied over a PVC-jacketed cord, or other small part that contributes negligible fuel to a fire need not be investigated, if the part is isolated from uninsulated electrical parts that are not power limited either by at least 0.5 inch (12.5 mm) of air, or a solid barrier of material classified V-2 or less flammable.

Exception No. 4: Tubing for air or fluid systems, and foamed plastic, need only be classified HB or HBF, if the tubing or foamed plastic is isolated from uninsulated electrical parts that are not power limited either by at least 0.5 inch (12.5 mm) of air, or a solid barrier of material classified V-2 or less flammable.

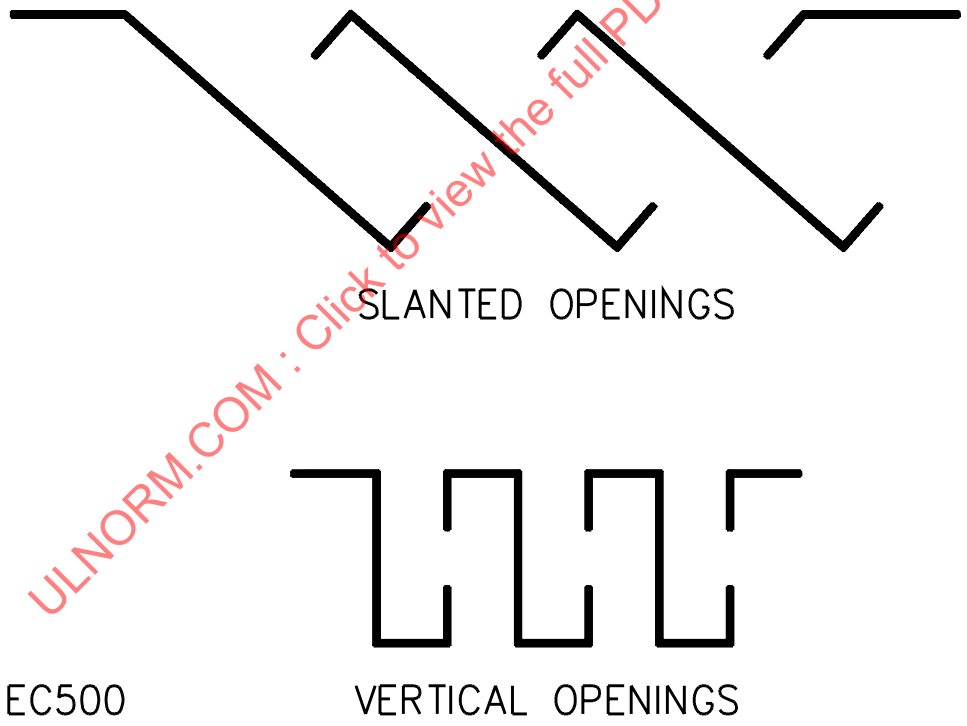
8.1.6 If an amplifier is not intended to be installed in a separate cabinet that has provision for connection to a Class I wiring system, as defined by the National Electrical Code, ANSI/NFPA 70, the enclosure of the amplifier shall have provision for connection to a Class I wiring system.

8.2 Openings

8.2.1 An opening in the top of the enclosure shall be sized and constructed so as to reduce the likelihood of entry of foreign objects.

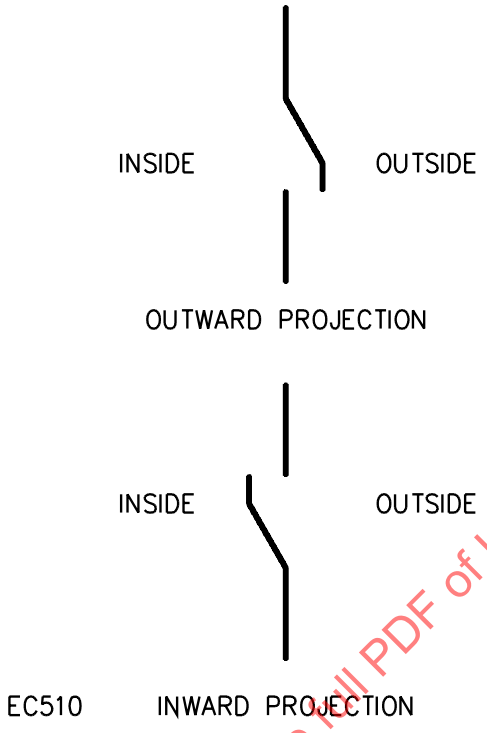
8.2.2 To comply with the requirements in 8.2.1, an opening directly over an uninsulated live part shall not exceed 0.187 inch (4.75 mm) in any dimension unless the configuration of the opening prevents direct entry to uninsulated high-voltage live parts. See Figure 8.1 for examples of top cover constructions which may be used.

Figure 8.1
Cross sections of top cover designs



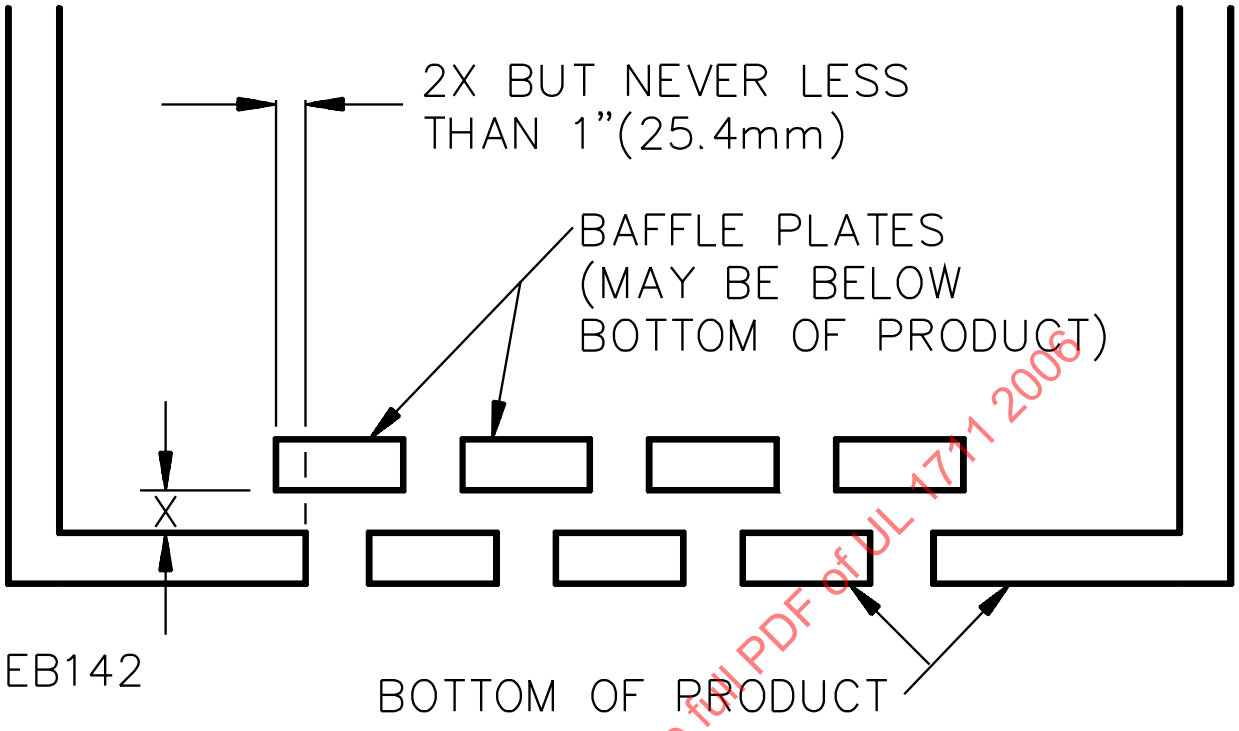
8.2.3 An opening in the side of the enclosure shall be sized and located so as to reduce the likelihood of entry of a foreign object, and contact by persons with internal parts. A louver may be used if shaped to deflect external falling objects outward. See Figure 8.2 for examples of louver constructions which may be used.

Figure 8.2
Louvers



8.2.4 Openings shall not be provided in the bottom panels or protective pans under areas containing materials not classified V-1 or less flammable, in accordance with the Standard for Tests for Flammability of Plastic Material for Use in Devices and Appliances, UL 94, unless constructed in a manner that prevents materials from falling directly from the interior of the product onto the supporting surface or onto any other location under the product. Figure 8.3 illustrates a type of baffle that complies with this requirement. A second construction that complies with this requirement is a 0.040-inch (1.02-mm) thick sheet steel bottom panel in which round holes of 5/64 inch (2.0 mm) maximum diameter are spaced not closer together than 1/8 inch (3.2 mm) center-to-center. See the Burnout Test, Section 43, and the Abnormal Operation Test, Section 45.

Figure 8.3
Bottom panel baffles



8.2.5 The bottom of the enclosure under areas containing only materials classified V-1 or less flammable, in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, may have openings not larger than 1/16 square inch (40 mm^2).

8.2.6 Openings may be used, without limitation on the size or number, in areas that contain only PVC, TFE, CTFE, FEP, and neoprene-insulated wire cable, and plugs and receptacles.

8.2.7 An opening in the enclosure shall not permit access to a relay, terminal, control, or related component that might be subject to tampering.

8.2.8 An enclosure intended for recessed mounting and having a front panel that is intended to be flush with the surface of the wall shall not have:

a) Nonfunctional openings nor

b) Openings that vent into concealed spaces of a building structure, such as into hollow spaces in the wall,

when the product is mounted as intended.

Exception: The requirement in (b) does not apply to an opening for a mounting screw or nail or for a manufacturing operation (such as paint drainage), if:

a) The opening has no dimension greater than 17/64 inch (6.75 mm) or an area greater than 0.055 square inch (35.5 mm^2) and

b) There is not more than one mounting screw hole for each 12 inches (305 mm) of length of mounting surface, or fraction thereof.

8.3 Cast metal

8.3.1 The thickness of cast metal for an enclosure shall be at least the applicable value specified in Table 8.1.

Exception: Cast metal of lesser thickness may be used if, consideration being given to the shape, size, and function of the enclosure, it is determined to provide equivalent mechanical strength.

Table 8.1
Cast-metal electrical enclosures

Use, or dimensions of area involved[a]	Minimum thickness			
	Die-cast metal,		Cast metal of other than the die-cast type,	
	inch	(mm)	inch	(mm)
Area of 24 square inches (154 cm^2) or less and having no dimension greater than 6 inches (152 mm)	1/16	1.6	1/8	3.2
Area greater than 24 square inches or having any dimension greater than 6 inches	3/32	2.4	1/8	3.2
At a threaded conduit hole	1/4	6.4	1/4	6.4
At an unthreaded conduit hole	1/8	3.2	1/8	3.2

[a] The area limitation for metal 1/16 inch (1.6 mm) thick may be obtained by the provision of reinforcing ribs subdividing a larger area.

8.3.2 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, there shall not be less than 3-1/2 nor more than five threads in the metal, and the construction shall be such that a standard conduit bushing can be attached as intended.

8.3.3 If threads for the connection of conduit are tapped only part of the way through a hole in an enclosure wall, there shall not be less than 3-1/2 full threads in the metal, and there shall be a smooth, rounded inlet hole that affords protection to the conductors that is determined to be equivalent to that provided by a standard conduit bushing.

8.3.4 A product intended to be supported by rigid conduit shall be provided with conduit hubs or the equivalent having not less than five full threads.

8.4 Sheet metal

8.4.1 The thickness of sheet metal employed for the enclosure of a product shall not be less than the applicable value specified in Table 8.2 or 8.3.

Exception: Sheet metal of lesser thickness may be used if, consideration being given to the shape, size, and function of the enclosure, it is determined to provide equivalent mechanical strength.

Table 8.2
Minimum thickness of sheet metal for electrical enclosures carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness			
Maximum width,[b]		Maximum length,[c]		Maximum Width,[b]		Maximum length,		Uncoated,		Metal coated,	
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inches (mm) [MSG]		inches (mm) [GSG]	
4.0	10.2	Not limited		6.25	15.9	Not limited		0.020	(0.51)	0.023	(0.58)
4.75	12.1	5.75	14.6	6.75	17.1	8.25	21.0	[24]		[24]	
6.0	15.2	Not limited		9.5	24.1	Not limited		0.026	(0.66)	0.029	(0.74)
7.0	17.8	8.75	22.2	10.0	25.4	12.5	31.8	[22]		[22]	
8.0	20.3	Not limited		12.0	30.5	Not limited		0.032	(0.81)	0.034	(0.86)
9.0	22.9	11.5	29.2	13.0	33.0	16.0	40.6	[20]		[20]	
12.5	31.8	Not limited		19.5	49.5	Not limited		0.042	(1.07)	0.045	(1.14)
14.0	35.6	18.0	45.7	21.0	53.3	25.0	63.5	[18]		[18]	
18.0	45.7	Not limited		27.0	68.6	Not limited		0.053	(1.35)	0.056	(1.42)
20.0	50.8	25.0	63.5	29.0	73.7	36.0	91.4	[16]		[16]	
22.0	55.9	Not limited		33.0	83.8	Not limited		0.060	(1.52)	0.063	(1.60)
25.0	63.5	31.0	78.7	35.0	88.9	43.0	109.2	[15]		[15]	
25.0	63.5	Not limited		39.0	99.1	Not limited		0.067	(1.70)	0.070	(1.78)
29.0	73.7	36.0	91.4	41.0	104.1	51.0	129.5	[14]		[14]	
33.0	83.8	Not limited		51.0	129.5	Not limited		0.080	(2.03)	0.084	(2.13)
38.0	96.5	47.0	119.4	54.0	137.2	66.0	167.6	[13]		[13]	
42.0	106.7	Not limited		64.0	162.6	Not limited		0.093	(2.36)	0.097	(2.46)
47.0	119.4	59.0	149.9	68.0	172.7	84.0	213.4	[12]		[12]	
52.0	132.1	Not limited		80.0	203.2	Not limited		0.108	(2.74)	0.111	(2.82)
60.0	152.4	74.0	188.0	84.0	213.4	103.0	261.6	[11]		[11]	
63.0	160.0	Not limited		97.0	246.4	Not limited		0.123	(3.12)	0.126	(3.20)
73.0	185.4	90.0	228.6	103.0	261.6	127.0	322.6	[10]		[10]	

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments which may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

1) A single sheet with single formed flanges (formed edges),
2) A single sheet which is corrugated or ribbed, and
3) An enclosure surface loosely attached to a frame, for example, with spring clips.

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

Table 8.2 Continued on Next Page

Table 8.2 Continued

Without supporting frame[a]		With supporting frame or equivalent reinforcing[a]		Minimum thickness	
Maximum width,[b] inches (cm)	Maximum length,[c] inches (cm)	Maximum Width,[b] inches (cm)	Maximum length, inches (cm)	Uncoated, inches (mm) [MSG]	Metal coated, inches (mm) [GSG]

[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

Table 8.3
Minimum thickness of sheet metal for electrical enclosures aluminum, copper, or brass

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness,	
Maximum width,[b] inches	(cm)	Maximum length,[c] inches	(cm)	Maximum width,[b] inches	(cm)	Maximum length, inches	(cm)	inches	(mm)
3.0	7.6	Not limited		7.0	17.8	Not limited		0.023	0.58
3.5	8.9	4.0	10.2	8.5	21.6	9.5	24.1		
4.0	10.2	Not limited		10.0	25.4	Not limited		0.029	0.74
5.0	12.7	6.0	15.2	10.5	26.7	13.5	34.3		
6.0	15.2	Not limited		14.0	35.6	Not limited		0.036	0.91
6.5	16.5	8.0	20.3	15.0	38.1	18.0	45.7		
8.0	20.3	Not limited		19.0	48.3	Not limited		0.045	1.14
9.5	24.1	11.5	29.2	21.0	53.3	25.0	63.5		
12.0	30.5	Not limited		28.0	71.1	Not limited		0.058	1.47
14.0	35.6	16.0	40.6	30.0	76.2	37.0	94.0		
18.0	45.7	Not limited		42.0	106.7	Not limited		0.075	1.91
20.0	50.8	25.0	63.4	45.0	114.3	55.0	139.7		
25.0	63.5	Not limited		60.0	152.4	Not limited		0.095	2.41
29.0	73.7	36.0	91.4	64.0	162.6	78.0	198.1		
37.0	94.0	Not limited		87.0	221.0	Not limited		0.122	3.10
42.0	106.7	53.0	134.6	93.0	236.2	114.0	289.6		
52.0	132.1	Not limited		123.0	312.4	Not limited		0.153	3.89
60.0	152.4	74.0	188.0	130.0	330.2	160.0	406.4		

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments which may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure which is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

1) A single sheet with single formed flanges (formed edges),
2) A single sheet which is corrugated or ribbed, and
3) An enclosure surface loosely attached to a frame, for example, with spring clips.

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

Table 8.3 Continued on Next Page

Table 8.3 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness,	
Maximum width,[b] inches	(cm)	Maximum length,[c] inches	(cm)	Maximum width,[b] inches	(cm)	Maximum length, inches	(cm)	inches	(mm)
[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.									

8.4.2 A hole larger than 1-3/8 inch (34.9 mm) diameter shall have a closure at least as thick as the enclosure of the product or shall have a standard knockout seal. Such plates or plugs shall be securely mounted.

8.4.3 A knockout in a sheet metal enclosure shall be reliably secured, but removal of the knockout shall not result in undue deformation of the enclosure.

8.4.4 A knockout shall be provided with a surrounding surface area of sufficient size to permit seating of a conduit bushing, and shall be located so that a bushing employed at any knockout likely to be used during installation will not reduce spacings between uninsulated live parts and the bushing to values less than those specified in Spacings, Section 27.

8.4.5 A sheet metal member to which a wiring system is to be connected in the field shall not be less than:

a) 0.032 inch (0.81 mm) thick if uncoated steel;

b) 0.034 inch (0.86 mm) thick if galvanized steel, and

c) 0.045 inch (1.14 mm) thick if nonferrous metal.

8.5 Nonmetallic

8.5.1 An enclosure or part of an enclosure of nonmetallic material shall have sufficient mechanical strength and durability and shall be formed so that operating parts will be protected against damage. The mechanical strength of the enclosure shall be at least equivalent to a sheet metal enclosure of the minimum thickness specified in Table 8.2.

8.5.2 Among the factors to be taken into consideration when determining the use of a nonmetallic enclosure or parts are:

a) Flammability;

b) Mechanical strength;

c) Resistance to impact;

d) Moisture absorptive properties;

e) Dielectric strength, insulation resistance, resistance to arc tracking; and

f) Resistance to distortion at temperatures to which the material may be subjected under conditions of anticipated use.

All these factors are to be considered with regard to aging. See the Polymeric Materials Tests, Section 51.

8.5.3 A wooden enclosure shall:

a) Be solid or laminated wood,

b) Be at least 3/8 inch (9.5 mm) thick,

c) Have no edge exposed to internal electrical parts, and

d) Be spaced at least 1/2 inch (12.7 mm) from live or arcing parts and potential sources of ignition.

All electrical parts shall be mounted to a chassis having a metal liner at least 0.010 inch (0.25 mm) thick. The liner shall completely cover the bottom of the enclosure. All high-voltage circuits and nonpower-limited low-voltage circuits shall be completely enclosed by metal not less than 0.010 inch thick.

8.6 Doors and covers

8.6.1 An enclosure cover shall be hinged, sliding, or similarly attached to prevent its being removed if it:

a) Gives access to a fuse or to any other overcurrent protective device, the intended functioning of which requires renewal or

b) Is necessary to open the cover in connection with the intended operation of the product.

Exception: A tamper switch may be used in lieu of a hinged cover, provided only an overcurrent protective device is enclosed.

8.6.2 Fasteners requiring the use of a tool or key shall be used for an enclosure if access is not required for intended operation of the product.

8.7 Screens and expanded metal

8.7.1 A screen and expanded metal used as a guard, enclosure, or part of an enclosure shall comply with the requirements in 8.7.2 and 8.7.3.

8.7.2 Perforated sheet steel and sheet steel used for expanded metal mesh shall not be less than 0.042 inch (1.07 mm) thick [0.045 inch (1.17 mm) if zinc coated] if the mesh openings or perforations are 1/2 square inch (323 mm^2) or less in area, and shall not be less than 0.080 inch (2.03 mm) thick [0.084 inch (2.13 mm) if zinc coated] for larger openings. The largest dimension shall not exceed 4 inches (102 mm).

Exception: If the indentation of a guard or the enclosure will not alter the clearance between uninsulated live parts and grounded metal so as to impair intended operation of the product or reduce spacings below the minimum required values (see Spacings, Section 27), 0.020 inch (0.53 mm) expanded metal mesh or perforated sheet metal [0.023 inch (0.58 mm) if zinc coated] may be used, if:

a) The exposed mesh on any one side or surface of the product so protected has an area of not more than 72 square inches (464 cm^2) and has no dimension greater than 12 inches (305 mm) or

b) The width of a protected opening is not greater than 3-1/2 inches (89 mm).

8.7.3 The wires of a screen shall not be smaller than No. 16 AWG (1.3 mm^2) if the area of the screen openings is 1/2 square inch (323 mm^2) or less, and shall not be smaller than No. 12 AWG (2.1 mm^2) for larger screen openings.

9 Electric Shock

9.1 Shock current

9.1.1 Any part that is exposed only during operator servicing shall not present a risk of electric shock. See the Electric Shock Current Test, Section 38.

9.2 Antenna terminals

9.2.1 Each terminal provided for the connection of an external antenna shall be conductively connected to the supply circuit grounded conductor. The conductive connection shall:

a) Have a maximum resistance of 5.2 megohms,

b) Have a minimum wattage rating of 1/2 watt, and

c) Be effective with the power switch in either the on or off position.

Exception: The conductive connection need not be provided if:

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

b) The breakdown does not result in a risk of electric shock, and

c) In a construction using an isolating power transformer, the resistance of the conductive connection between the supply circuit and chassis does not exceed 5.2 megohms.

9.2.2 The maximum value of 5.2 megohms mentioned in 9.2.1 is to include the maximum tolerance of the resistor value used; that is, a resistor rated 4.2 megohms with 20 percent tolerance or a resistor rated 4.7 megohms with a 10 percent tolerance may be used. A component comprised of a capacitor with a built-in shunt resistor that complies with the requirements for antenna isolating capacitors may be rated a minimum of 1/4 watt.

9.3 Circuit element replacement

9.3.1 The insertion in any socket of any vacuum tube, semiconductor, or similar replaceable circuit element shall not result in a risk of electric shock.

10 Protection Against Corrosion

10.1 An iron or steel part shall be protected against corrosion by enameling, galvanizing, sherardizing, plating, or other equivalent means.

Exception No. 1: This requirement does not apply where such protection is impracticable, such as on a bearing or similar part.

Exception No. 2: This requirement does not apply to a part such as a washer, screw, bolt, or the like, if corrosion of the unprotected part would not be likely to result in a risk of fire or electric shock or in unintentional contact with moving parts that may involve a risk of injury to persons.

Exception No. 3: A part made of stainless steel, polished or treated, if necessary, does not require additional protection against corrosion.

10.2 The requirement in 10.1 applies to an enclosure of sheet steel or cast iron and to a spring or other part upon which intended mechanical operation may depend.

10.3 Bearing surfaces shall be of materials and construction that resist binding due to corrosion.

10.4 Metals shall be used in combinations that are galvanically compatible.

10.5 A cabinet or enclosure of corrosion-resistant material may be used without additional corrosion protection.

FIELD-WIRING CONNECTIONS

11 General

11.1 A product shall be provided with wiring terminals or leads for connection of conductors of at least the size required by the National Electrical Code, ANSI/NFPA 70, corresponding to the electrical rating of the product.

12 Field-Wiring Compartment

12.1 The field-wiring compartment to which connections are to be made shall be of sufficient size for completing all wiring connections specified by the installation wiring diagram.

12.2 Wiring intended for mounting in an outlet box shall be located or protected so that, upon installation, the wiring in the outlet box is not forced against the terminals or other sharp edges that can damage the conductor insulation.

12.3 An outlet box or compartment in which field-wiring connections are to be made shall be located such that the connections may be inspected after the product is installed as intended. The removal of mounting screws, or equivalent arrangement, to view the field-wiring connections may be performed.

13 Power-Limited Circuits

13.1 When the design of the product is such that the product either requires or permits power-limited fire alarm circuit conductors to occupy the same enclosure as electric light, power, Class 1, or non-power-limited fire alarm circuit conductors, both of the following conditions shall be met:

a) The enclosure shall provide:

1) A minimum of two cable openings into the enclosure; or

2) When a single opening is provided, a continuous and firmly fixed nonconductor, such as flexible tubing,

so that the power-limited fire conductors are segregated from electric light, power, Class 1, and non-power-limited fire alarm conductors. The installation document of the product shall completely detail cable entry routing of all conductors into the product.

b) The product shall be constructed so that, with all field-installed wiring connected to the product, either:

1) A minimum 6.4 mm (1/4 inch) separation is provided between all power-limited fire alarm conductors and all electric light, power, Class 1, or non-power-limited fire alarm conductors; or

2) For circuit conductors operating at 150 volts or less to ground and for power-limited fire alarm conductors that are installed using Types FPL, FPLR or FPLP cables, a minimum 6.4 mm (1/4 inch) separation is provided between cable conductors extending beyond the jacket and all electric light, power, and non-power-limited fire alarm conductors.

c) Compliance with the requirement of (b) is to be achieved either by:

1) Specific wire routing configurations that are detailed in the installation document; or

2) Using barriers or nonconductive sleeving to provide separation when a wire routing scheme does not maintain the required spacing.

14 Field-Wiring Terminals

14.1 General

14.1.1 A field-wiring terminal shall be prevented from turning or shifting in position. This may be accomplished by means such as:

a) Two screws or rivets;

b) Square shoulders or mortises;

c) A dowel pin, lug, or offset; or

d) A connecting strap or clip fitted into an adjacent part.

Friction between surfaces may not be used for preventing movement of the terminal.

14.2 General application

14.2.1 A nonferrous soldering lug or solderless (pressure) wire connector shall be used for No. 8 AWG (8.4 mm^2) and larger wire. If the connector or lug is secured to a plate, the plate shall not be less than 0.050 inch (1.3 mm) thick. A securing screw may be of plated steel.

14.2.2 A wire-binding screw intended for field-wiring connections shall not be smaller than No. 8 (4.2 mm diameter). The screw may be of plated steel.

Exception: A No. 6 (3.5 mm diameter) screw may be used for the connection of one No. 14 AWG (2.1 mm^2) or smaller conductor, and a No. 4 (2.8 mm diameter) screw may be used for the connection of a No. 19 AWG (0.65 mm^2) or smaller conductor.

14.2.3 A terminal plate tapped for wire-binding screws shall:

a) Have not less than two full threads in the metal (the terminal plate metal may be extruded to provide the two full threads) and shall have upturned lugs, clamps, or the equivalent to hold the wires in position. Other constructions may be used if they are determined to provide equivalent security of the wire-binding screw threads.

b) Be of a nonferrous metal not less than 0.050 inch (1.3 mm) thick for a No. 8 (4.2 mm diameter) or larger screw, and not less than 0.030 inch (0.76 mm) thick for a No. 6 (3.5 mm diameter) screw.

14.2.4 If two or more conductors are intended to be connected by wrapping under the same screw, a nonferrous intervening metal washer shall be used for each additional conductor. A separator washer is not required if two conductors are separated and intended to be secured under a common clamping plate. If the wires protrude above terminal barriers, the nonferrous separator shall include means, such as upturned tabs or sides, to retain the wire.

14.2.5 Any of the following terminal configurations may be used on all circuits to which field-wiring connections are made, within the limitations specified in 14.2.6:

a) Quick-Connect Terminals – Nonferrous quick connect (push type) terminals consisting of male posts permanently secured to the product and provided with compatible female connectors for connection to field wiring. Such terminals require a specific tool for crimping of field wires. Mating terminals shall be shipped with the product with instructions for their installation.

b) Push-In Terminals – Nonferrous (screwless) push-in terminals of the type used on some switches and receptacles. Solid conductors are pushed into slots containing spring-type contacts. The leads can be removed by means of a tool inserted to relieve the spring tension on the conductor. Push-in terminals shall not be used with aluminum conductors, and a marking adjacent to the terminal shall indicate that only copper conductors are to be used.

c) Wire-Wrapped Terminals – Terminals of copper or brass having at least two sharp edges, and requiring a specific connection tool and terminal post design.

d) Other Terminals – Other terminal connections and materials may be used if determined to be equivalent to those specified in (a), (b), or (c) and limited to the same restrictions.

14.2.6 A product using a terminal of any of the configurations described in 14.2.5 shall comply with all of the following:

a) If a specific tool is required for connection, its use shall be indicated on the installation wiring diagram by name of manufacturer and model number or equivalent.

b) The range of wire sizes shall be indicated on the installation wiring diagram. The minimum permissible wire size to be used shall not be smaller than No. 18 AWG (0.82 mm^2).

c) The wire size to be used shall be intended for the current-carrying capacity of the circuit application.

15 Leads

15.1 A lead provided for field connections shall be:

a) Not less than 6 inches (152 mm) long,

b) Provided with strain relief, and

c) Not smaller than No. 18 AWG (0.82 mm^2).

The insulation, if of rubber or thermoplastic, shall not be less than 1/32 inch (0.8 mm) thick.

Exception: A lead may be less than 6 inches (152 mm) long if it is evident that the use of a longer lead may result in damage to the insulation.

16 Cords and Plugs

16.1 A product intended for installation in an overall enclosure and that has provision for connection to line voltage may be provided with a supply cord not greater than 6 feet (1.8 m) long, having a three-prong attachment plug with a current rating intended for the supply circuit to which the product is to be connected.

16.2 The supply cord shall be a Type S, SE, ST, SJ, SJE, SJO, SJT, SPE, or SVE, or a type having at least an equivalent service rating to a cord within the referenced service category. The cord shall be a minimum of No. 18 AWG (0.82 mm^2) and rated for use at the voltage and current rating of the product.

16.3 The power supply cord shall be provided with strain relief so that a stress on the cord will not be transmitted to terminals, splices, or internal wiring. See the Strain Relief Tests, Section 48.

16.4 If a knot in a flexible cord serves as strain relief, a surface against which the knot may come in contact shall be free from projections, sharp edges, burrs, fins, and the like, that may cause abrasion of the insulation on the conductors.

16.5 A clamp of any material (metal or otherwise) may be used without varnished-cloth insulating tubing or the equivalent under the clamp unless such tubing or the equivalent is necessary to prevent the clamp from damaging the cord or supply leads.

16.6 Means shall be provided to prevent the supply cord from being pushed into the product through the cord-entry hole if such displacement is likely to:

a) Subject the cord to mechanical damage or to exposure to a temperature higher than that for which the cord is intended,

b) Reduce spacings (such as to a metal strain-relief clamp) below the minimum intended values, or

c) Damage internal connections or components.

17 Grounding

17.1 For a product intended to be connected to a grounded circuit, one terminal or lead shall be identified for the connection of the grounded conductor. The identified terminal or lead shall be the one that is connected to the screw shells of lampholders and to which no primary overcurrent-protective devices of the single-pole type are connected.

17.2 A terminal intended for the connection of a grounded supply conductor shall be of, or plated with, metal that is white in color and distinguishable from the other terminals; or identification of the terminal shall be clearly shown in some other manner, such as on an attached wiring diagram. A lead intended for the connection of a grounded power-supply conductor shall be finished to show a white or natural gray color and shall be readily distinguishable from the other leads.

17.3 The following circuits of an amplifier shall have provision for equipment-grounding under the indicated conditions:

a) AC circuits less than 50 volts:

1) If supplied by a transformer, the supply system of which exceeds 150 volts to ground.

2) If supplied by a transformer, the supply system of which is ungrounded.

3) If installed as overhead conductors outside of buildings.

b) AC circuits of 50 volts and over:

1) If the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts.

2) If the system is nominally rated 240/120 volt, 3-phase, 4-wire in which the midpoint of one phase is used as a circuit conductor.

c) DC circuits operating at 51 – 300 volts, except for power-limited circuits [see 3.2(c)].

17.4 The following may be used as means for equipment-grounding:

a) For a product intended to be permanently connected by a metal-enclosed wiring system, a knockout or equivalent opening in the metal enclosure.

b) For a product intended to be connected by a nonmetal-enclosed wiring system, such as nonmetallic-sheathed cable or multiple-conductor cord, an equipment-grounding terminal or lead.

17.5 A wire-binding screw intended for the connection of an equipment-grounding conductor shall have a green colored head that is hexagonal, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be plainly marked ″G,″ ″GR,″ ″GROUND,″ ″GROUNDING,″ or the like, or by a marking on a wiring diagram provided on the product. The wire-binding screw or pressure wire connector shall be secured to the frame or enclosure of the product and shall be located so that it is unlikely to be removed during servicing of the product.

17.6 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. No other lead shall be so identified.

17.7 If a multiple-conductor cord is used, the insulation of the equipment-grounding conductor shall be green, with or without one or more yellow stripes. The equipment-grounding conductor shall be secured to the equipment-grounding terminal or lead at the enclosure and to the grounding blade or equivalent contacting member of an attachment plug. In no case shall a green-identified conductor of a cord be used as a circuit conductor. Ordinary solder alone shall not be used for securing the equipment-grounding conductor.

INTERNAL WIRING AND ASSEMBLY

18 General

18.1 Internal wiring shall have insulation rated for the potential involved and the temperature to which it may be subjected.

18.2 A lead or a cable assembly connected to a part mounted on a hinged cover shall be of sufficient length to permit the full opening of the cover without applying stress to the leads or their connections. The leads shall be secured or equivalently arranged to reduce the likelihood of the insulation and jamming of the leads between parts of the enclosure.

18.3 Insulation, such as coated fabric and extruded tubing, shall be intended for the temperature or other environmental conditions to which it may be subjected in the use of the product.

18.4 A wireway shall be smooth and free from sharp edges, burrs, fins, moving parts, and the like, that may cause abrasion of conductor insulation.

18.5 A splice or connection shall be mechanically secure and bonded electrically.

18.6 A stranded conductor clamped under a wire-binding screw or similar part shall have the individual strands soldered together or equivalently arranged.

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

19 Separation of Circuits

19.1 Internal wiring of circuits that operate at different potentials shall be separated by barriers, clamps, routing, or other equivalent means, unless all conductors are provided with insulation rated for the highest potential involved.

19.2 A metal barrier used to provide separation between the wiring of different circuits shall have a thickness at least equal to the applicable minimum value specified in Table 8.2. A barrier of insulation material shall not be less than 0.028 inch (0.71 mm) thick and shall be of greater thickness if its deformation may be readily accomplished so as to defeat its purpose. Any clearance between the edge of a barrier and a compartment wall shall not be more than 1/16 inch (1.6 mm).

20 Bonding for Grounding

20.1 An exposed dead metal part that could become energized shall be bonded to the point of connection of the equipment-grounding terminal or lead, and to the metal surrounding the knockout, hole, or bushing provided for field power-supply connections.

20.2 An uninsulated dead metal part of a cabinet, electrical enclosure, motor frame, or mounting bracket, capacitor, or other electrical component shall be bonded for equipment-grounding if the part may be contacted by the user or by service personnel when servicing the product.

Exception No. 1: An adhesive-attached metal-foil marking, screw, handle, or the like, that is located on the outside of enclosures or cabinets and isolated from electrical components or wiring by grounded metal parts so that it is not likely to become energized, need not be bonded.

Exception No. 2: An isolated metal part, such as a relay frame or armature, assembly screw, or the like, that is separated from both wiring and uninsulated live metal parts need not be bonded.

Exception No. 3: A panel or cover that does not enclose uninsulated live parts need not be bonded if wiring is separated from the panel or cover so that it is not likely to become energized.

Exception No. 4: A panel or cover need not be bonded if it is insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 1/32 inch (0.8 mm) thick and secured in place.

20.3 A bonding means shall comply with the requirements for an electrical conductor. If of ferrous metal, it shall be protected against corrosion by painting, plating, or the equivalent. A separate bonding conductor shall be installed so that it is protected from mechanical damage.

20.4 The bonding shall be by a positive means, such as by clamping, riveting, bolted or screwed connection, brazing, or welding. The bonding connection shall penetrate nonconductive coatings such as paint. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.

20.5 A bolted or screwed connection that incorporates a star washer or serrations under the screwhead may be used for penetrating nonconductive coatings as required in 20.4.

20.6 If the bonding means depends upon screw threads, either two or more screws or two full threads of a single screw engaging metal may be used.

20.7 A metal-to-metal hinge-bearing member for a door or cover may be used as a means for bonding the door or cover for grounding, if a multiple bearing-pin type (piano-type) hinge is used.

20.8 The size of a copper or aluminum conductor used to bond an electrical enclosure or motor frame shall be based on the rating of the branch-circuit overcurrent device by which the product will be protected. The size of the conductor shall be as specified in Table 20.1.

Table 20.1
Bonding wire conductor size

Rating of overcurrent device, amperes	Size of bonding conductor[a]			
	Copper wire,		Aluminum wire,	
	AWG	(mm^2)	AWG	(mm^2)
15	14	2.1	12	3.3
20	12	3.3	10	5.3
30	10	5.3	8	8.4
40	10	5.3	8	8.4
60	10	5.3	8	8.4
100	8	8.4	6	13.3
200	6	13.3	4	21.2

[a] Or equivalent cross-sectional area.

20.9 A conductor, such as a clamp or strap, may be used in place of a separate wire conductor if the minimum cross-sectional conducting area of the bonding means is not less than that of the wire specified in Table 20.1.

20.10 A splice shall not be used in wire conductor used for bonding.

20.11 The electrical continuity of the bonding system of a product shall not rely on the dimensional integrity of nonmetallic material.

COMPONENTS – ELECTRICAL

21 General

21.1 Mounting of components

21.1.1 A stationary part that supports a moving component shall be securely mounted in position and prevented from loosening or turning by means other than friction between surfaces.

21.1.2 An uninsulated live part shall be secured to the base or mounting surface so that the part will be prevented from turning or shifting in position, if such motion may result in a reduction of spacings below the required minimum values. See Spacings, Section 27.

21.1.3 Friction between surfaces may not be used as a means to prevent turning, loosening, or shifting of a part as required in 21.1.1 and 21.1.2, but a toothed-lock washer that provides both spring take-up and an interference lock or equivalent means may be used.

21.2 Insulating materials

21.2.1 A base for the support of live parts shall be noncombustible, moisture-resistant insulating material, such as porcelain, phenolic, or cold-molded composition, or the equivalent.

21.2.2 Among the factors to be considered in evaluating electrical insulation are:

a) Mechanical and electrical strength;

b) Resistance to burning, moisture, arcing, and creep (flow due to stress); and

c) Thermal endurance at temperatures encountered in intended use.

See the Polymeric Materials Tests, Section 51.

21.2.3 A base mounted on a metal surface shall be provided with an insulating barrier between the mounting surface and all live parts on the underside of the base that are not staked, upset, sealed, or equivalently prevented from loosening so as to prevent such parts and the ends of replaceable terminal screws from coming in contact with the supporting surface.

21.2.4 Vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not for the sole support of live parts if shrinkage, current leakage, or warping of the fiber may result in a risk of fire or electric shock.

21.2.5 A countersunk sealed live part shall be covered with a waterproof insulating compound that will not melt at a temperature 15°C (27°F) higher than the maximum normal operating temperature of the assembly, and at not less than 65°C (149°F) in any case. The depth or thickness of sealing compound shall not be less than 1/8 inch (3.2 mm).

21.2.6 The thickness of a flat sheet of insulating material, such as phenolic composition, or the equivalent, used for panel-mounting of parts, shall not be less than the applicable value specified in Table 21.1.

Table 21.1
Thickness of flat sheets of insulating material

Maximum dimensions				Minimum thickness,[a]	
Length or width,		Area,			
inches	(cm)	inches^2	(cm^2)	inch	(mm)
24	60.9	360	2322	3/8	9.5
48	122.0	1152	7432	1/2	12.7
48	122.0	1728	11,148	5/8	15.9
over 48	122.0	over 1728	11,148	3/4	19.1

[a] Material less than 3/8 inch (9.5 mm) but not less than 1/8 inch (3.2 mm) in thickness may be employed for a panel if the panel is adequately supported or reinforced to provide rigidity not less than that of a 3/8 inch sheet. Material less than 3/16 inch (4.8 mm) may be employed for subassemblies, such as supports for terminals for internal wiring, resistors, and other components.

21.2.7 A small conforming-shaped insulating cover, such as might be secured over an exposed transistor or other small component, the omission of which may result in a risk of electric shock to the user or service personnel, shall be secured to the component so that it is not likely to be discarded during intended use or servicing, and shall comply with the following:

a) Its removal shall be required only during servicing or replacement of the component it covers and

b) It shall not be essential to the intended functioning of the product.

21.3 Current-carrying parts

21.3.1 A current-carrying part shall be of silver, copper, copper-alloy, or equivalent.

21.3.2 A bearing, hinge, or the like shall not be used as a current-carrying part.

21.4 Bushings

21.4.1 A hole in a wall or partition through which insulated wires or flexible cords pass and on which they may bear shall have smooth, rounded surfaces to prevent abrasion of the insulation. A bushing, if used, shall be ceramic, phenolic or cold-molded composition, fiber, or other equivalent material. Polymeric material shall not be clamped so as to cause cold-flow of the material that could result in a risk of fire or electric shock.

21.4.2 If a hole through which a wire or cord passes is of phenolic composition or other nonconducting material, a smooth, rounded surface is considered to be the equivalent of a bushing.

21.4.3 Ceramic materials and some molded compositions may be used for insulating bushings, but bushings of wood and of hot-molded shellac shall not be used.

21.4.4 Vulcanized fiber may be used where it will not be subjected to a temperature higher than 90°C (194°F) under intended operating conditions, if the bushing:

a) Is not less than 3/64 inch (1.2 mm) thick and

b) Will not be exposed to moisture.

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

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

22 Overcurrent Protection

22.1 The rating of a primary circuit breaker or fuse, if provided, shall not be less than 150 percent of the maximum input to the product.

23 Semiconductors

23.1 A semiconductor shall be rated for the intended application under all environmental conditions to which it may be exposed in service.

24 Switches

24.1 A switch provided as part of the product shall have a current and voltage rating not less than that of the circuit it controls when the product is operated under any condition of intended service. If the circuit controlled has a power factor less than 75 percent, the switch shall have:

a) A horsepower rating (evaluated on the basis of the ampere equivalent) or

b) A current rating of not less than 200 percent of the maximum load current.

25 Transformers and Relays

25.1 A branch-circuit-supply voltage transformer shall be of the two-coil or insulated type.

Exception: An autotransformer may be used if the terminal or lead common to both input and output circuits is identified for connection to a grounded conductor and the output circuits are located within the enclosure containing the autotransformer. See 17.1 for terminal or lead identification specifications.

25.2 A coil shall be treated with a film-coating, and baked or otherwise impregnated to exclude moisture.

25.3 Film-coated or equivalently coated wire is not required to be given additional treatment to prevent moisture absorption.

26 Printed-Wiring Boards

26.1 A printed-wiring board shall comply with the applicable requirements in the Standard for Printed-Wiring Boards, UL 796. The securing of components to the board shall be made in the intended manner and the spacings between circuits shall comply with the requirements in Spacings, Section 27. The board shall be securely mounted so that deflection of the board during servicing will not result in damage to the board or in a risk of fire or electric shock.

26.2 A printed-wiring board shall comply with the flammability requirements in 8.1.5.

27 Spacings

27.1 The spacings between an uninsulated live part and:

a) A wall or cover of a metal enclosure,

b) A fitting for conduit or metal-clad cable, and

c) A metal piece attached to a metal enclosure, where deformation of the enclosure is likely to reduce spacings,

shall not be less than the applicable value specified in Table 27.1.

Table 27.1
Minimum spacings

Point of application	Voltage range, volts	Minimum spacings through-air,		Minimum spacings over-surface,	
		inch[a]	(mm)	inch[a]	(mm)
To walls of enclosure					
Cast metal enclosures	0 – 300	1/4	6.4	1/4	6.4
Sheet metal enclosures	0 – 50	1/4	6.4	1/4	6.4
	51 – 300	1/2	12.7	1/2	12.7
Installation wiring terminals (general application)[a]					
With barriers	0 – 30	1/8	3.2	3/16	4.8
	31 – 150	1/8	3.2	1/4	6.4
	151 – 300	1/4	6.4	3/8	9.5
Without barriers	0 – 30	3/16	4.8	3/16	4.8
	31 – 150	1/4	6.4	1/4	6.4
	151 – 300	3/8	9.5	3/8	9.5
Rigidly clamped assemblies[b]					
100 volt-amperes maximum	0 – 30	1/32[c]	0.8	1/32[c]	0.8
Over 100 volt-amperes	0 – 30	3/64	1.2	3/64	1.2
	31 – 150	1/16	1.6	1/16	1.6
	151 – 300	3/32	2.4	3/32	2.4
Other parts	0 – 30	1/16	1.6	11/8	3.2
	31 – 150	1/8	3.2	1/4	6.4
	151 – 300	1/4	6.4	3/8	9.5

[a] Measurements are to be made with solid wire of adequate ampacity for the applied load connected to each terminal. In no case is the wire to be smaller than No. 18 AWG (0.82 mm^2).

[b] Rigidly clamped assemblies include such parts as contact springs on relays or cam switches, printed-wiring boards, and the like.

[c] Spacings less than those indicated, but not less than 1/64 inch (0.4 mm), are acceptable for the connection of integrated circuits and similar components where the spacing between adjacent connecting wires on the component is less than 1/32 inch (0.8 mm).

27.2 The spacings between an uninsulated live part and:

a) An uninsulated live part of opposite polarity,

b) An uninsulated grounded part other than the enclosure, and

c) An exposed dead metal part that is isolated (insulated),

shall not be less than the applicable value specified in Table 27.1. See also 27.4 and 27.6.

27.3 If a short-circuit between uninsulated live parts of the same polarity would prevent the intended signaling operation of the product without simultaneously producing an alarm or emergency signal, the spacings between such parts shall not be less than the applicable value specified for ″Other parts″ in Table 27.1.

27.4 The spacings within a snap switch, lampholder, or similar device supplied as part of a product are evaluated under other requirements for such devices and need not comply with the requirements in Table 27.1.

27.5 Film-coated wire is considered an uninsulated live part in determining compliance with spacing requirements, but a film coating may be used as turn-to-turn insulation in coils.

27.6 Minimum values of spacings are not specified for a socket or similar related component part, such as a potentiometer and the like, used in an electronic circuit. However, if the spacings in such a component do not comply with the requirements in 27.2 – 27.5, the circuit shall comply with the requirements of the Dielectric Voltage-Withstand Test, Section 52.

27.7 An insulating liner or barrier of vulcanized fiber, varnished cloth, mica, phenolic composition, or similar material used where spacings would otherwise be insufficient, shall not be less than 0.028 inch (0.7 mm) thick.

Exception: A liner or barrier not less than 0.013 inch (0.3 mm) thick may be used in conjunction with an air spacing of not less than one-half of the through-air spacing required, if the liner is located so that it will not be subjected to the direct effects of arcing.

OPERATING COMPONENTS

28 General

28.1 A cam or similar part shall be securely fastened to prevent independent turning or loosening.

28.2 A moving part shall have sufficient play at bearing surfaces to prevent binding.

28.3 An adjusting screw or similar adjustable part shall be prevented from loosening under the conditions of intended use.

28.4 Interrelated operating parts shall be formed and assembled so that their alignment will be maintained under all conditions of intended use.

PERFORMANCE

29 Test Samples

29.1 Samples that are fully representative of production are to be used for each of the following tests unless otherwise specified.

29.2 The loads used for the following tests are to be those specified by the wiring diagram of the product. However, substitute loads may be used if they produce functions and conditions equivalent to those obtained with the loads intended to be used in service.

29.3 If a product is intended to be mounted in a specified position in order to function as intended, it is to be tested in that position.

29.4 Installation and operating instructions (see 4.1 and 4.2) are to be provided for use as a guide in testing. In addition, the following number of samples are to be provided for testing:

a) Two complete amplifiers of each rating and

b) One or more of each encapsulated or sealed assembly used in a product, prior to sealing.

30 Test Voltages

30.1 Unless specifically noted otherwise, the test voltage for each test of a product is to be as specified in Table 30.1, at rated frequency.

Table 30.1
Test voltages

Nameplate voltage rating	Test voltage
110 to 120	120
220 to 240	240
Other	Marked nameplate rating
NOTE – Products rated at frequencies other than 60 hertz are to be tested at their rated nameplate voltage and frequency.	

31 Waveform Analysis Test

31.1 Amplifier output is to be analyzed for distortion as specified in 31.2 and 31.3 when the test requirements specify performance of a waveform analysis.

31.2 A pure sine-wave signal, with rated amplitude as specified by the manufacturer, is to be introduced into the input of an amplifier. The input and resulting output signals are to be registered on a dual-trace oscilloscope. The input signal is to sweep between 800 and 2800 hertz, or the frequency range specified by the manufacturer.

31.3 Frequency sweep is to be arrested at 50-hertz intervals and at any frequency at which marked distortion is observed. The fixed-frequency pattern is then to be compared to distortion limits displayed on the oscilloscope screen. The limits are to be shown as two sine curves, each in phase with the input signal, and each having the same amplitude as the input signal, but with their horizontal axes vertically displaced so that the positive peak amplitude of one is 110 percent of the input wave positive peak amplitude and the positive peak amplitude of the other is 90 percent of the input wave positive peak.

31.4 If any part of the output-signal curve extends beyond the 10-percent distortion limits, amplifier distortion is to be evaluated at the frequency at which questionable distortion occurs, in compliance with the requirements of the Harmonic Distortion Test, Section 35.

32 Power Input/Output Characteristics Tests

32.1 The power input to an amplifier shall not exceed 110 percent of the marked rating while delivering rated output power to the specified load or a resistive load of equivalent magnitude.

32.2 An amplifier shall deliver rated output power and voltage to a rated load when a sinusoidal signal of minimum rated input voltage and having a frequency of 1 kilohertz is applied to the input circuit of the amplifier while the amplifier is connected to a source of rated voltage.

32.3 An amplifier shall deliver not less than 60 nor more than 120 percent of rated output power (80 – 110 percent of rated output voltage) over an 800 – 2800 hertz bandwidth. The input signal is to be at rated voltage and is to be constant over the range of signal frequencies, as established at a test signal frequency of 1 kilohertz.

32.4 If the manufacturer specifies a bandwidth for the product that includes frequencies lower than 800 or higher than 2800 hertz, the product shall comply with the requirement of 32.3 over these additional frequency ranges.

32.5 For these tests, all operator-accessible gain controls are to be adjusted to impose worst case (maximum distortion) operating conditions on the system with regard to output (power) to the load.

33 Variable Voltage Operation Test

33.1 An amplifier shall deliver not less than 60 percent nor more than 170 percent of its rated output power (80 – 130 percent of rated output voltage) when the power-supply input voltage is varied between 85 and 110 percent of the rated voltage. The 1 kilohertz signal described in 32.2 is not to be adjusted.

33.2 When the power-supply input voltage is established at 85 percent and 110 percent of the rated voltage, the 1 kilohertz signal described in 32.2 is to be varied, as needed, so that the rated output voltage is delivered to the load. The amplifier shall comply with the requirement of the Waveform Analysis Test, Section 31, at 85 percent and 110 percent of rated voltage.

34 Electrical Supervision Tests

34.1 An open fault in any field wiring connection (each connection tested separately) shall either have no effect on system operation or shall be annunciated by an audible signal.

34.2 A ground fault on any field wiring connection (each connection tested separately) shall have no effect on system operation.

35 Harmonic Distortion Test

35.1 Crossover

35.1.1 The crossover distortion of an amplifier rated for speech power shall not be greater than 7 percent, when measured at 1/10 power points (10 decibels down from rated power output) at a signal frequency of 1000 hertz. Measurements of crossover distortion are to be made over the rated frequency range of the amplifier.

35.1.2 During the measurement of crossover distortion, the amplifier is to be tested using a sine wave input and while delivering to a rated load consisting of speakers or any combination of speakers and simulated resistive loading of equivalent impedance.

35.2 Total harmonic

35.2.1 If an upper frequency cutoff is not specified, the total harmonic distortion of an amplifier shall not exceed 20 percent in the frequency range of 800 – 2800 hertz while delivering full rated load and operating as specified in 35.1.2.

35.2.2 If the specified upper frequency cutoff is greater than 2800 hertz, the total harmonic distortion of an amplifier shall not exceed 20 percent in the frequency range of 800 – 2800 hertz. In the range of 2800 – 15000 hertz, the total harmonic distortion at any frequency (f) shall not exceed the value determined by the formula:

$$\text{Percent Total Harmonic Distortion} = 20e^{[\,-0.000189\ (f-2800)\,]}$$

35.2.3 During the measurements of total harmonic distortion specified in 35.2.1 and 35.2.2, a minimum of ten measurements are to be made within the appropriate frequency range with the amplifier adjusted to deliver maximum rated output and 10 decibels below the maximum rated output.

36 Variable Ambient Temperature Test

36.1 An amplifier shall operate as intended following exposure for 3 hours to air at temperatures of 0°C (32°F) and at 49°C (120°F).

36.2 Immediately following exposure to each of the temperatures specified in 36.1, the product shall comply with the requirements of the Waveform Analysis Test, Section 31, at the maximum and minimum frequencies of the bandwidth.

37 Humidity Test

37.1 An amplifier shall operate as intended during and after exposure for 24 hours to air having a relative humidity of 85 percent at a temperature of 30 ±2°C (86 ±3°F).

37.2 Immediately following exposure to the humid environment, the product shall comply with the requirements in the Waveform Analysis Test, Section 31, at the maximum and minimum frequencies of the bandwidth.

38 Electric Shock Current Test

38.1 If the open circuit potential between any part that is exposed only during operator servicing and either:

a) Earth ground or

b) Any other exposed accessible part

exceeds 42.4 volts peak, the part shall comply with the requirements of 38.2 – 38.4, as applicable.

38.2 The continuous current flow through a 500-ohm resistor shall not exceed the values specified in Table 38.1 when the resistor is connected between any part that is exposed only during operator servicing and either:

a) Earth ground or

b) Any other exposed accessible part.

Table 38.1
Maximum current during operator servicing

Frequency, hertz[a]	Maximum current through a 500-ohm resistor, milliamperes peak
0 – 100	7.1
500	9.4
1000	11.0
2000	14.1
3000	17.3
4000	19.6
5000	22.0
6000	25.1
7000 or more	27.5

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

38.3 The duration of a transient current flowing through a 500-ohm resistor connected as described in 38.2 shall not exceed:

a) The value determined by the following equation:

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

in which:

T is the interval, in seconds, between the time that the instantaneous value of the current first exceeds 7.1 milliamperes and the time that the current falls below 7.1 milliamperes for the last time; and

I is the peak current in milliamperes, and

b) 809 milliamperes, regardless of duration.

The interval between occurrences shall be equal to or greater than 60 seconds if the current is repetitive. Typical calculated values of maximum transient current duration are shown in Table 38.2.

Table 38.2
Maximum transient current duration

Maximum peak current (I) through 500-ohm resistor, milliamperes	Maximum duration (T) of waveform containing excursions greater than 7.1 milliamperes peak
7.1	7.26 seconds
8.5	5.58
10.0	4.42
12.5	3.21
15.0	2.48
17.5	1.99
20.0	1.64
22.5	1.39
25.0	1.19
30.0	919 milliseconds
40.0	609
50.0	443
60.0	341
70.0	274
80.0	226
90.0	191
100.0	164
150.0	92
200.0	61
250.0	44
300.0	34
350.0	27
400.0	23
450.0	19
500.0	16
600.0	12

Table 38.2 Continued on Next Page

Table 38.2 Continued

Maximum peak current (I) through 500-ohm resistor, milliamperes	Maximum duration (T) of waveform containing excursions greater than 7.1 milliamperes peak
700.0	10
809.0	8.3

38.4 The maximum capacitance between the terminals of a capacitor that is accessible during operator servicing shall comply with the following equations:

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

$$C = 33{,}288E^{1.5364} \text{ for } 400 \leq E \leq 1000$$

in which:

C is the maximum capacitance of the capacitor in microfarads, and

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

E is to be measured 5 seconds after the capacitor terminals are made accessible, such as by the removal or opening of an interlocked cover, or the like. Typical calculated values of maximum capacitance are shown in Table 38.3.

Table 38.3
Electric shock – stored energy

Potential in volts, across capacitance prior to discharge	Maximum capacitance in microfarads
1000	0.868
900	1.02
800	1.22
700	1.50
600	1.90
500	2.52
400	3.55
380	3.86
360	4.22
340	4.64
320	5.13
300	5.71
280	6.40
260	7.24
240	8.27
220	9.56
200	11.2

Table 38.3 Continued on Next Page

Table 38.3 Continued

Potential in volts, across capacitance prior to discharge	Maximum capacitance in microfarads
180	13.4
160	16.3
140	20.5
120	26.6
100	36.5
90	43.8
80	53.8
70	68.0
60	89.4
50	124.0
45	150.0
42.4	169.0

38.5 With reference to the requirements of 38.2 and 38.3, the current is to be measured while the resistor is connected between ground and:

a) Each accessible part individually and

b) All accessible parts collectively if the parts are simultaneously accessible.

The current also is to be measured while the resistor is connected between one part or group of parts and another part or group of parts, if the parts are simultaneously accessible.

38.6 With reference to the requirements of 38.5, 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 to be considered to be able to contact parts simultaneously if the parts are within a 4 by 8 inch (102 by 203 mm) rectangle; and two hands of a person are considered to be able to contact parts simultaneously if the parts are not more than 6 feet (1.8 m) apart.

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

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

38.9 Current measurements are to be made:

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

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

These measurements are to be made with controls placed in the position that causes maximum current flow.

39 Leakage Current Test

39.1 If the open circuit potential is greater than 42.4 volts peak as measured between any accessible part and:

a) Earth ground or

b) Any other accessible part,

the leakage current at any accessible part shall not be more than the following values tested in accordance with 39.2 – 39.8:

1) 0.5 milliampere for an ungrounded (2-wire) portable, stationary, or fixed product;

2) 0.5 milliampere for a grounded (3-wire) portable product; and

3) 0.75 milliampere for a grounded (3-wire) stationary or fixed product.

Exception: If an electromagnetic radiation suppression filter is necessary for the product to function as intended, the leakage current may be not more than 2.5 milliamperes if the product complies with the following conditions:

a) The product is provided with grounding means in accordance with the applicable requirements for a cord connected product in Bonding for Grounding, Section 20;

b) With the filter removed from the product, the leakage current does not exceed the limits specified in (1) and (2), as applicable; and

c) The product is marked in accordance with 56.13.

39.2 With reference to the requirements of 39.1, leakage current refers to all currents, including capacitively coupled currents, that may be conveyed between exposed conductive surfaces of the equipment and ground, or between exposed conductive surfaces of the equipment.

39.3 Leakage currents from all exposed surfaces are to be measured to the grounded supply conductor individually as well as collectively where exposed surfaces are simultaneously accessible, and from one surface to another where simultaneously accessible (see 38.6). A part is considered to be an exposed surface unless it is guarded by an enclosure considered to protect against the risk of electric shock.

39.4 With reference to 39.3, if all accessible surfaces are bonded together and connected to the grounding conductor of the power-supply cord, the leakage current may be measured between the grounding conductor and the grounded supply conductor. If exposed dead metal parts of a product are connected to the neutral supply conductor, this connection is to be open during the measurement.

39.5 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using a metal foil with an area of 4 by 8 inches (10 by 20 cm) in contact with the surface. If the surface is less than 4 by 8 inches, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the product.

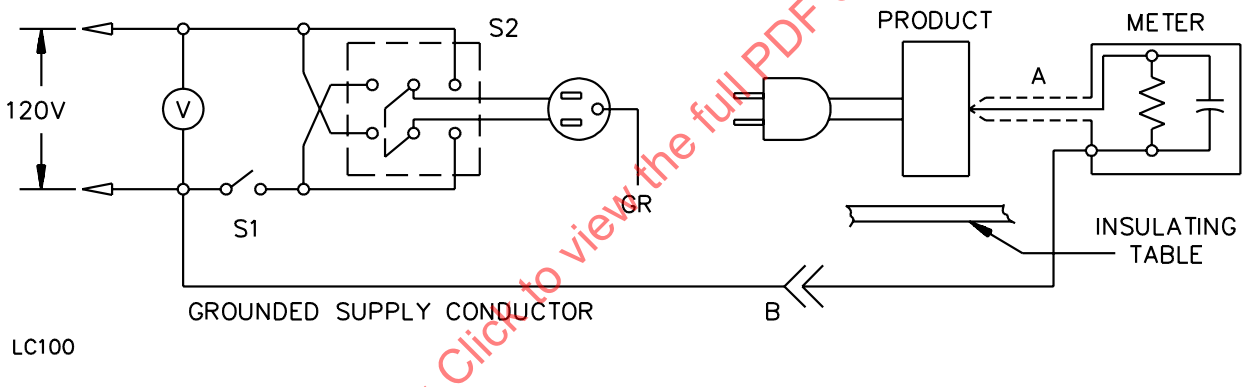
39.6 The measurement circuit for the leakage current test is to be as illustrated in Figure 39.1. The measurement instrument is defined in (a) – (c). The meter used for a measurement need only indicate the same numerical value for the particular measurement as would the defined instrument; it need not have all of the attributes of the defined instrument.

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

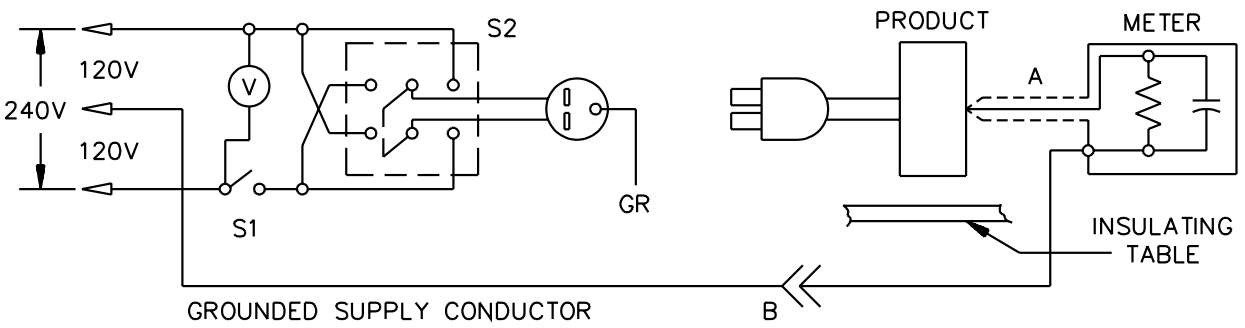
b) The meter is to indicate 1.11 times the average of the full wave rectified composite waveform of voltage across the resistor or current through the resistor.

c) Over a frequency range of 0 – 100 kilohertz, the measurement circuitry is to have a frequency response (ratio of indicated to actual value of current) that is equal to the ratio of the impedance of a 1500-ohm resistor shunted by a 0.15 microfarad capacitor to 1500 ohms. At an indication of 0.5 or 0.75 milliampere, the measurement is to have an error of not more than 5 percent at 60 hertz.

Figure 39.1
Leakage-current measurement circuits



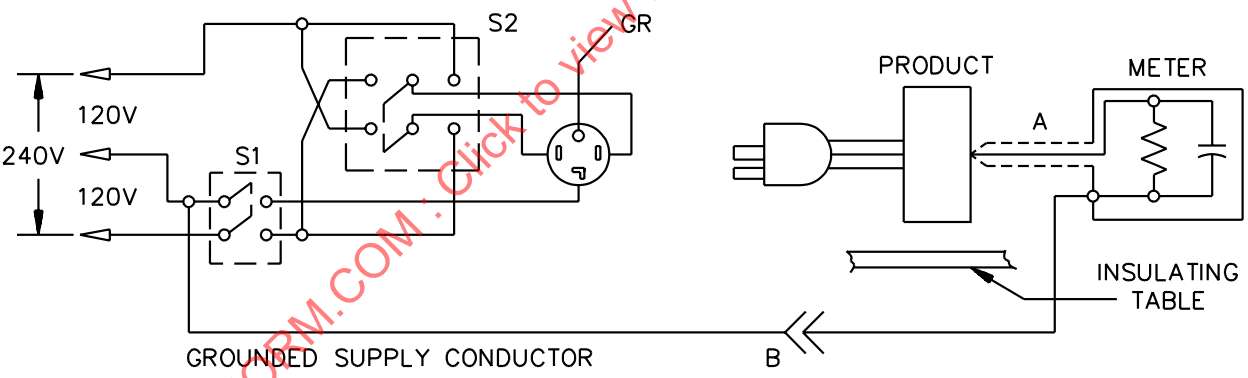
Equipment intended for connection to a 120-volt power supply.



LC200

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

(Continued)



LC300

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

A – Probe with shielded lead.

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

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

39.8 A sample of the product is to be tested initially in the as-received condition with all switches closed, but with its equipment-grounding conductor, if any, open at the attachment plug. A product that has not been energized for a minimum of 48 hours prior to the test, and that is at room temperature, is considered to be in the as-received condition. The supply voltage is to be the maximum voltage marked on the product, but not less than 120 or 240 volts. The test sequence, with reference to the measuring circuit in Figure 39.1, is to be as follows:

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

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

c) Leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation of the product as in the Temperature Test, Section 40.

40 Temperature Test

40.1 The materials used in the construction of a product shall not attain temperature rises greater than those specified in Table 40.1 under any condition of intended operation.

Table 40.1
Maximum temperature rises

Device or material	°C	(°F)
A. MOTORS		
1. Class A insulation systems on coil windings of an alternating current motor:		
a) In an open motor and on vibrator coils		
Thermocouple or resistance method	75	135
b) In a totally enclosed motor		
Thermocouple or resistance method	80	144
2. Class B insulation systems on coil windings of an alternating current motor:		
a) In an open motor		
Thermocouple or resistance method	95	171
b) In a totally enclosed motor		
Thermocouple or resistance method	100	180
B. COMPONENTS		
1. Capacitors[a]	25	45
2. Fuses	25	45
3. Rectifiers – at any point		
a) Germanium	25	45
b) Selenium	25	45
c) Silicon	25	45
4. Relays and other coils with:		
a) Class 105 insulated windings		
Thermocouple method	65	117

Table 40.1 Continued on Next Page

Table 40.1 Continued

Device or material	°C	(°F)
Resistance method	75	135
b) Class 130 insulated windings		
Thermocouple method	85	153
Resistance method	95	171
5. Resistors[b]		
a) Carbon	25	45
b) Wire wound	50	90
6. Sealing compounds	See note c	
7. Solid state devices	See note d	
C. INSULATED CONDUCTORS[e]		
1. Appliance wiring material	25°C (45°F) less than the temperature limit of the wire	
D. ELECTRICAL INSULATION – GENERAL		
1. Fiber used as electrical insulation or cord bushings	25	45
2. Phenolic composition used as electrical insulation or as parts where deterioration could result in a risk of fire, electric shock, or injury to persons	25	45
3. Printed-wiring boards	Based on maximum use temperature rating of printed-wiring board material	
a) Varnished cloth	25	45
E. GENERAL		
1. Mounting surfaces	25	45
2. Wood or other combustible material	25	45
3. Enclosure surfaces	40	72

[a] In lieu of complying with these temperature limits, these components may be evaluated in accordance with the applicable sections of Cat. No. RDH-376, Reliability Design Handbook (March 1976), ITT Research Institute.

[b] In lieu of complying with these temperature limits, a resistor may be used if it dissipates not more than one-half of its maximum power rating under the test condition specified.

[c] Unless a thermosetting material, the maximum sealing compound temperature, when corrected to a 25°C (77°F) ambient temperature, shall be 15°C (27°F) less than the softening point of the compound as determined by the Ball and Ring Apparatus, ASTM E28-77.

[d] The temperature of a solid-state device (for example, transistor, SCR, integrated circuits), shall not exceed 50 percent of its rating during the normal standby condition. The temperature of a solid state device shall not exceed 75 percent of its rated temperature under any condition of operation that produces the maximum temperature dissipation of its components. For reference purposes, 0°C (32°F) shall be considered as 0 percent. For integrated circuits, the loading factor shall not exceed 50 percent of its rating under the normal standby condition and 75 percent under any other condition of operation. Both solid-state devices and integrated circuits may be operated up to the maximum ratings under any one of the following conditions:

1) The component complies with the requirements of MIL-STD. 883E.

2) A quality control program is established by the manufacturer consisting of inspection and test of 100 percent of all components, either on an individual basis, as part of a subassembly, or the equivalent.

3) Each assembled production unit is subjected to a burn-in test, under the condition that results in the maximum temperatures, for 24 hours while connected to a source of rated voltage and frequency in an ambient of at least 49°C (120°F) followed by an operation test for normal signaling performance.

[e] For standard insulated conductors other than those specified, reference should be made to the National Electrical Code, ANSI/NFPA 70; the maximum allowable temperature rise in any case is 25°C (45°F) less than the temperature limit of the wire in question.

40.2 During this test, combinations of speakers and equivalent resistive loads are to be connected to the amplifier output as necessary to result in maximum rated power being delivered by the amplifier. The 1 kilohertz signal described in 32.2 shall be adjusted so that the maximum evacuate power is delivered to the load.

40.3 The values for temperature rises specified in Table 40.1 are based on an assumed ambient temperature of 25 ±15°C (77 ±27°F), and tests are to be conducted at an ambient temperature within that range. A temperature is considered to be constant when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 5 minutes, indicate no change.

40.4 Temperatures are to be measured by the use of thermocouples consisting of wires not larger than No. 24 AWG (0.21 mm^2), except that the temperature of a coil may be measured by either the thermocouple or change-in-resistance method. Thermocouples consisting of No. 30 AWG (0.06 mm^2) iron and constantan wires and a potentiometer-type indicating instrument are to be used if referee temperature measurements by thermocouples are necessary.

40.5 A thermocouple is not to be used for a temperature measurement at any point where supplementary thermal insulation is employed.

40.6 In measuring the temperature of a copper coil winding by the change-in-resistance method, the resistance of the winding at the temperature to be determined with the resistance at a known temperature by means of the formula:

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

in which:

Δt is the temperature rise in degrees C;

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

r is the resistance of the coil at the start of the test in ohms,

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

t_1 is the room temperature at the start of the test in degrees C, and

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

40.7 The circuit of a current-regulating resistor or reactor is to be adjusted for the maximum resistance or reactance at rated current.

41 Overload Test

41.1 An amplifier shall operate as intended after operating at 115 percent of rated supply voltage while delivering rated output current (sine wave) for at least 1 hour at the frequency that results in the greatest output voltage (greatest amplifier gain). The output is to be connected to a resistive load equal to the combined maximum system load intended for use with the amplifier.

41.2 Following the 1 hour of operation, the amplifier shall not show evidence of smoke, flame, or non-operation, or distortion greater than the limits specified in the Waveform Analysis Test, Section 31.

42 Endurance Test

42.1 An amplifier shall operate as intended when operated continuously at full rated speech power for 250 hours.

42.2 The amplifier is to be mounted as intended and operated with a sine wave input whose rms value is adjusted to deliver rated output voltage. The input frequency is to be varied from 800 to 2800 hertz at a uniform rate, then returned to 800 hertz, so that the amplifier is subjected to 800 to 2800 hertz frequency sweeps 12 times per minute. The output of the amplifier is to be a resistive load equal to the combined maximum system load intended for use with the amplifier. Gain controls, if provided, are to be adjusted to the maximum gain setting.

42.3 Following 250 hours of operation, there shall not be evidence of flame or smoke, or distortion greater than the limits specified in the Waveform Analysis Test, Section 31.

43 Burnout Test

43.1 A product or component intended for connection to input supply line voltage shall withstand a continuous energization without the emission of flame or molten metal from the enclosure.

43.2 The product or component is to be covered with a single layer of cheesecloth and then operated continuously at test voltage (see Table 30.1), until constant temperatures are attained or until burnout occurs. During the test, exposed dead metal parts are to be connected to ground through a 15-ampere fuse.

43.3 There shall not be development of a risk of fire or electric shock when a nonreliable component, such as an electrolytic capacitor, is opened or shorted. The product is to be connected to a source of rated voltage and frequency and the enclosure is to be grounded. Each fault (component opening or shorting) is to be applied separately until temperatures stabilize or burnout occurs.

44 Component Failure Test

44.1 Opening or shorting of capacitors shall not impair the operation of the product or be indicated by some form of an audible or visual signal. For this test, the fault is applied and the results noted while the product is energized in the standby condition and connected to a source of test voltage (see Table 30.1).

44.2 If it is not practical to have a component failure indicated, a reliable component may be used if its reliability is attained by derating or it is evaluated by supporting reliability data.

45 Abnormal Operation Test

45.1 An amplifier that is operated only for a limited period in most conditions of intended application, but may be operated continuously with the output circuits shorted, shall withstand the tests specified in 45.2 – 45.7 without manifestation of a risk of fire.

45.2 The product is to be operated under the most severe foreseeable conditions likely to be encountered in service while connected to a source of test voltage (see Table 30.1). As a result of these conditions, there shall not be emission of flame or molten metal, or any other manifestation of a risk of fire.

45.3 A product intended to produce a continuous signal is to be operated until constant temperatures are attained.

45.4 In determining if a product complies with the requirement in 45.1 with regard to installation-wiring circuit fault conditions, the fault conditions are to be maintained continuously until constant temperatures are attained, or until burnout occurs, if the fault does not result in the operation of an overload-protective device.

45.5 There shall not be emission of flame or molten metal or other development of a risk of fire or electric shock when each output circuit of the amplifier is individually shorted. Each interchangeable fuse is to be replaced with either:

a) A noninterchangeable type fuse of the same rating or

b) An interchangeable fuse of the same size but having the highest current rating available for that size.

45.6 All openings of the amplifier enclosure are to be covered with surgical cotton, and the enclosure, if of metal, is to be connected to ground through a fuse of the same rating as indicated by the marked rating of the product.

45.7 At the conclusion of this test, the cotton shall not have ignited and the enclosure grounding fuse shall not have opened.

46 Transient Tests

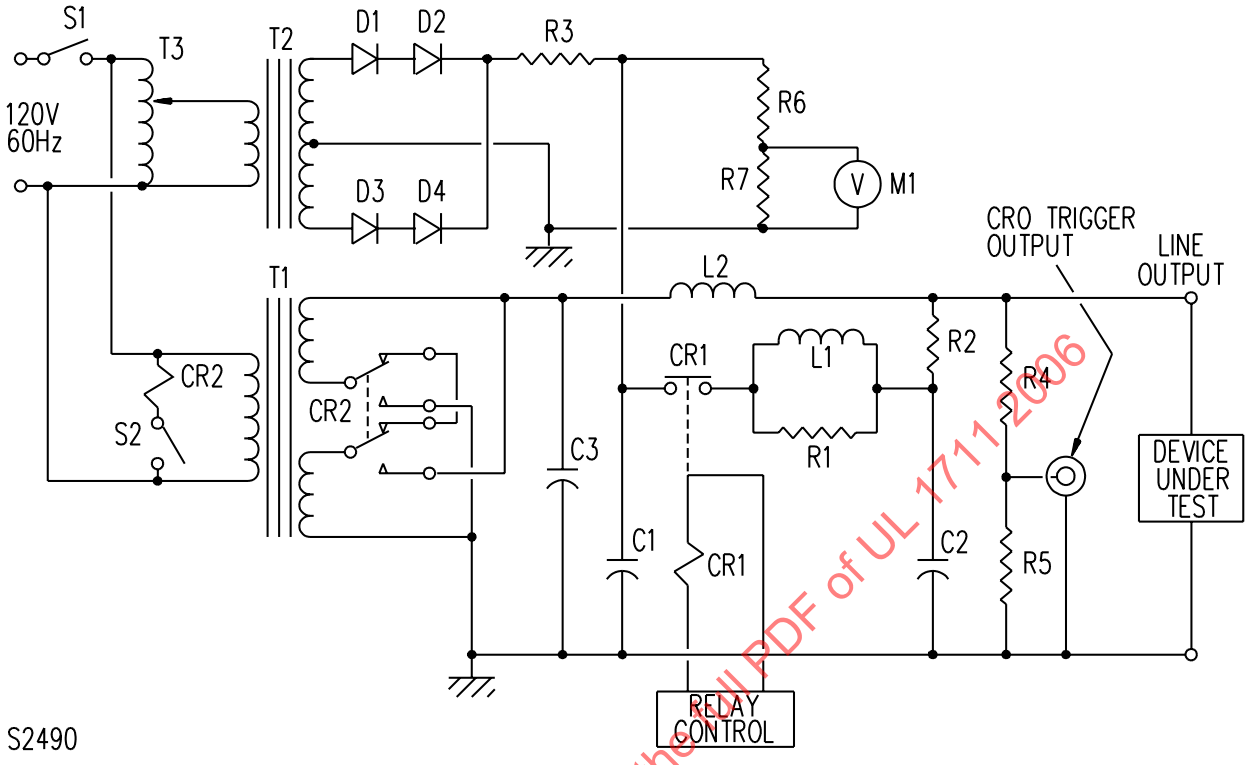
46.1 General

46.1.1 An amplifier shall operate as intended after being subjected to 500 supply line transients, while energized from a source of supply in accordance with 30.1.

46.2 Supply line transients

46.2.1 The product is to be connected to a transient generator consisting of a 2 kilovolt-ampere isolating power transformer and control equipment that produces the transients described in 46.2.2. See Figure 46.1. The source impedance of the transient generator is to be 50 ohms.

Figure 46.1
Surge generator circuit



C1 – Capacitor, 0.025 µF, 10 kV

C2 – Capacitor, 0.006 µF, 10 kV

C3 – Capacitor, 10 µF, 400 V

CR1 – Relay, coil 24 VDC. Contacts, 3-pole, single throw, each contact rated 25 A, 600 VAC maximum: All three poles wired in series

CR2 – Relay, coil 120 VAC. Contacts DPDT. Provides either 120 V or 240 V test circuit.

D1 – D4– Diodes, 25 kV PIV each

L1 – Inductor, 15 µH [33 turns, No. 22 AWG wire, wound on 0.835 inch (21.2 mm) diameter PVC tubing]

L2 – Inductor, 70 µH [45 turns, No. 14 AWG wire, wound on 2.375 inch (60.33 mm) diameter PVC tubing]

M1 – Meter, 0 – 20 VDC

R1 – Resistor, 22 Ohms, 1 W, composition

R2 – Resistor, 12 Ohms, 1 W, composition

R3 – Resistor, 1.3 Megohms (12 in series, 110 k Ohms each, 1/2 W)

R4 – Resistor, 47 k Ohms (10 in series, 4.7 k Ohms each, 1/2 W)

R5 – Resistor, 470 Ohms, 1/2 W

R6 – Resistor, 200 Megohms, 2 W, 10 kV

R7 – Resistor, 0.2 Megohms (2 in series, 100 k Ohms each, 2 W, carbon)

S1– Switch, SPST

S2 – Switch, SPST, key-operated, 120 VAC, 1 A

T1 – Transformer, 2 kVA, 120 V primary, 1:1 (120 V or 240 V output)

T2 – Transformer, 90 VA, 120/15,000 V

T3 – Variable autotransformer, 2.5 A

46.2.2 The transients produced are to be oscillatory and are to have an initial peak voltage of 6000 volts. The rise time is to be less than 1/2 microsecond. Successive peaks of the transient are to decay to a value of not more than 60 percent of the value of the preceding peak.

46.2.3 The product is to be subjected to 500 transients induced at a rate of 6 pulses per minute. Each transient is to be induced 90 degrees into the positive half of the 60 hertz cycle. A total of 250 pulses are to be applied so that the polarity of the transients is positive with reference to earth ground, and the remaining 250 pulses are to be negative with regard to earth ground.

46.2.4 At the conclusion of the test, the amplifier shall comply with the requirements in the Waveform Analysis Test, Section 31.

47 Mechanical Strength Tests

47.1 Jarring test – complete product

47.1.1 A product shall withstand jarring resulting from impact and vibration anticipated in the intended application, without generation of signaling operation of any part and without impairment of its intended operation.

47.1.2 The product and associated equipment are to be mounted as intended to the center of a 6- by 4-foot (1.8- by 1.2-m), nominal 3/4-inch (19.1-mm) thick plywood board secured in place at four corners. An impact is to be applied to the center of the reverse side of this board by means of a 1.18-pound (0.54-kg), 2-inch (50.8-mm) diameter steel sphere either:

a) Swung through a pendulum arc from a height of 2.54 feet (775 mm) or

b) Dropped from a height of 2.54 feet, depending upon the intended mounting of the product.

See Figure 47.1 for the jarring test diagram.