JOINT CANADA-UNITED STATES
NATIONAL STANDARD

ANSI/CAN/UL 2524:2024

STANDARD FOR SAFETY

Emergency Responder Communication Enhancement Systems

Approved American National Standard

ANSI/UL 2524-2024

SCC FOREWORD

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UL Standard for Safety for Emergency Responder Communication Enhancement Systems, ANSI/CAN/UL 2524

Third Edition, Dated March 22, 2024

Summary of Topics

This new Third Edition of ANSI/CAN/UL 2524 dated March 22, 2024 includes the following changes in requirements:

– Correction to Polarity Reversal Test; 46.1

– Revised standard title to "Emergency Responder Communication Enhancement System"; 1.1, 1.3, 6.2, 6.10, 33.2, 36.1.1 – 36.1.3, 36.1.5 and 54.12

– Updated references to Model Building and Installation Codes; 1.2, Section 5 and 53.1.1

– Optical fiber technology and relaxation of enclosure requirements for equipment intended for indoor use/dry locations; 9.1.1

– Clarification of on-premises visual and labeled indications; 6.30, 36.1.3; 36.1.6; 34.2 and 34.3

– Update of Annex A – Standards for Components

– Addition of requirements for products intended to be installed outdoors; Section 49, Section 51, and 53.1.22

– Corrections to Section 28.3

– Clarification of maximum propagation delay; 34.4

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated September 29, 2023 and December 20, 2023.

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ANSI/UL 2524-2024

MARCH 22, 2024

ANSI/CAN/UL 2524:2024

Standard for Emergency Responder Communication Enhancement Systems

First Edition – October, 2018
Second Edition – January, 2019

Third Edition

March 22, 2024

This ANSI/CAN/UL Safety Standard consists of the Third Edition.

The most recent designation of ANSI/UL 2524 as an American National Standard (ANSI) occurred on March 22, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on March 22, 2024.

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Preface

This is the Second Edition of the ANSI/CAN/UL 2524, Standard for Emergency Responder Communication Enhancement Systems.

ULSE is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO).

This Standard has been developed in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization.

This ANSI/CAN/UL 2524 Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

Annex A, identified as informative, is for information purposes only.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

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

This Edition of the Standard has been formally approved by the Technical Committee (TC) on Emergency Responder Communication Enhancement Systems, TC 2524.

This list represents the TC 2524 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

TC 2524 Membership

Name	Representing	Interest Category	Region
Patrick Adamo	Firecom Inc	Producer	USA
Chad Brown	Peterborough Fire Services	AHJ	Ontario
Mike Brownson	Westell Technologies INC	Producer	USA
Adam Carroll	Hartland Deerfield Fire Authority	AHJ	USA
Rick Cheung	City Of Vancouver	AHJ	British Columbia
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Louis Fiore	L T Fiore Inc	General Interest	USA

TC 2524 Membership Continued on Next Page

TC 2524 Membership Continued

Name	Representing	Interest Category	Region
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Vince Zagarri	Zagarri Engineering	Supply Chain	USA

International Classification for Standards (ICS): 33.060.30; 33.060.20

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This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

CETTE NORME NATIONALE DU CANADA EST DISPONIBLE EN VERSIONS FRANÇAISE ET ANGLAISE

INTRODUCTION

1 Scope

1.1 These requirements cover products (e.g. repeater, transmitter, receiver, signal booster components, remote annunciators and operational consoles, power supply, and battery charging system components) used for emergency responder communication enhancement systems installed in a location to improve wireless communication at that location.

1.2 In the United States – These requirements cover products to be employed in accordance with the following Model Building and Installation Codes:

a) Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems, NFPA 1221;

b) Standard for Emergency Services Communications, NFPA 1225;

c) National Electrical Code, NFPA 70;

d) Fire Code NFPA 1;

e) Life Safety Code, NFPA 101;

f) International Fire Code

g) Building Construction and Safety Code, NFPA 5000.

1.3 The products covered by this standard are intended to be used in combination with other products and devices to form an emergency responder communication enhancement system. An installation document(s) provided with the product describes the various products needed to form an emergency responder communication enhancement system and their intended use and installation.

1.4 These requirements address the safety, reliability and operational requirements prior to installation.

1.5 These requirements do not include determination of compliance with national regulations addressing electromagnetic radiation and use of radio frequencies. Should products covered by these requirements be required to comply with national regulations, a report of verification from the manufacturer is required as evidence of such compliance.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this standard shall comply with the requirements for that component. See Annex A for a list of standards covering components used in the products covered by this standard.

2.2 A component is not required to comply with a specific requirement that:

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

b) Is superseded by a requirement in this standard.

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

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

3 Units of Measurement

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

4 Undated References

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

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance.

ASTM B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*

ASTM D396, *Standard Specification for Fuel Oils*

ASTM E11, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves*

ASTM E230/E230M, *Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples*

CSA C22.1, *Canadian Electrical Code, Part I, Safety Standard for Electrical Installations*

CSA C22.2 No. 0.15-01, *Adhesive Labels*

CSA C22.2 No. 0.17, *Evaluation of Properties of Polymeric Materials*

CSA C22.2 No. 65, *Wire Connectors*

CSA C22.2 No. 88, *Splicing Wire and Cable Connectors*

CSA C22.2 No. 94.1, *Enclosures for Electrical Equipment, Non-Environmental Considerations*

CSA C22.2 No. 94.2, *Enclosures for Electrical Equipment, Environmental Considerations*

CSA C22.2 No. 158, *Terminal Blocks*

CSA C22.2 No. 223, *Power Supplies with Extra-Low-Voltage Class 2 Outputs*

CSA C22.2 No. 60065, *Audio, Video, and Similar Electronic Apparatus-Safety Requirements*

CSA C22.2 No. 60950-1, *Information Technology Equipment*

CSA C22.2 No. 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

IEEE C62.41, *Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits*

IEC 60417-1, *Graphical Symbols for Use on Equipment – Part 1: Overview and Application*

International Fire Code

NFPA 1, *Fire Code*

NFPA 70, *National Electrical Code*

NFPA 72, *National Fire Alarm and Signaling Code*

NFPA 101, *Life Safety Code*

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*

NFPA 1225, *Standard for Emergency Services Communications*

6 Glossary

6.1 ACKNOWLEDGE – Action taken to confirm that a message or signal has been received, such as pressing a button.

6.2 ACTIVE RADIO FREQUENCY EMITTING DEVICE – A powered device that emits a radio frequency signal as part of an emergency responder communication enhancement system.

6.3 ADVERSE CONDITION – Any condition occurring in a circuit or communication path that interferes with the proper signaling or interpretation of status-change signals or both. Conditions include radio frequency interference.

6.4 AIR-HANDLING SPACE – Space used for environmental air-handling purposes other than ducts or plenums. The space over a hung ceiling used for environmental air-handling is an example.

6.5 ANNUNCIATOR – A unit containing one or more indicator lamps, alphanumeric displays, or other equivalent means in which each indication provides status information about a circuit, condition, or location.

6.6 AVERAGE VALUE – The sum of all instantaneous values of current (or voltage), averaged over one-half of an alternating cycle.

6.7 BATTERY CHARGER – A product intended to deliver sufficient current to maintain storage batteries in their fully-charged condition while the batteries are not connected to a load.

6.8 DAQ (Delivered Audio Quality) – A measure of speech intelligibility of Land Mobile Radio.

6.9 DISCHARGED BATTERY – A standby battery discharged as described in 37.2.

6.10 DONOR ANTENNA – Antennas used with the emergency responder communication enhancement systems that provide the connection between it and the wide area communications system of interest.

6.11 END-OF-LINE DEVICE – A device installed at the end of a circuit for the purpose of monitoring the circuit for fault conditions.

6.12 EXTERNAL CIRCUITS – Circuits or wiring leaving the product.

6.13 FAULT – An open, ground, or short-circuit condition on any line extending from a product.

6.14 FIELD WIRING – Conductors to be installed in the field to connect a product to source(s) of supply, devices, other products, and loads.

6.15 FIXED EQUIPMENT – Any equipment product that is intended to be permanently connected electrically to the wiring system.

6.16 GROUNDED CONDUCTOR – A conductor employed to connect the intentionally grounded circuit of a wiring system to a grounding electrode.

6.17 GROUND FAULT – A circuit impedance to ground sufficient to result in the annunciation of a trouble condition.

6.18 GROUNDING CONDUCTOR – A conductor employed to connect non-current-carrying parts of equipment, raceways, and enclosure to a grounding electrode at the service which is, in turn, connected to earth ground or to some conducting body which serves in place of earth ground.

6.19 OPEN FAULT – A circuit impedance increase sufficient to prevent normal operation.

6.20 OPERATOR – Individual(s) responsible to access and operate the product and/or system, but does not have access to portions of the product required for servicing and maintenance.

6.21 OPERATOR INTERFACE – Providing controls for manually operating the product/system or interrogating the system for faults.

6.22 PASSIVE RF COMPONENT – Any device that RF passes through that does not have an active electronic component that requires external power. This includes antennas, splitters, couplers, coaxial cable and connectors. Passive components cannot amplify RF signals.

6.23 PATH (PATHWAY) – Any conductor, optic fiber, radio carrier, or other means for transmitting information between two or more units and/or locations.

6.24 POWER SUPPLY – A source of electrical operating power including the circuits and terminations connecting it to the dependent product/system components.

6.25 POWER SUPPLY-BATTERY CHARGER – A power supply that serves the dual function of providing operating power and charging storage batteries. The power supply is usually permanently connected to storage batteries, and the power supply-battery combination is intended to provide all of the electrical operating power required by the equipment to which the combination is connected, when the equipment is operating in its intended manner.

6.26 REPEATER – A device for receiving and re-transmitting two-way communication signals.

6.27 RESET – A control function that attempts to return a system or device to its normal state.

6.28 RISK OF ELECTRIC SHOCK – A risk of electric shock is determined to exist at any part if:

a) The potential between the part and earth ground or any other accessible part is more than 42.4 V peak, and

b) The continuous current flow through a 1500 W resistor connected across the potential exceeds 0.5 mA.

6.29 RISK OF FIRE – A risk of fire is considered to exist at any two points in a circuit where:

a) The open circuit voltage is more than 42.4 V peak and the energy available to the circuit under any condition of load including short circuit, results in a current of 8 A or more after 1 min of operation; or

b) A power of more than 15 W can be delivered into an external resistor connected between the two points.

6.30 SIGNAL SOURCE MALFUNCTION -– An abnormal condition resulting in the loss of the RF signal from the public safety radio communications system to the ERCES. Examples include the disconnection of the antenna coax, a short in the coax, a damaged coax, a misdirected donor antenna, donor antenna malfunction, damage to fiber optic cable (if the source of the signal is a fiber optic cable between the sites), and oscillation detection.

6.31 SOFTWARE – Programs, instructions, procedures, data, and the like that are executed by a central processing unit of a product and which influences the functional performance of that product. For the purpose of this standard, software is one of two types:

a) EXECUTIVE SOFTWARE – Control and supervisory program which manages the execution of all other programs and directly or indirectly causes the required functions of the product to be performed.

b) SITE-SPECIFIC SOFTWARE – Program that is separate from, but controlled by, the executive software which allows inputs, outputs, and system configuration to be selectively defined to meet the needs of a specific installation.

c) DEVICE SPECIFIC FIRMWARE – Firmware that is accessed via a connection and modified via a graphical user interface.

6.32 STANDBY POWER SOURCE – Provides power when the primary power source fails.

6.33 STORAGE BATTERY – Any battery which, by design or construction, is intended to be recharged. The storage battery is intended to provide a secondary source of operating power in response to failure of the primary source of operating power.

6.34 SUPERVISORY SIGNAL – A signal indicating the need of action in connection with the supervision of watchmen, sprinkler and other extinguishing systems or equipment, or with the maintenance features of other protective systems.

6.35 SUPPLEMENTARY – Refers to equipment or operations not required by this standard.

6.36 SUPPLEMENTARY DEVICE – A device intended to be connected to a supplementary device circuit.

6.37 SUPPLEMENTARY-DEVICE CIRCUIT – A circuit provided by a product for controlling a device, the operation of which is supplementary to the primary initiating and indicating devices of the control unit.

6.38 TROUBLE SIGNAL – A visual or audible signal indicating a fault condition of any nature, such as a circuit break or ground or other trouble condition occurring in the device or wiring associated with a protective signaling system.

6.39 USER – An individual who operates or services the product.

6.40 WIRE-TO-WIRE FAULT – A wire-to-wire (short circuit) fault is determined to be a resistance of 0.1 Ohm or less across the circuit.

7 Information Required for Assessment

7.1 The following documentation may be required to determine compliance:

a) Schematic diagrams of all circuits.

b) Where the product uses software, the software revision level.

c) Marking to be applied to the product as required in Markings, Section 53.

d) Installation wiring diagram/instructions as required in Installation Wiring Diagram/Instructions, Section 54.

7.2 Samples representative of all manufactured components utilized in the system may be required to determine compliance.

CONSTRUCTION

8 General

8.1 A product shall use materials that have been determined to comply with the requirements for the particular use, as indicated by the performance requirements of this standard.

8.2 Metals, when required to meet the requirements of this standard, shall not be used in such combination as to cause galvanic action that will increase the risk of fire, electric shock, injury to persons, or impair the operation of a product associated with the safety of life and/or property protection.

8.3 Where breakage or deterioration of a part such as an enclosure, a frame, a guard, or the like can result in a risk of injury to persons, the part shall be constructed to meet the demand or expected loading conditions.

8.4 The requirement in 8.3 applies also to those positions of a part adjacent to a moving part identified to involve a risk of injury to persons.

8.5 Electrical equipment with nonmetallic enclosures and other non-metallic discrete objects, intended to be installed in air-handling spaces shall additionally comply with the requirements in:

a) United States, The Standard for Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces, UL 2043, or

b) Canada, Fire Test for Heat and Visible Smoke Release for Discrete Products, ULC-S142.

8.6 Products that currently meet all the requirements of one of the standards indicated below need only be evaluated to the following sections with respect to the construction requirements: 9.1, 9.2, 9.3, 12.5, 14.1.1, 14.2.1.1, 14.2.2.1, 14.2.5, 15.1.2 – 15.1.5, 15.3, 15.6, 17.4, 22, and 26.1.

a) In the United States

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

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

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

b) In Canada

1) CSA C22.2 No. 60950-1, Information Technology Equipment, or

2) CSA C22.2 No. 60065, Audio, Video, and Similar Electronic Apparatus-Safety Requirements, or

3) CSA C22.2 No. 62368-1, Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements.

9 Enclosures

9.1 General

9.1.1 All repeater, transmitter, receiver, signal booster components, optical-to-RF converters, RF-to-optical converters, external filters, and battery system components shall be contained in enclosures that comply with the requirements for a Type 4 or 4X enclosure covered by the standards indicated below:

a) In the United States

1) Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50 and

2) Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

b) In Canada

1) CSA C22.2 No. 94.1, Enclosures for Electrical Equipment, Non-Environmental Considerations, and

2) CSA C22.2 No. 94.2, Enclosures for Electrical Equipment, Environmental Considerations.

Exception No. 1: Rechargeable standby batteries are permitted to be contained in enclosures that comply with the requirements for a Type 3R specified in the following standards:

a) In the United States

1) Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50 and

2) Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

b) In Canada

1) CSA C22.2 No. 94.1, Enclosures for Electrical Equipment, Non-Environmental Considerations, and

2) CSA C22.2 No. 94.2, Enclosures for Electrical Equipment, Environmental Considerations.

Exception No. 2: Polymeric enclosures and/or including polymeric fasteners, hinges and parts attached to the ultimate enclosure of products intended for installation in indoor locations only are not required to be evaluated for ultraviolet light weathering.

Exception No. 3: Type 3R, 4 or 4x ferrous enclosures and external ferrous parts attached to these enclosures for products intended for installation in indoor locations only, shall either:

a) Be protected against corrosion by enameling, painting, galvanizing or other equivalent means; or

b) Be tested in accordance with UL 50E or CSA C22.2 No. 94.2 Clause 8.7.

Exception No. 4: Enclosures of equipment intended for installation in indoor locations only are not required to be evaluated for external icing.

9.1.2 All electrical parts of a product shall be enclosed to provide protection of internal components and prevent contact with uninsulated live parts.

9.1.3 Enclosures not described in 9.1.1 shall meet the requirements for Type 3R, 4, or 4X enclosures in 9.1.1 or meet the requirements of 9.4 – 9.9.

9.2 Enclosure covers

9.2.1 An enclosure cover shall be hinged, sliding, pivoted or similarly attached to provide access to fuses or any other over current-protective device, the intended protective functioning of which requires renewal or resetting, or when it is necessary to open the cover in connection with the normal operation of the unit.

Exception: In lieu of providing a hinged, sliding, or pivoted cover, supervision of the enclosure cover by means of a tamper feature is suitable when its operation results in an audible and visual signal. This applies only when the cover provides access to overcurrent devices such as fuses or circuit breakers or other indicators that are not used on a continuing basis.

9.2.2 Normal operation referenced in 9.2.1 is determined to be operation of a switch for testing or for silencing an audible signal appliance or operation of any other component of a unit which requires such action in connection with its intended performance.

9.2.3 A transparent material panel for an opening having an area of more than 144 in^2 (929 cm^2), or having any dimension greater than 12 in (305 mm), shall be supported by a continuous groove not less than 3/16 in (4.8 mm) deep along all four edges of the panel, or other means that have been determined to be an equivalent arrangement.

9.2.4 A transparent material used for the cover of an observation opening shall not introduce a risk of fire, distort, nor become less transparent at the temperature to which it is intended to be subjected under either normal or abnormal service conditions. See 9.5.2.

9.3 Battery compartments

9.3.1 A compartment for vented storage batteries shall have a total volume at least twice the volume occupied by the batteries. Ventilating openings shall be provided and so located as to permit circulation of air for dispersion of gas while the battery is being charged at the highest rate permitted by the means incorporated in the control unit.

9.3.2 The interior of a storage battery compartment shall be protected so that it will be resistant to detrimental action by the electrolyte.

9.4 Metallic material

9.4.1 An enclosure of metal shall have a minimum thickness as specified in Table 9.1 or Table 9.2.

Table 9.1
Minimum Thickness of Sheet Metal for Electrical Enclosures of Carbon or Stainless Steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness			
								Uncoated		Metal coated	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		in	(mm)	in	(mm)
in	(cm)	in	(cm)	in	(cm)	in	(cm)	[MSG]		[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 that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and that has sufficient torsional rigidity to resist the bending moments 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.

[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 in (12.7 mm) wide.

Table 9.2
Minimum Thickness of Sheet Metal for Electrical Enclosures of Aluminum, Copper, or Brass

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

[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.

[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 in (12.7 mm) wide.

9.4.2 Where threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or where a construction that is determined to be equivalent is used, there shall not be less than 3-1/2 nor more than 5 threads in the metal, and the construction shall be such that a standard conduit bushing can be attached.

9.4.3 Where 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 five full threads in the metal, and there shall be a smooth, rounded inlet hole for the conductors which shall afford protection to the conductors equivalent to that provided by a standard conduit bushing.

9.4.4 At any point where conduit or metal-clad cable is to be attached to the enclosure, sheet metal shall be of such thickness or shall be so formed or reinforced that it will have stiffness at least equivalent to that of an uncoated flat sheet of steel having a minimum thickness of 0.032 in (0.81 mm).

9.5 Polymeric materials

9.5.1 Polymeric materials used as an enclosure shall comply with the applicable portions of the following standards and also with the additional requirements specified in this standard:

a) In the United States, Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C

b) In Canada, CSA C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials

9.5.2 Polymeric material that is not used as an enclosure, but that is attached to or exposed on the outside of a product such as a viewing window, shall have flammability characteristics as shown in Table 9.3.

Table 9.3
Flammability Characteristics of Polymeric Material

Polymeric material area/dimensions	Flammability rating
0.24 in^3 (4 cm^3) maximum and 2.4 in (61 mm) maximum length	None
Greater than 0.24 in^3 (4 cm^3) and less than 2 ft^2 (0.19 m^2), 6 ft (1.83 m) maximum length	HB, V-2, V-1, V-0, or 5V
Greater than 2 ft^2 (0.19 m^2) and less than 10 ft^2 (0.93 m^2), 6 ft (1.83 m) maximum length	V-1, V-0, or 5V
Greater than 10 ft^2 (0.93 m^2), or longer than 6 ft (1.83 m)	Maximum flame spread rating of 200 as specified in the Standard for Test for Surface Burning Characteristics of Building Materials, UL 723, or radiant panel as specified in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94

9.5.3 Conductive coatings applied to nonmetallic surfaces such as the inside surface of an enclosure, shall comply with the appropriate requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, unless flaking or peeling of the coating cannot result in the reduction of spacings or the bridging of live parts.

9.5.4 A polymeric enclosure intended for connection to a rigid metallic conduit system shall comply with the requirements for polymeric enclosure rigid metallic conduit connections in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50.

9.5.5 The continuity of a conduit system shall be provided by metal-to-metal contact and not rely on a polymeric material and shall comply with the requirements for polymeric enclosure bonding in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50.

9.6 Enclosure openings – general

9.6.1 An enclosure intended for recessed mounting and whose front panel is to be flush with the surface of the wall shall have no 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: In the United States, products supplied solely from power-limited sources and controlling only power-limited loads.

9.6.2 The requirement in 9.6.1 does not apply to an opening for a mounting screw or nail or for a manufacturing operation (such as paint drainage) when:

a) An opening for non-mounting purposes does not have a dimension greater than 17/64 in (6.75 mm) or an area greater than 0.055 ft^2 (35.5 mm^2); and

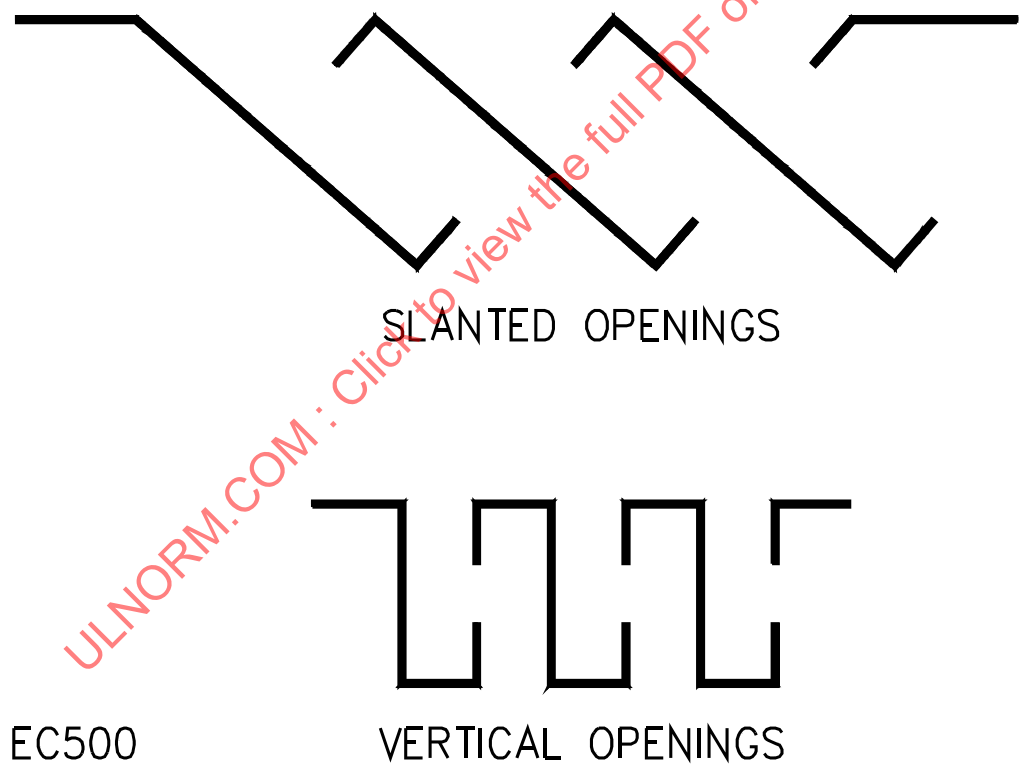
b) An opening for mounting does not have a dimension greater than 0.75 in (19.05 mm) or an area greater than 0.7 in^2 (430 mm^2) and there are no more holes than are needed to mount the product.

9.7 Enclosure top openings

9.7.1 An opening directly over an uninsulated live part involving a risk of fire, electric shock, or electrical-energy/high-current levels, shall not exceed 0.20 in (5.0 mm) in any dimension unless the configuration is such that a vertically falling object cannot fall into the unit and contact an uninsulated live part. See Figure 9.1 for examples of top-cover designs complying with the intent of the requirement.

Figure 9.1

Cross-Sections of Top-Cover Designs



9.8 Enclosure side openings

9.8.1 An opening in the side of the enclosure shall:

a) Not exceed 0.19 in (4.8 mm) in any dimension;

b) Be provided with louvers shaped to deflect an external falling object outward (see Figure 9.2 for examples of louver designs complying with the requirement); or

c) Be located and sized so that objects which are present cannot drop into the unit and fall (with no horizontal velocity) onto uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high-current levels, or parts involving injury to persons (see Figure 9.3).

9.8.2 When a portion of a side panel falls within the area traced out by the 5° angle in Figure 9.4, that portion of the side panel shall be investigated as a bottom enclosure in accordance with 9.9.1 – 9.9.3.

Figure 9.2

Louvers

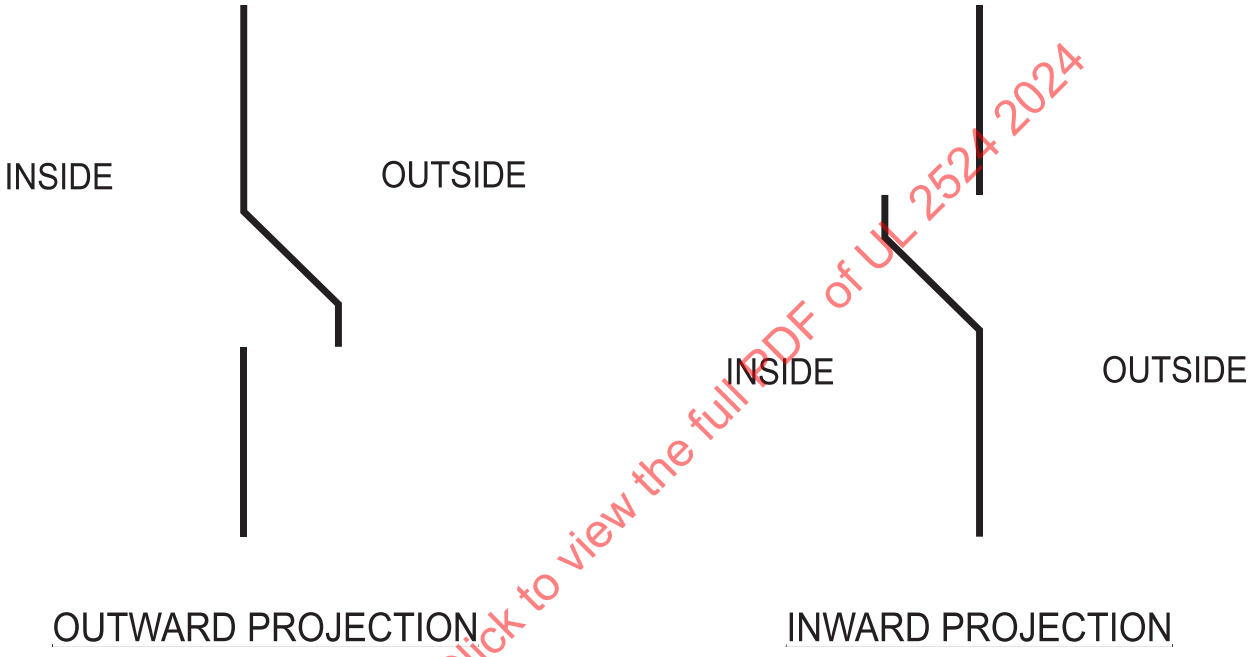


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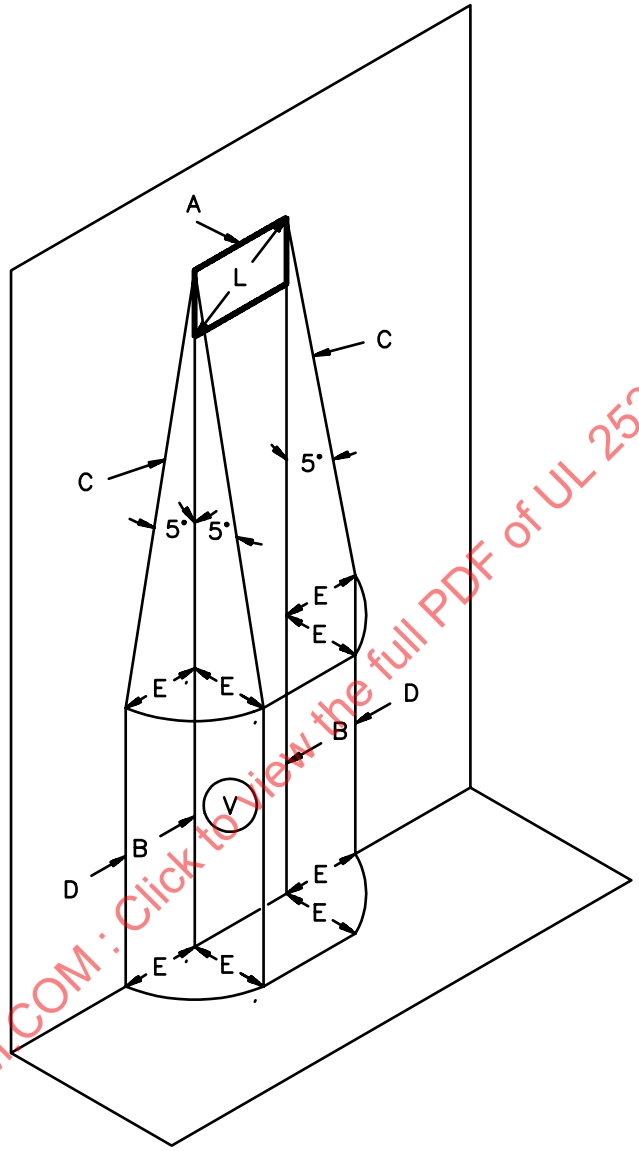
Figure 9.3

Example of Enclosure Side Opening



A – Enclosure side opening.

B – Vertical projection of the outer edges of the side opening.

C – Inclined lines that project at a 5° angle from the edges of the side opening to point located E distance from B.

D – Line which is projected straight downward in the same plane as the enclosure side wall.

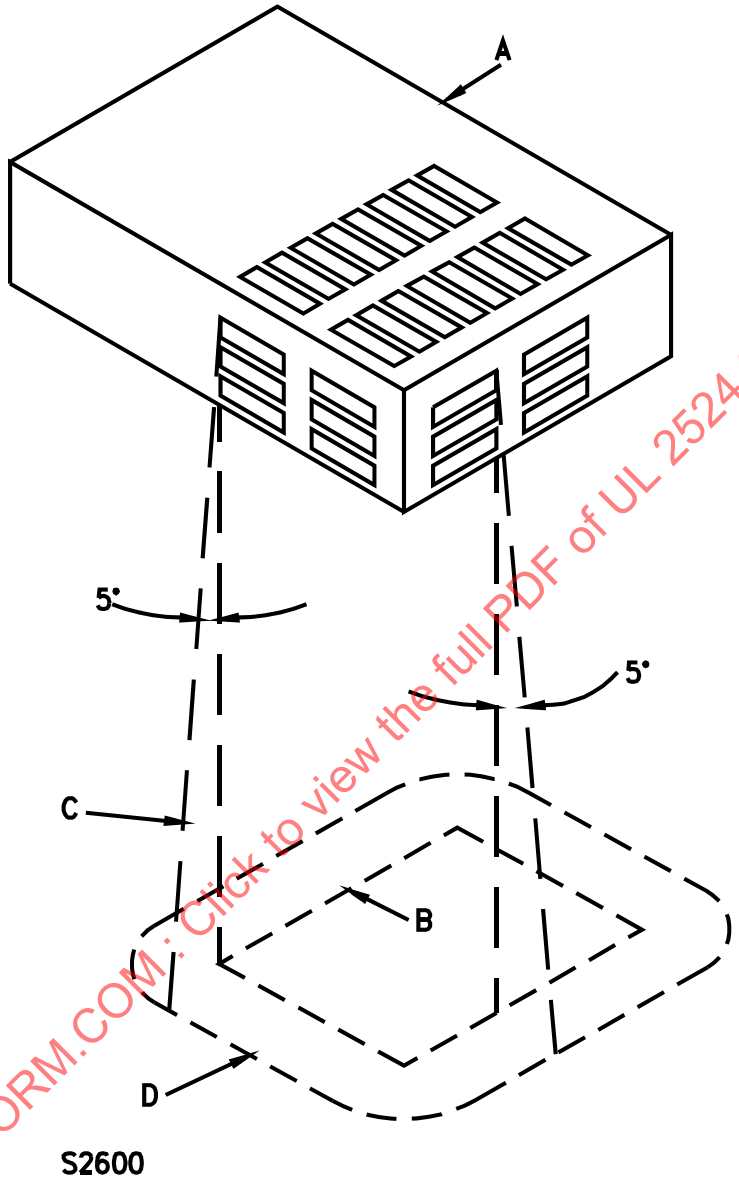
E – Projection of the opening (not to be greater than L).

L – Maximum dimension of the enclosure side opening.

V – Volume in which bare parts at uninsulated live parts are not located.

Figure 9.4

Enclosure Bottom



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

B – Projection of the outline of the area of A that requires a bottom enclosure vertically downward onto the horizontal plane of the lowest point on the outer edge D of the enclosure.

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

D – Minimum outline of the enclosure, except that the extension B to D is not required to exceed 6 in (152 mm), flat or dished with or without a tip or other raised edge. The bottom shall either be flat or formed in any manner when every point of area D is at or below the lowest point on the outer edge of the enclosure.

9.9 Enclosure bottom openings

9.9.1 The bottom of an enclosure shall consist of a complete or partial bottom enclosure under a component, groups of components, or assemblies, as shown in Figure 9.4, that complies with the ventilation opening requirements in 9.9.2 and 9.9.3 unless a test demonstrates that the bottom enclosure provided contains flames, glowing particles or similar burning debris when all combustible material in the interior is ignited.

Exception: Openings without limitation on their size and number are permitted in areas that contain only wires, cables, plugs, receptacles, and impedance- and thermally-protected motors.

9.9.2 Ventilation openings provided in the bottom of an enclosure under materials that are not rated V-1 or less flammable meet the intent of the requirements when the openings are constructed so that materials do not fall directly from the interior of the unit. Other bottom-opening constructions that comply with the intent of the requirements are those that incorporate a perforated metal plate as described in Table 9.4, or a galvanized or stainless-steel screen having a 14 by 14 mesh per 1 in (25.4 mm) constructed of wire with a minimum diameter of 1/64 in (0.4 mm).

Table 9.4
Perforated Metal Plates

Minimum thickness		Maximum diameter of holes		Minimum spacing of holes center-to-center	
in	(mm)	in	(mm)	in	(mm)
0.026	(0.66)	0.045	(1.14)	0.67	(1.70)
				[233 holes per in^2]	[36 holes per cm^2]
0.026	(0.66)	0.047	(1.19)	0.093	(2.36)
0.032	(0.81)	0.075	(1.91)	0.125	(3.18)
				[72 holes per in^2]	[11 holes per cm^2]
0.036	(0.91)	0.063	(1.60)	0.109	(2.77)
0.036	(0.91)	0.078	(1.98)	0.125	(3.18)

9.9.3 The bottom of the enclosure under areas containing only materials rated V-1 or less flammable shall have openings no larger than 1/16 in^2 (40 mm^2).

9.9.4 The bottom-panel constructions described in 9.9.1 – 9.9.3 are permitted without testing. Other constructions can be used when they comply with the test described in 9.9.5 – 9.9.8.

9.9.5 Openings in a bottom panel shall be arranged and sufficiently small in size and few in number so that hot flaming No. 2 furnace oil poured three times onto the openings from a position above the panel is extinguished as it passes through the openings.

9.9.6 A sample of the complete, finished bottom panel is to be supported in a horizontal position a short distance above a horizontal surface under a hood or in another area that is ventilated but free from drafts. Bleached cheesecloth running 14 – 15 yd^2/lb mass (26 – 28 m^2/kg mass) and having what is known to the trade as "a count of 32 by 28" (a square 1 in on a side has 32 threads in one direction and 28 in the other or square 1 cm on a side has 13 threads in one direction and 11 in the other), is to be draped in one layer over a shallow flat-bottomed pan that is of a size and shape to cover completely the pattern of openings in the panel but is not sufficiently large to catch any of the oil that runs over the edge of the panel or otherwise does not pass through the openings. The pan is to be centered under the center of the pattern of openings in the panel. The center of the cheesecloth is to be 2 in (50 mm) below the openings. Use of

metal screen or wire-glass enclosure surrounding the test area is recommended to keep splattering oil from causing injury to persons.

9.9.7 A small metal ladle not more than 2-1/2 in (65 mm) in diameter, with a pouring lip and a long handle whose longitudinal axis remains horizontal during pouring, is to be partially filled with 0.34 ounces (10 cm^3 or 10 ml) of No. 2 fuel oil, which is a medium-volatile distillate having a minimum API gravity of 30° , a flash point of 110 – 190 °F (43.3 – 87.7 °C), and an average calorific value of 136,900 Btu/gal (38.2 MJ/L); see the Standard Specification for Fuel Oils, ASTM D396. The ladle containing the oil is to be heated and the oil is to be ignited. The oil is to flame for 1 min and then is to be poured at the approximate rate of, but not less than 0.034 ounces (1 cm^3/s or 1 mL/s) in a steady stream onto the center of the pattern of openings from a position 4 in (100 mm) above the openings. It is to be observed whether the oil ignites the cheesecloth.

9.9.8 Five min after completion of the pouring of the oil, the cheesecloth is to be replaced with a clean piece and a second 0.34-ounce (10-cm^3 or 10-mL) ladle of hot flaming oil is to be poured onto the openings, again to be observed whether the cheesecloth is ignited. Five min later a third identical pouring is to be made. The openings do not comply with the requirement in 9.9.5 if the cheesecloth is ignited during any of the three pourings.

10 Internal Materials

10.1 Polymeric materials used within an enclosure shall be evaluated in accordance with:

a) In the United States, Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C

b) In Canada, CSA C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials

Exception: Unrated resistors, capacitors, semiconductors, integrated circuit packages, optical isolators, and similar electrical components meet the intent of the requirement when they are mounted on a material with a minimum flammability rating of V-1.

10.2 All combustible material used within an enclosure shall be V-2, HF-2, or better.

Exception No. 1: Motors, relays, capacitors, semiconductors, transformers, switches, insulating tubing or tape, and other electrical elements are exempt from the above requirement when they comply with the flame test applicable to the component. Meter faces and cases (when determined capable for mounting live parts) and indicator lamps or jewels, or both, are exempt from flammability requirements. The following requirements apply to parts that are isolated either by at least 0.5 in (12.5 mm) of air, or a solid barrier of V-1 or less-flammable material from uninsulated electrical parts that involve a risk from electrical energy-high current levels:

a) Gears, cams, belts, bearings, strain-relief bushings applied over PVC-jacketed cords, and other small parts that contribute negligible fuel to a fire is not required to be investigated.

b) Tubing for air or fluid systems, and plastics, shall not be more flammable than HB. Foamed plastics classed HBF in accordance with:

1) In the United States, Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, are determined as complying with this requirement.

2) In Canada, CSA C22.2 No. 0.17-00, Evaluation of Properties of Polymeric Materials.

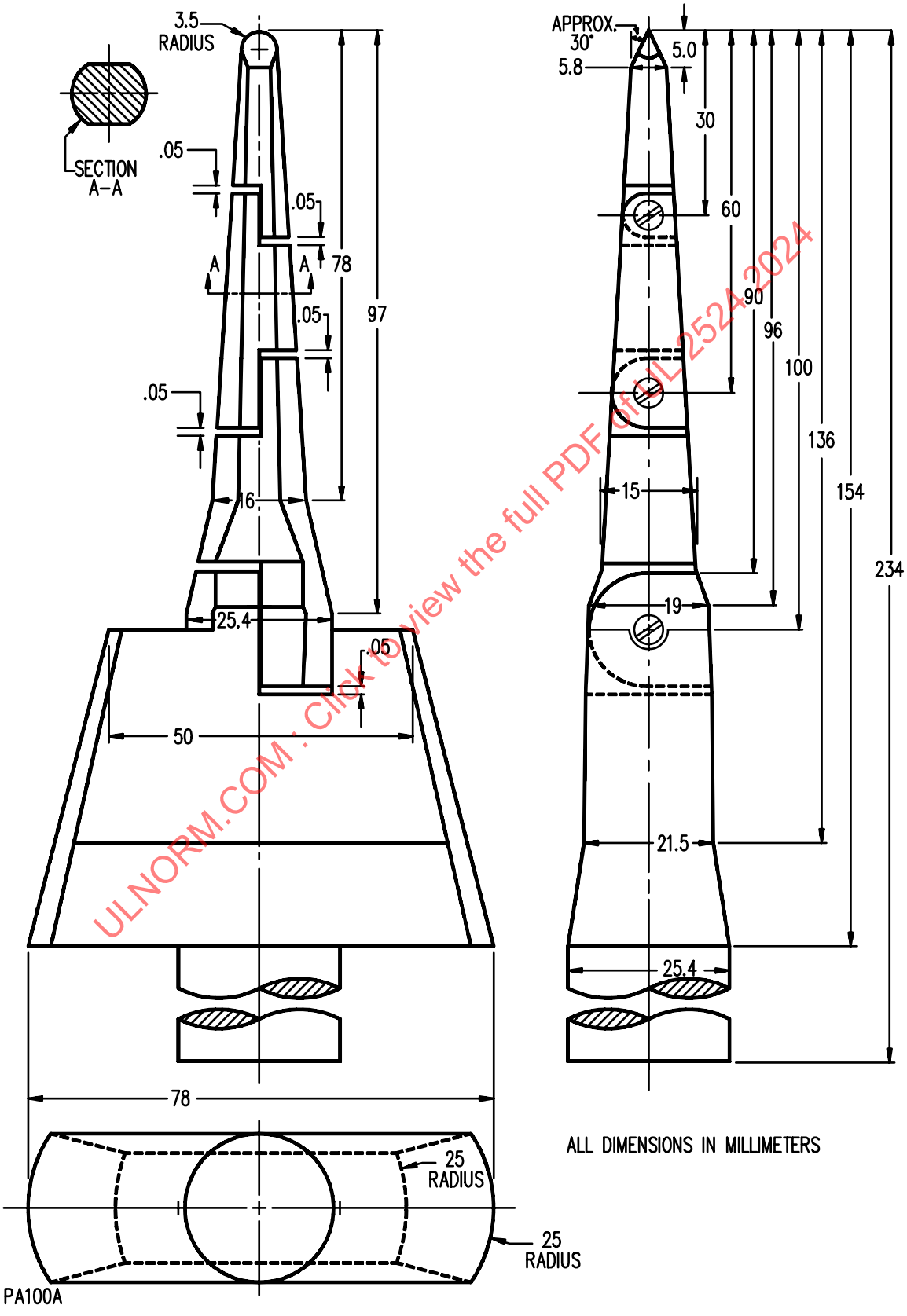
Exception No. 2: Combustible material used within an enclosure is not prohibited from being HB when the power sources to the enclosure meet the criteria for no risk of fire as defined in 6.29.

11 Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts

11.1 To reduce the risk of unintentional contact and electric shock from an uninsulated live part or film-coated wire, and injury to persons from a moving part, an opening in an enclosure shall have a minor dimension less than 1 in (25.4 mm), and such a part or wire shall not be contacted by the probe illustrated in Figure 11.1.

Figure 11.1

Articulate Probe with Web Stop



11.2 The probe illustrated in Figure 11.1 shall be applied to any depth that the opening will permit. The probe shall be rotated or angled before, during, and after insertion through the opening to any position that is required in order to examine the enclosure. The probe illustrated in Figure 11.1 shall be applied in any possible configuration and, when necessary, the configuration shall be changed after insertion through the opening.

11.3 The probe illustrated in Figure 11.1 shall be used as a measuring instrument to evaluate the accessibility provided by an opening, and not as an instrument to evaluate the strength of a material. It shall be applied with the minimum force required to determine accessibility.

11.4 During the examination of a product to determine whether it complies with the requirement in 11.1, a part of the enclosure that is to be opened or removed by the operator without using a tool (to attach an accessory, to make an operating adjustment, or for other reasons) shall be opened or removed.

12 Mechanical Assembly

12.1 All parts of a product shall be mounted in position and prevented from loosening or turning when such motion may adversely affect the performance of the product, or may increase the risk of fire, electric shock, and/or injury to persons incident to the operation of the product.

12.2 A switch, fuseholder, lampholder, attachment-plug receptacle, motor-attachment plug, or other similar component shall be mounted securely and shall not turn.

Exception No. 1: When the turning of a switch is possible, all four of the following conditions shall be met:

a) The switch shall be of a plunger, slide, or other type that does not tend to rotate when operated. A toggle switch is determined to be subject to forces that tend to turn the switch during intended operation of the switch;

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

c) The spacings are not reduced below the minimum required values when the switch rotates; and

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

Exception No. 2: When rotation does not reduce spacings below the minimum required value, a lampholder of the type in which the lamp cannot be replaced, such as a neon pilot or indicator light in which the lamp is sealed in a nonremovable jewel, complies with the intent of the requirement.

12.3 Friction between surfaces shall not be used for securing the position of the parts specified in 12.2.

12.4 A rotating part that by loosening presents a risk of fire, electric shock, electrical-energy/high-current levels, or injury to persons, shall be assembled so that the direction of rotation tends to tighten the means that hold the rotating part in place.

Exception: A keyed part, a press fit, a part locked in place with a pin, or means that have been determined to be equivalent, can be used to hold a rotating part in place.

12.5 All subassemblies, modules, and printed-wiring boards shall be held in their intended place in the product by mechanical means.

13 Protection Against Corrosion

13.1 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other means that have been determined to be equivalent, when corrosion of unprotected parts results in a risk of fire, electric shock, or injury to persons.

Exception No. 1: Surfaces of sheet-steel and cast-iron parts within an enclosure are not required to be protected against corrosion when oxidation of the metal due to exposure to air and moisture is not likely to weaken the parts to result in a condition of risk. The thickness of metal and temperature are also to be evaluated.

Exception No. 2: Bearings, laminations, or minor parts or iron or steel, such as washers, screws, and similar equipment, are not required to be protected against corrosion.

14 Branch-Circuit Connection

14.1 General

14.1.1 Products intended to be connected to the branch circuit supply shall be provided with a means for permanent connection to the branch-circuit supply.

14.2 Permanently connected

14.2.1 General

14.2.1.1 A product intended for permanent connection to the branch-circuit supply shall have provision for mechanically protecting the supply conductors.

14.2.1.2 A knockout or other supply-connection opening located where temperatures in excess of 140 °F (60 °C) have been measured during the Component Temperature Test, Section 42, and not having qualifying marking as specified in 53.1.10, shall be sealed by welding or the equivalent or be permanently marked adjacent to the opening with: "Do Not Use".

14.2.2 Field-wiring compartment

14.2.2.1 The location of a terminal box or compartment, in which branch-circuit connections to a permanently-wired product are to be made, shall be such that the connections can be readily inspected without disturbing the wiring or the product after the product has been installed as intended.

14.2.2.2 A terminal compartment intended for connection of a supply raceway shall be attached to the product so that it does not turn.

14.2.2.3 The field-wiring compartment area of a product shall be of sufficient size for completing all wiring connections as specified by the installation wiring diagram.

14.2.2.4 Where damage to field-wiring insulation may be caused by internal components or sharp edges in the wiring compartment, insulating or metal barriers having smooth, rounded edges shall be provided or the following or equivalent wording marked in the wiring area: “CAUTION – When Making Installation, Route Field Wiring Away From Sharp Projections, Corners, and Internal Components.”

14.2.2.5 The wiring terminals of a product 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 so as to damage the conductor insulation, and/or the terminals or stripped leads do not come into contact with the walls of the outlet box.

14.2.3 Field-wiring terminals and leads

14.2.3.1 A permanently connected product shall be provided with wiring terminals or leads for the connection of conductors having an ampacity not less than 125 % of the current input of the product when connected to a power-supply voltage in accordance with 32.1.1 – 32.1.6.

14.2.3.2 The free length of a lead inside a terminal box or compartment shall be 6 in (152 mm) or more, provided with strain relief, shall not be smaller than 18 AWG (0.82 mm^2), and the insulation, when of rubber or thermoplastic, shall not be less than 0.030 in (0.76 mm) minimum average and 0.027 in (0.69 mm) minimum at any point when the lead is intended for field connection to an external circuit.

Exception: The lead shall be less than 6 in (152 mm) long when it is evident that the use of a longer lead results in a risk of fire or electric shock

14.2.3.3 A field-wiring terminal shall be kept from turning or shifting in position by means other than friction between surfaces. This shall be accomplished by two screws or rivets, by square shoulders or mortises, by a dowel pin, lug or offset, by a connecting strap or clip fitted into an adjacent part, or by some other method determined to be the equivalent.

14.2.3.4 A field-wiring terminal shall comply with the requirements in 15.4 for field-wiring terminals (general application) except a wire-binding screw shall not have a diameter smaller than No. 8 (4.2 mm).

14.2.4 Identified terminals and leads

14.2.4.1 A permanently-connected product rated 125 or 125/250 V (3-wire) or less, and using a single-pole switch or overcurrent protective device other than an automatic control without a marked-off position, shall have one terminal or lead identified for the connection of the grounded conductor of the supply circuit.

14.2.4.2 A terminal intended for the connection of a grounded supply conductor shall be of or plated with metal that is white in color and shall be distinguishable from the other terminals, or identification of that terminal shall be shown in some other manner, such as on an attached wiring diagram.

14.2.4.3 A lead intended for the connection of a grounded power-supply conductor shall be finished white or gray color and shall be distinguishable from the other leads.

14.2.5 Strain relief

14.2.5.1 A means of strain relief shall be provided for the field supply leads of a product to prevent any mechanical stress from being transmitted to internal connections. Inward movement of the leads provided with a ring-type strain relief or means determined to be the equivalent shall not damage internal connections or components, or result in a reduction of electrical spacings.

14.2.5.2 Each lead used for field connections or an internal lead subjected to movement or handling during installation and servicing shall be capable of withstanding for 1 min a pull of 10 lbs (4.54 kg) without any evidence of damage or of transmitting the stress to internal connections.

15 Other Field-Wiring Connections

15.1 General

15.1.1 A product shall be provided with wiring terminals or leads for the connection of conductors of at least the size required by the National Electrical Code, NFPA 70, in the United States, or the Canadian Electrical Code in Canada, corresponding to the rating of the circuit.

15.1.2 All field-wiring connections shall be contained in either an enclosed field wiring compartment integral with the product or in a separate outlet box to which the product is to be mounted.

15.1.3 Duplicate terminals or leads, or an equivalent arrangement, shall be provided for circuits of products intended to be connected to initiating-device circuits of a fire alarm control unit, one for each incoming and one for each outgoing wire. It is not prohibited that a common terminal be used in lieu of duplicate terminals when it is intended to prevent the looping of an unbroken wire around or under a terminal screw in a manner that permits the looped wire to remain unbroken during installation, thereby precluding supervision in the event the wire becomes dislodged from under the terminal. A notched clamping plate under a single securing screw, where separate conductors are intended to be inserted in each notch, is an equivalent arrangement.

Exception: Duplicate terminals or leads are not required where the interconnecting pathway is intended to be made within 20 ft (6.1 m) of each other and are enclosed within conduit or equivalently protected against mechanical injury.

15.1.4 When duplicate terminals are not used in accordance with 15.1.3 and there is no provision to prevent looping an unbroken wire around or under one terminal, the information in 54.7 shall be included in the installation wiring diagram/instructions.

15.1.5 A single terminal intended to retain more than one conductor shall comply with the requirements of 15.4.2.

15.2 Field-wiring compartment

15.2.1 There shall be adequate space within a terminal or wiring compartment to permit the use of a standard conduit bushing when a bushing is required for installation.

15.2.2 The field-wiring compartment area of a product to which connections are to be made is to be of sufficient size for completing all wiring connections as specified by the installation wiring diagram.

15.2.3 Where it is possible for damage to field-wiring insulation to be caused by internal components or sharp edges in the wiring compartment, insulating or metal barriers having smooth, rounded edges shall be provided or the following (or wording determined to be the equivalent) marked in the wiring area: "CAUTION – When Making Installation, Route Field Wiring Away From Sharp Projections, Corners And Internal Components."

15.2.4 The wiring terminals of a product intended for mounting in an outlet or junction type box shall be located or protected so that, upon installation:

a) The wiring in the outlet box is not forced against the product, product's terminals, or sharp edges so as to damage the conductor insulation or product's unprotected components; and/or

b) A product with exposed wiring terminals shall be held in its intended mounting location inside the box by mechanical means.

15.3 In the United States – Power-limited circuits

15.3.1 When the design of the product is such that the product either requires or permits power-limited circuit conductors to occupy the same enclosure as electric light, power, Class 1, or non-power-limited fire-protective signaling-circuit conductors, or medium-power network-powered broadband communications-circuit conductors, both of the conditions in (a) and (b) shall be met:

a) The enclosure shall provide one or more cable openings into the enclosure. When a single opening is provided, a continuous and firmly fixed nonconductor, such as flexible tubing, shall be provided. This is required so that the power-limited conductors are segregated from electric light, power, Class 1 conductors, non-power-limited fire-protective signaling conductors, and medium-power network-powered broadband communications-circuit 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 1/4 in (6.4 mm) is provided between all power-limited conductors and all electric light, power, Class 1 conductors, non-power-limited fire-protective signaling conductors, or medium-power network-powered broadband communications-circuit conductors, or

2) For circuit conductors operating at 150 V or less to ground where the power-limited conductors are installed using Types FPL, FPLR, FPLP, or equivalent cables, a minimum 1/4 in (6.4 mm) separation is provided between these power-limited cable conductors extending beyond the jacket and all electric light, power, Class 1 conductors, non-power-limited fire-protective signaling conductors, and medium-power network-powered broadband communications-circuit conductors.

15.3.2 Compliance with this requirement shall be achieved by specific wire routing configurations that are detailed in the installation document, or when a wire routing scheme will not maintain the required separation, barriers, or nonconductive sleeving shall be used to provide separation.

15.4 Field-wiring terminals (general application)

15.4.1 A field-wiring terminal to which field-wiring connections are made shall comply with the requirements in:

a) 15.4.3 – 15.4.6;

b) In the United States

1) The field-wiring requirements in the Standard for Electrical Quick-Connect Terminals, UL 310;

2) The Standard for Wire Connectors, UL 486A-486B;

3) The Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E; or

4) The Standard for Terminal Blocks, UL 1059, rated for field-wiring (FW) Code 2 applications and also suitable for the voltage, current, wire range, and wire type of the intended application.

c) In Canada

1) The field-wiring requirements in the CSA C22.2 No. 223, Power Supplies with Extra-Low-Voltage Class 2 Outputs;

2) The CSA C22.2 No. 65, Wire Connectors, and CSA C22.2 No. 88, Splicing Wire and Cable Connectors; or

3) The CSA C22.2 No. 158, Terminal Blocks rated for field-wiring (FW) Code 2 applications and also suitable for the voltage, current, wire range, and wire type of the intended application.

15.4.2 A single terminal intended to concurrently retain more than one conductor shall meet the requirements of 15.4.1 (b), (c), (d), or (e) while retaining the intended multiple conductors.

15.4.3 Nonferrous soldering lugs or solderless (pressure) wire connectors shall be used for 10 AWG (5.3 mm^2) and larger wires. When the connectors or lugs are secured to a plate, the plate thickness shall not be less than 0.050 in (1.3 mm) thick. Securing screws of plated steel have been determined to meet the requirements.

15.4.4 A wire-binding screw used at a wiring terminal shall not be smaller than No. 8 (4.2 mm) diameter. Plated screws are not prohibited.

Exception: A No. 6 (3.5 mm) diameter screw is appropriate for use for the connection of a 14 AWG (2.1 mm^2) and a No. 4 (2.8 mm) diameter screw is appropriate for use for the connection of a 19 AWG (0.65 mm^2) or smaller conductor.

15.4.5 Terminal plates 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 provide equivalent thread security of the wire-binding screw.

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

15.4.6 When 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 when two conductors are separated and intended to be secured under a common clamping plate. When the wires protrude above terminal barriers, the nonferrous separator shall include means, such as upturned tabs or sides, to retain the wire.

15.5 Field-wiring terminals (qualified application)

15.5.1 Any of the following terminal configurations are suitable for connection of field wiring when all of the conditions in 15.5.2 are met:

a) Telephone-Type Terminals – Nonferrous terminal plates using a narrow, V-shaped slot for securing of a conductor in a special post design (requires a special tool for wire connection);

b) Solderless Wrapped Terminals – Solderless, wrapped, nonferrous terminals which require a special tool and terminal post design;

c) Quick-Connect Terminals – Nonferrous, quick-connect (push-type) terminals consisting of male posts permanently secured to the device and provided with compatible, female connectors for

connection to field wiring. These require a special tool for crimping of field wires. Mating terminals shall be shipped with the control unit with instructions for their installation;

d) 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 are removable by means of a tool inserted to relieve the spring tension on the conductor. Push-in terminals are not to be used with aluminum conductors. The marking adjacent to the terminal shall indicate that copper conductors only are to be used; and

e) Other Terminals – Other terminal connections are not prohibited when determined to be equivalent to (a) – (d) and are limited to the same restrictions.

15.5.2 Any of the terminal configurations listed in 15.5.1 are appropriate for connection of field wiring provided all of the following indicated conditions are met.

a) When a special tool is required for connection, it shall be provided and its use indicated on the installation wiring diagram by name of the manufacturer and the 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 less than 26 AWG (0.13 mm^2).

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

d) Removal of a lead for testing or routine servicing, including detection, location, and correction of installation wiring faults, is prohibited.

e) A means for testing for an open and a ground fault on the circuit(s) to which the wiring is connected shall be incorporated into the control unit or indicated on the installation wiring diagram.

f) The terminal assembly shall comply with the Tests on Special Terminal Assemblies, Section 44.

15.6 Field-wiring leads

15.6.1 General

15.6.1.1 Leads provided for splice connections shall be minimum 6 in (152 mm) long.

Exception: The free-lead length is not prohibited from being less than 6 in long when it is evident that the use of a longer lead results in damage to the lead insulation or product, or in a risk of fire, electric shock, or injury to persons.

15.6.1.2 A means of strain relief shall be provided for the field wiring leads, and all internally connected wires which are subject to movement in conjunction with the installation, operation, or servicing of a product to prevent any mechanical stress from being transmitted to terminals and internal connections. Inward movement of the leads provided with a ring-type strain relief or means determined to be the equivalent shall not damage internal connections or components, or result in a reduction of electrical spacings.

15.6.1.3 Each lead used for field connections or an internal lead subjected to movement or handling during installation and servicing shall be capable of withstanding for 1 min a pull of 10 lbs (4.54 kg) without any evidence of damage or of transmitting the stress to internal connections.

15.6.2 Circuits with voltages exceeding 30 V rms or 42.4 v dc

15.6.2.1 A lead provided for field connection to a circuit with voltages exceeding 30 V rms or 42.4 V DC shall not be smaller than 18 AWG (0.82 mm^2), and the insulation, when of rubber or thermoplastic, shall be minimum 0.30 in (0.76 mm) minimum average and 0.027 in (0.69 mm) minimum at any point.

15.6.3 In the United States – Power-limited circuits

15.6.3.1 A lead provided for field connection to a power-limited circuit involving a potential of not more than 30 V alternating current (AC) rms, 42.4 V direct current (DC) shall be no smaller than 22 AWG (0.32 mm^2) and the insulation shall be a minimum of 1/64 in (0.4 mm) thick.

Exception: Copper leads as small as 26 AWG (0.13 mm^2) are permitted to be used only when:

a) The current does not exceed 1 amp for lengths up to 2 ft (61 cm) or 0.4 amp for lengths up to 10 ft (3.05 m);

b) There are two or more conductors and they are covered by a common jacket or the equivalent;

c) The assembled conductors comply with the strain-relief requirement specified in the Strain-Relief Test, Section 45; and

d) The installation instructions indicate that the lead shall not be spliced to a conductor larger than 18 AWG (0.82 mm^2).

16 Internal Wiring

16.1 General

16.1.1 The wiring and connections between parts of a product shall be protected or enclosed, or they shall be in a cord or cable that has been evaluated and determined to be rated for the application.

16.1.2 Internal wiring shall be routed and secured so that the wires and electrical connections are not subjected to stress or mechanical damage.

16.1.3 A hole in a wall within the overall enclosure of a product through which insulated wires pass, shall be provided with a bushing or shall have smooth, rounded surfaces.

16.1.4 Internal wiring shall be evaluated and determined to be rated for the application, with respect to temperature, voltage, ampacity, and exposure to oil, grease, solvents, acids, and other conditions of service to which the wiring is subjected.

16.1.5 When it is possible that internal wiring is to be exposed to moisture, including any condensation resulting from operation of the product, the wiring shall be evaluated and determined to be rated for such exposure.

16.1.6 Vibration, impact, flexing, or other movement of wires during intended use, including user servicing, shall not reduce the wire insulation or the wire termination integrity.

16.1.7 A lead or a cable assembly connected to a part mounted on a hinged cover shall be long enough to permit the full opening of the cover without applying stress to the lead or the connections. The lead shall be secured, or equivalently arranged, to reduce the risks of abrasion of the insulation and jamming of the leads between parts of the enclosure.

16.1.8 Metal clamps and guides used for routing stationary internal wiring shall be provided with smooth, well-rounded edges. Auxiliary non-conducting mechanical protection shall be provided:

a) Under a clamp at which pressure is exerted on a conductor having thermoplastic insulation less than 1/32 in (0.8 mm) thick and no overall braid and

b) On any wire(s) that is subject to motion.

16.1.9 Wires shall be routed away from sharp edges (such as those found on screw threads, burrs, and fins), moving parts, and similar hazards, which tend to damage the wire insulation.

16.1.10 Insulated wires bunched and passed through a single opening in a metal wall within the enclosure of the product are not prohibited when the other requirements of this standard are met.

16.1.11 Supplementary insulation shall be applied to internal wiring that involves a risk of electric shock and is exposed during user servicing.

16.1.12 Internal wiring of circuits that operate at different potentials shall be separated by barriers or shall be segregated, unless the conductors of the circuits of lower voltage are provided with insulation for the highest voltage.

16.1.13 Clamping, routing, or equivalent means that ensures permanent separation may accomplish segregation of insulated conductors.

16.2 Splices and connections

16.2.1 All splices and connections shall be mechanically secure and shall be investigated and determined to provide intended electrical continuity. A soldered connection shall be made mechanically secure before being soldered. Consideration shall be given to vibration when investigating electrical connections. Pressure-wire connectors have been determined to comply with the requirements.

16.2.2 A splice shall be provided with insulation determined to be the equivalent to that of the wires involved when permanence of spacing between the splice and other metal parts is incapable of being maintained.

16.2.3 In determining whether or not splice insulation consisting of coated-fabric, thermoplastic, or another type of tape or tubing complies with the aforementioned requirements, a comparison is to be made of factors such as mechanical strength, dielectric properties, and heat- and moisture-resistant characteristics. Thermoplastic tape wrapped over sharp edges does not comply with the intent of this requirement.

16.2.4 When stranded internal wiring is connected to a wire-binding screw, there shall not be loose strands of wire that contact other uninsulated live parts or dead-metal parts. This shall be accomplished by use of pressure-terminal connectors, soldering lugs, crimped eyelets, soldering all strands of the wire together, or other means that have been determined to be equivalent.

16.3 Connectors and receptacles

16.3.1 A receptacle or connector shall be suitable for the current and voltage to which it is to be subjected.

17 Protective Devices

17.1 A fuseholder, overcurrent protective device (other than an automatic control without a marked off position), the center contact of a screwshell-base lampholder, an interlock, and a manual on-off switch with a marked off position shall be connected to the ungrounded side of the line when used in a circuit with voltages exceeding 30 V rms or 42.4 V DC.

17.2 A fuseholder shall be of either the cartridge-enclosed or plug-fuse type. The use of plug fuses is to be limited to equipment rated at not more than 125 or 125/250 V.

17.3 Fuses, fuseholders and circuit breakers shall be rated for the application.

17.4 In the United States – All external circuits intended to be connected to nonpower-limited wire shall contain either current-limiting or overcurrent protection to prevent fault currents in excess of the current rating for the gauge wire size permitted by the National Electrical Code, NFPA 70, or as specified in the installation wiring diagram/instructions. See 38.2.3.

17.5 In Canada – All external circuits intended to be connected to non-Class 2 wire shall contain either current-limiting or overcurrent protection to prevent fault currents in excess of the current rating for the gauge wire size permitted by the CSA C22.1, Canadian Electrical Code, Part I, Safety Standard for Electrical Installations, or as specified in the installation wiring diagram/instructions. The overcurrent protection provided shall be as specified in CSA C22.1, Canadian Electrical Code, Part I, Safety Standard for Electrical Installations. See 38.2.3.

18 Current-Carrying Parts

18.1 Except as noted in 18.2, current-carrying parts shall be of silver, copper, a copper alloy, stainless steel, aluminum, or other nonferrous material intended for the application.

18.2 Plated steel meets the intent for some secondary-circuit or primary-circuit parts (such as capacitor terminals) when a glass-to-metal seal is necessary and for leads or threaded studs of semiconductor devices. Blued steel or steel with an equivalent corrosion resistance meets the intent for the current-carrying arms of mechanically or magnetically-operated leaf switches, and within a motor and motor governor including the motor terminals, or when the temperature is in excess of 100 °C (212 °F) during the intended operation.

18.3 Bearings, hinges, and the like shall not be used as current-carrying parts.

19 Spacings

19.1 A product shall provide maintained spacings between uninsulated live parts and the enclosure or dead-metal parts, and between uninsulated live parts of opposite polarity. The spacings shall not be less than those indicated in Table 19.1.

Exception: On printed-wiring boards having a flammability classification of V-0 in accordance with:

a) In the United States, Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94

b) In Canada, CSA C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials

spacings (other than spacings to dead metal traces, between primary and secondary circuits, and at field wiring terminals) are not specified between traces of different potential connected in the same circuit when:

1) The spacings are adequate to comply with the requirements in 43.8, Evaluation of reduced spacings on printed-wiring boards; or

2) An analysis of the circuit indicates that no more than 12.5 mA of current is available between short-circuited traces having reduced spacings.

Table 19.1
Minimum Spacings

Point of application	Minimum spacings				
	Voltage range	Through air		Over surface	
	V	in	(mm)	in	(mm)
To walls of enclosure:					
Cast metal enclosures	0 – 300	1/4	(6.4)	1/4	(6.4)
Sheet metal enclosures	Power or non-power limited 0 – 50	1/4	(6.4)	1/4	(6.4)
	Power limited 51 – 300	1/4	(6.4)	1/4	(6.4)
	Non-power limited 51 – 150	1/2	(12.7)	1/2	(12.7)
	Non-power limited 300 – 600	1/2	(12.7)	1/2	(12.7)
Installation wiring terminals:					
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	1/4	(6.4)	3/8	(9.5)
Rigidly clamped assemblies:[b]					
Class 2, Power Limited	0 – 30	–	–	–	–
Non Class 2, Power Limited	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)
	300 – 600	3/8	(9.5)	1/2	(12.7)
Other parts					
	0 – 30	1/16	(1.6)	1/8	(3.2)
	31 – 150	1/8	(3.2)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)
	300 – 600	3/8	(9.5)	1/2	(12.7)

[a] Measurements are to be made with solid wire of adequate ampacity for the applied load connected to each terminal. In no case shall the wire be smaller than 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.

19.2 The through-air and over-surface spacings at an individual component part are to be determined on the basis of the volt-amperes used and controlled by the individual component. The spacing from one component to another, however, and from any component to the enclosure or to other uninsulated dead metal parts, shall be determined on the basis of the maximum voltage and total volt-ampere rating of all components in the enclosure.

19.3 The spacing requirements in Table 19.1 do not apply to the inherent spacings inside motors, except at wiring terminals, or to the inherent spacings of a component which is provided as part of the control unit. Such spacings are determined on the basis of the requirements for the component. The electrical clearance resulting from the assembly of a component into the complete device, including clearances to dead metal or enclosures, shall be as specified in Table 19.1.

19.4 The "To-walls-of-enclosure" spacings indicated in Table 19.1 are not to be applied to an individual enclosure of a component part within an outer enclosure.

19.5 An insulating liner or barrier of vulcanized fiber, varnished cloth, mica, phenolic composition, or similar material used where spacings would otherwise be insufficient, shall be minimum 0.028 in (0.71 mm) thick; except that a liner or barrier that is minimum 0.013 in (0.33 mm) thick meets the intent when used in conjunction with a minimum of one-half of the through-air spacing required. The liner shall be located so that it will not be affected adversely by arcing.

19.6 Insulating material having a thickness less than that specified in 19.5 meets the intent when it has been determined to have equivalent mechanical and electrical properties.

19.7 Film-coated wire is identified as a bare current-carrying part in determining compliance of a device with the spacing requirements, but the coating is suitable as turn-to-turn insulation in coils.

19.8 The spacings within snap switches, lampholders, and similar wiring devices supplied as part of a unit are determined under other requirements for such devices and is not required to comply with the requirements of Table 19.1. See Sections 2 – 5.

20 Insulating Material

20.1 Uninsulated live parts involving risk of fire, electric shock, or electrical-energy/high-current levels shall be mounted on porcelain, phenolic composition, or other material that has been determined acceptable for the application.

20.2 Vulcanized fiber is not prohibited from being used for insulating bushings, washers, separators, and barriers, but not as the sole support for uninsulated live parts when shrinkage, current leakage, or warpage introduces a risk of fire, electric shock, or injury to persons. Thermoplastic materials used for the direct or indirect support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high-current shall comply with the requirements:

a) In the United States, Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C

b) In Canada, CSA C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials.

20.3 Molded parts shall have the mechanical strength and rigidity to withstand the stresses of actual service.

20.4 An insulating liner shall be investigated and determined to be rated for the purpose. Barriers shall be held in place by a means more secure than friction between surfaces. The elasticity of tubing shall not be depended upon to hold the tubing in place. Heat-shrink tubing has been determined to meet this requirement where a sharp edge or point is not involved.

21 Printed-Wiring Boards

21.1 Printed-wiring boards shall be suitable for the application. The securing of components to the board shall be made in the intended manner and the spacings between circuits shall comply with the

requirements for Spacings, Section 19. The board shall be reliably mounted so that deflection of the board during installation or servicing shall not result in damage to the board or in developing a risk of fire or electric shock.

21.2 All printed-wiring boards shall have a minimum flammability rating of V-2, rated for direct support of current-carrying parts, and be suitable for the soldering process used.

22 End-of-Line Devices

22.1 An end-of-line device shall be constructed as follows:

a) Where the circuit in which the end-of-line device is to be connected is intended for connection by conduit or metal-clad cable, the device shall be arranged for mounting inside of a metal box to which such connection can be made. Mounting on an outlet box cover with terminals or leads provided for field connection, or an equivalent arrangement, has been determined as complying with the intent of this requirement.

b) Where the end-of-line device is intended to be installed inside a back-box, splice leads, or terminals suitable for making field connections, shall be provided. Splice leads shall have a diameter of not less than 18 AWG (0.82 mm^2). The exposed live parts of the assembly, except for the connection portion of the terminal, shall be covered with insulating tubing or the equivalent.

c) Where the end-of-line device is intended to be installed inside a product, such as a 2-way emergency radio enhancement unit or accessory:

1) Splice leads or terminals suitable for making field connections shall be provided. Splice leads shall have a diameter not less than 18 AWG. The exposed live parts of the assembly, except for the connection portion of the terminal, shall be covered with insulating tubing or the equivalent; or

2) It shall be provided with terminations compatible with the product's provisions for field wiring connections. When installed per the manufacturer's installation instructions, it shall be securely fastened with no means to open circuit, short to an adjacent circuit node, or cause a risk of electric shock. To avoid damage to the body of the end-of-line device during installation, the device shall be either supplied pre-formed or forming instructions shall be included in the installation instructions.

d) Where the circuit in which the end-of-line device is to be connected is intended for connection by coaxial cable, the device shall be enclosed. The coaxial connections may be internal or external on the enclosure. The enclosure shall be provided with a means for mounting.

23 Voltage-Dropping Resistors

23.1 A carbon composition resistor shall not be used as a line voltage-dropping resistor in a supply circuit with voltages exceeding 30 V rms or 42.4 V DC of a product.

24 Coil Windings

24.1 Relays, transformers, and similar devices used in circuits with voltages exceeding 30 V rms or 42.4 V DC shall be evaluated and rated for the intended purpose, or comply with the applicable requirements for the component. See Annex A.

24.2 The insulation of coil windings of relays, transformers, and similar components, shall be such as to resist the absorption of moisture.

24.3 Film-coated wire is not required to have an additional treatment to prevent moisture absorption.

25 Components

25.1 Switches

25.1.1 A switch provided as part of a product shall have a current and voltage rating not less than that of the circuit which it controls when the device is operated under any condition of intended service.

25.2 Lampholders and lamps

25.2.1 Lampholders and lamps shall be rated for the circuit in which they are employed when the product is operated under any condition of intended service.

25.2.2 Except for circuits operating at 30 V, root-mean-square (rms), 42.4 V direct current (DC) or 42.4 V peak, or less, a lampholder shall be installed so that uninsulated live parts other than a screw shell will not be exposed to contact by persons removing or replacing lamps.

25.2.3 The color coding of lamps or equivalent indicators employed as part of a product shall not be the sole means of identifying the function of the indicator.

Exception: Lamps and indicators used by service personnel for diagnostic purposes, provided that they are identified in the product's installation instructions/manual.

25.3 Operating mechanisms

25.3.1 Operating parts, such as light-duty relays and similar devices, shall be protected against fouling by dust or by other material that may adversely affect their intended operation, by individual protection or dust-tight cabinets. A relay employing contacts having a wiping action does not require any special protection against fouling by dust.

25.3.2 The assembly of an operating mechanism included as a part of a control unit or accessory shall be such that it will not be adversely affected by any condition of intended operation.

25.3.3 Moving parts shall have sufficient play at bearing surfaces to prevent binding.

25.3.4 Provision shall be made to prevent adjusting screws and similar adjustable parts from loosening under the conditions of actual use.

25.3.5 Manually-operated parts shall withstand the stresses to which they will be subjected in operation.

25.3.6 An electromechanical device shall be constructed to provide reliable and positive electrical and mechanical performance under all conditions of intended operation.

25.3.7 Relays used in separately emerged circuits and in battery charger transfer circuits shall be rated for the intended loading and comply with the applicable requirements for the component.

25.3.8 When a circuit controlled by an operating device described in 25.3.7 has a power factor less than 75 %, the integral operating device shall employ the following ratings:

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

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

25.4 Across-the-line components

25.4.1 Components such as capacitors and EMI filters, connected across the supply circuit of a product with voltages exceeding 30 V rms or 42.4 V DC, shall be rated for the purpose and comply with the applicable requirements for the component. See Annex A.

25.4.2 A component is considered to be across the supply circuit with voltages exceeding 30 V rms or 42.4 V DC when, in a shorted condition, a current of more than 1 amp passes through it when the product is in any condition where the individual components have reached ultimate operating temperatures. The current through the component can be limited to 1 amp or less by a fixed impedance or a protective device rated 1 amp or less.

25.4.3 A capacitor is also considered to be across-the-line when it is used under either of the following conditions:

a) For supply-line bypass of voltages exceeding 30 V rms or 42.4 V DC in equipment provided with a terminal or connection intended to be grounded or

b) For antenna blocking or supply-line bypass of voltages exceeding 30 V rms or 42.4 V DC in equipment provided with one or more external antenna terminals that may be grounded.

26 Batteries

26.1 Rechargeable storage-type used as standby power source

26.1.1 A storage battery shall have sealed cells, or cells with spray trap vents, and shall be maintained in the charged state.

26.1.2 Batteries shall be located and mounted so that terminals of cells are prevented from coming into contact with terminals of adjacent cells or with metal parts of the battery enclosure as a result of shifting of the batteries.

26.1.3 The mounting arrangement for the batteries shall permit access to the cells for testing and maintenance, or the product shall provide integral meters or readily accessible terminal facilities for the connection of meters for determining battery voltage and charging current.

26.1.4 A conditioning charge shall be limited so that, with the maximum rate of charge that can be obtained, the battery gases do not adversely affect any part of the product. The trickle and fast charge rates of a battery shall not exceed the battery manufacturer's recommended rates.

26.1.5 The battery shall be protected against excessive loading or charging current by a fuse or other overcurrent protective device.

26.2 Lithium batteries

26.2.1 Multiple lithium batteries connected in series or parallel shall comply with the requirements in the Standard for Household and Commercial Batteries, UL 2054.

26.2.2 A lithium battery shall be protected from abnormal charging currents during use as required in the Standard for Lithium Batteries, UL 1642.

Exception: A circuit that obtains power solely from a lithium battery (for example, a circuit in which the lithium battery serves as the sole power source as opposed to serving as a standby power source) is not required to be subjected to the abnormal charging current requirements in UL 1642.

27 Grounding for Products Containing Circuits with Voltages Exceeding 30 V rms or 42.4 V DC

27.1 A product which involves circuits with voltages exceeding 30 V rms or 42.4 V DC shall have provision for the grounding of all exposed dead metal parts that might become energized from circuits involving a risk of electric shock.

Exception: Metal parts as described in (a) – (d):

a) Adhesive-attached metal-foil markings, screws, handles, etc., which are located on the outside of the enclosure and isolated from electrical components or wiring by grounded metal parts so that they are not liable to become energized.

b) Isolated metal parts, such as small assembly screws, etc., which are positively separated from wiring and uninsulated live parts.

c) Panels and covers that do not enclose uninsulated live parts when wiring is positively separated from the panel or cover so that it is not liable to become energized.

d) Panels and covers which are insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material that is a minimum of 0.8 mm (1/32 in) thick.

27.2 On fixed equipment, the provision of a knockout or other opening in a metal enclosure for the connection of metal-clad cable, conduit, metal raceway, or the like is permitted as a means for grounding.

27.3 When a product is provided with means for separate connection to more than one power supply, each such connection shall be provided with a means for grounding.

27.4 All dead-metal parts that are accessible during intended use or user servicing, and that are capable of becoming energized from circuits involving a risk of electric shock, shall be connected together and to the grounding means.

Exception: Metal parts as described in the Exception to 27.1.

27.5 The following circuits shall be bonded to ground under the indicated conditions:

a) Alternating current circuits less than 50 V:

1) Where supplied by transformers if the transformer supply system exceeds 150 V to ground.

2) Where supplied by transformers if the transformer supply system is ungrounded.

3) Where installed as overhead conductors outside of buildings.

b) Alternating current circuits of 50 V and over:

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

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

c) Direct-current circuits operating at 51 – 300 V.

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

27.7 A bolted or screwed connection that incorporates a star washer or serrations under the screw head for penetrating nonconductive coatings is identified as complying with 27.6.

27.8 Where the bonding means depends upon screw threads, the use of two or more screws or two full threads of a single screw engaging metal is in compliance with 27.6.

27.9 A field-wiring terminal intended solely for connection of an equipment-grounding conductor shall be capable of securing a conductor of the size specified in Table 27.1.

Table 27.1
Bonding Wire Conductor Size

Rating of overcurrent device, amp	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.

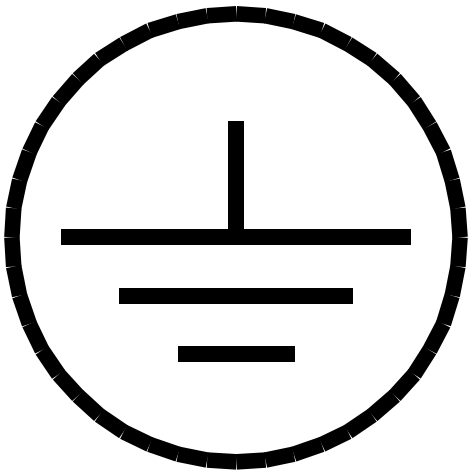
27.10 The size of a copper or aluminum conductor used to bond an electrical enclosure shall be based on the rating of the branch-circuit overcurrent device by which the equipment will be protected. The size of the conductor shall be in accordance with Table 27.1.

27.11 Splices shall not be used in wire conductors used for bonding.

27.12 A wire-binding screw or a pressure wire connector intended for the connection of an equipment-grounding conductor shall have a green-colored head or shall be plainly identified as such by being marked "G," "GR," "GND," "Ground," "Grounding," or the like, or with the Symbol 5019 graphic from IEC Publication 60417-1 shown in Figure 27.1, or by a marking on the wiring diagram provided on the product. The wire-binding screw or pressure wire connector shall be located so that it is not able to be removed during intended servicing of the product. When used alone, the Symbol 5019 graphic from IEC Publication 60417-1 shall be defined in the installation instructions provided with the equipment.

Figure 27.1

International Electrical Symbol



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

27.14 The grounding conductor in a flexible cord shall be green with or without one or more yellow stripes. The grounding conductor shall be secured to the frame or enclosure of the product by means of a screw, rivet, or similar equipment that is not removable during intended servicing not involving the supply cord. Solder shall not be used alone for securing the grounding conductor. The grounding conductor shall be connected to the grounding terminal of an attachment plug.

27.15 When a means for grounding is provided on the product, even though it is not required, it shall comply with the requirements in 27.1 – 27.14.

27.16 Metal-to-metal hinge-bearing members for doors or covers are considered to meet the requirement for bonding the door or cover to ground, when a multiple bearing pin type (piano-type hinge) is used.

Exception: Slip-joint or similar, hinge-bearing members are not required to comply with this requirement when the resistance between the two parts connected by the bonding element is not more than 0.1 ohm. The resistance shall be determined by a resistance-measuring instrument. When unacceptable results are recorded, an alternating or direct current of at least 20 amp from a power supply of not more than 12 V shall be passed between the two parts connected by the bonding element. The resulting drop in potential and the test current shall be measured between the two points. The resistance in ohms shall be determined by dividing the drop in potential in volts by the current in amperes.

28 Servicing Protection

28.1 General

28.1.1 Uninsulated live parts of circuits exceeding 30 V rms or 42.4 v dc, hazardous moving parts, sharp corners and projections shall be formed, located, guarded, or enclosed so as to prevent contact by persons during servicing such as relamping, fuse or rod replacement, battery replacement, adjusting controls, and routine maintenance.

28.2 Trained service personnel

28.2.1 When the linear distance from a component requiring servicing or an operating switch and any uninsulated current-carrying parts of circuits with voltages exceeding 30 V rms or 42.4 V DC is less than 152 mm (6 in), then protection by properly applied insulating tape, barriers, or equivalent, shall be provided.

28.2.2 Insulating barriers, or equivalent required by 28.2.1 shall be permanently and prominently marked with the cautionary marking:

a) In the United States, “WARNING: ELECTRICAL SHOCK HAZARD” or equivalent

b) In Canada, “WARNING: ELECTRICAL SHOCK HAZARD” and « AVERTISSEMENT: RISQUE DE CHOC ELECTRIQUE ».

28.2.3 In lieu of the minimum 152 mm (6 in) requirement only for serviceable components, the product shall comply with one of the following:

a) An interlock shall be provided on the cover to de-energize all live parts in the enclosure; or

b) The following permanent and prominent marking shall be provided on the cover front:

1) In the United States, "CAUTION – De-Energize Unit Prior To Servicing."

2) In Canada, "CAUTION – De-Energize Unit Prior To Servicing" « MISE EN GARDE – De-Energize appareil avant entretien. »

28.2.4 Uninsulated live parts or moving parts involving a risk of injury shall be located, guarded, or enclosed so as to reduce the risk of contact by persons during servicing conditions such as relamping, changing fuses, adjusting controls, and operating switches.

28.3 Antenna terminal discharge assembly

28.3.1 Each terminal provided for the connection of an external antenna shall be conductively connected to the supply circuit grounded conductor. The conductive connection shall have a maximum resistance of 5.2 Mohm, a minimum wattage rating of 1/2 W, and shall be effective with the power switch in either the on or off position.

Exception No. 1: The conductive connection need not be provided when:

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

b) The breakdown does not result in a 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 Mohm.

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

28.3.2 The maximum value of 5.2 Mohm specified in 28.3.1 is to include the maximum tolerance of the resistor value used; that is, a resistor rated 4.2 Mohm with 20 % tolerance or a resistor rated 4.7 Mohm with a 10 % tolerance.

PROTECTION AGAINST INJURY TO PERSONS

29 General

29.1 When the operation and maintenance of a product by the user involves a risk of injury to persons, protection shall be provided to reduce the risk.

29.2 When investigating a product with regard to 29.1, determination shall be given to foreseeable misuse of the product.

29.3 An accessory that is made available or recommended by the manufacturer for use with the basic product shall be included in the evaluation of the product.

29.4 The suitability of a guard, a safety release, an interlock and similar devices, and whether such a device is required, is to be determined from an investigation of the complete product, its operating characteristics, and the risk of injury to persons. The investigation is to include evaluation of the results of breakdown or malfunction of any one component, but not more than one component at a time, unless one event contributes to another. When the investigation shows that breakdown or malfunction of a component results in a risk of injury to persons, the component shall be investigated for reliability.

29.5 A risk of injury to persons is possible when one or more of the following conditions exist:

a) Power-operated moving parts such as gears and linkages are accessible during intended operation or maintenance and are capable of causing a cut or laceration;

b) Sharp edges, burrs, or projections are present during use or servicing;

c) The stability of a product is such that it is capable of causing injury to persons (see Stability, Section 31);

d) There is a possibility that a part of the body is endangered or that clothing is capable of being entangled by a moving part.

30 Sharp Edges

30.1 An enclosure, edge, frame, projection, guard, opening, handle, or similar construction shall be smooth and free from sharp edges that are capable of injury to persons during intended maintenance and use.

Exception: A sharp edge that must be exposed to enable the product to perform its intended function.

30.2 For edges where the degree of sharpness cannot be determined by inspection, compliance with 30.1 is determined by the test procedure in the Standard for Test for Sharpness of Edges on Equipment, UL 1439.

31 Stability

31.1 Under all conditions of servicing and intended use, a fully assembled product shall not become physically unstable to the degree that creates a risk of injury to operators or service personnel.

31.2 A product shall not tip over when tilted 10° from its intended, upright position, while all doors, covers, gates, drawers, and similar parts are in place and closed, and all casters and jacks, when provided, are in their most unfavorable position.

Exception: For fixed or stationary equipment without casters where specialized handling is required to transport the product, this test is to be performed after the equipment is installed as intended.

31.3 The requirements in 31.4 – 31.8 apply to all freestanding products. A freestanding product is defined as one that is floor standing and not intended to be secured to other units or to the floor or other parts of the building.

31.4 In conducting the tests described in 31.5 – 31.7, the equipment shall be installed as intended. All casters and jacks, when provided, are to be placed in their most unfavorable positions, and wheels are to be locked or blocked. However, when casters are being used only to transport the product, and jacks are lowered after installation, then the jacks (and not the casters) are to be used in their most unfavorable position for the test, consistent with reasonable leveling of the product.

31.5 A freestanding product that has an external surface (work top or ledge) at a height not exceeding 39-3/8 in (1.00 m) from the floor and that is prone to being stepped on or sat upon, shall not tip over when a continuous downward force of 179.8 lbf (800 N) is applied to that surface at the point of maximum moment. For this test, all doors, covers, gates, drawers, and similar parts shall be in place and closed.

31.6 With regard to the requirement in 31.5, delicate parts such as keyboards, control panels, or spools are not determined as prone to being stepped on or sat upon.

31.7 A freestanding product more than 39-3/8 in (1.00 m) high and weighing more than 55.1 lbs (25.0 kg) shall not tip over when a force equal to 1/5 the weight of the unit but not more than 56.2 lbf (250 N) is applied in any direction, except upward, at a height not exceeding 78-3/4 in (2.00 m) from the floor. For this test, all doors, drawers, frames, and the like that can be opened for operator or serviceman servicing are to be opened and in the most unfavorable position. Separate tasks are to be performed when operator and service extensions are different or when special stabilizers are used in accordance with 31.8.

31.8 A stabilizing means is not prohibited from being used to improve stability when doors, drawers, and the like are opened. The stabilizing means shall be automatic in operation or interlocked when associated with user use. For service personnel, where it is not automatic in operation, a conspicuous marking shall be provided to caution the personnel on its use. See 53.1.19.

PERFORMANCE – GENERAL

32 Details

32.1 Tests and voltages

32.1.1 Except as otherwise indicated, the performance of a product shall be investigated by subjecting a representative sample in commercial form to the tests described in Section 33 – 47.

32.1.2 Products that currently meet all the requirements of one of the standards indicated below are not required to be evaluated to the following sections: 38.1, 39, 40, 41, 42, 43, 44, and 46.

a) In the United States

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

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

3) Standard for Audio, Video, and Similar Electronic Apparatus – Safety Requirements, UL 60065.

b) In Canada

1) CSA C22.2 No. 60950-1, Information Technology Equipment, or

2) CSA C22.2 No. 60065, Audio, Video, and Similar Electronic Apparatus – Safety Requirements, or

3) CSA C22.2 No. 62368-1, Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements

32.1.3 Unless otherwise specified, the test voltage for each test of a product is to be as indicated in Table 32.1 at the rated frequency of the product.

Table 32.1
Test Voltages

	Product rated voltage, nameplate	Test voltage
60 cycle, 50/60 cycle	110 – 120	120
	220 – 240	240
Rated frequency	Other	Maximum marked rating
DC	Battery circuit	Marked nominal battery voltage
50 cycle	110 – 120	120
	220	220
	240	240

32.1.4 Radio frequency transmitters and equipment intended to be connected to the public telephone network shall comply with:

a) In the United States, applicable Federal Communications Commission (FCC) rules and regulations.

b) In Canada, applicable Industry Canada rules and regulations.

32.1.5 When a product must be mounted in a definite position in order to function as intended, it shall be tested in that position.

32.1.6 All measurements are to be made with a true RMS meter or an oscilloscope.

32.2 Maximum rated load

32.2.1 A product shall operate as intended and without the risk of fire, electric shock, or injury to persons with all external circuits connected to maximum rated load.

32.2.2 Units that are provided with connectors for the installation of accessories or with open card slots, or both, shall be subjected to the tests in this standard with such connectors or card slots, or both, loaded to the maximum rated output capability for the unit specified by the manufacturer.

32.2.3 Maximum rated electrical loading

32.2.3.1 Maximum rated load is that value of impedance which causes rated current to flow in the external circuit or the maximum number of specific devices or appliances, as specified in the installation

instructions/wiring diagram, connected to the external circuit, with the input voltage to the product adjusted to the value determined by 32.1.3.

32.2.4 Maximum rated signal booster emissions

32.2.4.1 Signal boosters shall be loaded and operated within the designated emissions mask(s).

32.2.5 Maximum rated system configuration relative to maximum system response time and time domain interference delay (propagation delay)

32.2.5.1 The system configuration is to include the maximum number of active devices to produce the least favorable propagation delay.

32.2.6 Maximum rated system configuration response time for non-RF components

32.2.6.1 The system configuration is to include the maximum number of devices and components, or equivalent, to produce the least favorable supervisory response times.

OPERATION TESTS

33 General

33.1 A product shall be capable of operating for all conditions of its intended performance when used in conjunction with initiating devices, notification appliances, power supplies, and interconnected equipment to form a system of the service specific type indicated in the marking and shown in the installation wiring diagram/instructions.

33.2 To determine compliance with 33.1, the emergency responder communication enhancement system is to be connected as specified by the installation wiring diagram/instructions to form a typical system, and the system operated for each condition of its intended performance.

33.3 Unless indicated, each power-supply circuit shall be supplied from a source of rated frequency and voltage as specified in 32.1.3 during the tests in Sections 35 – 50.

33.4 To determine if a product complies with those requirements that specify the application of a circuit fault, adverse condition, or malfunction of specified equipment/components, the investigation is to start with the representative system combination in the operating condition. The fault condition is then to be separately introduced, the results noted, the fault removed, and the system restored to the operating condition before the next fault is introduced.

34 Operation

34.1 The emergency responder communication enhancement systems shall have the capability of simultaneously supporting both analog and digital communications.

34.2 Bidirectional amplifiers shall have oscillation detection and control functionality to reduce gain and maintain operation.

34.3 In the event of uncorrectable oscillation, the system shall be permitted to shut down.

34.4 The maximum propagation delay, in microseconds, for a maximum rated system configuration as described in 32.2.5.1 shall be compliant with manufacturer's maximum specified propagation delay in microseconds.

34.5 The system shall be sufficiently modular to have the capability to support revised and/or additional system frequencies within the same frequency band of the bi-directional amplifier supplied to maintain radio system coverage as it was originally intended without the need to replace the system.

34.6 Radio enhancement systems supporting more than one channel or talk path shall have the capability to support two radios simultaneously transmitting on different talk paths or channels.

35 Power Supplies

35.1 General

35.1.1 Each product shall be supplied by at least two independent power sources (one primary and one secondary), each of which is able to separately power the product.

Exception No. 1: In the United States – Products deriving power from separate equipment complying with UL 864, the Standard for Control Units and Accessories for Fire Alarm Systems or UL 1481, the Standard for Power Supplies for Fire Protective Signaling Systems, and which are supplied by at least two independent power sources.

Exception No. 2: In the United States – Products deriving power from an engine driven generator meeting NFPA 72, The National Fire Alarm and Signaling Code.

Exception No. 3: In Canada – Products deriving power from separate equipment complying with ULC 527, Standard for Control Units and Accessories for Fire Alarm Systems.

Exception No. 4: In Canada – Products deriving power from an engine driven generator meeting ULC S524, Standard for Installation of Fire Alarm Systems.

35.1.2 A visual “power-on” indication shall be visible at a dedicated annunciator meeting the requirements of 36.1.3.

35.2 Primary power source

35.2.1 AC primary power source(s) shall be monitored for the presence of voltage at the point of connection to each directly AC primary powered RF emitting device and system component such that complete loss of AC primary power shall result in the annunciation described in 36.1.2 – 36.1.10.

35.2.2 The requirement of 35.2.1 does not apply to the following circuits:

a) A power supply for supplementary equipment.

b) The neutral of a three-, four-, or five-wire AC or DC supply source.

35.2.3 Operating power of the product shall automatically be transferred to the secondary power source within 10 s without required signals being lost, interrupted, or delayed by more than 10 s and while maintaining compatibility of connected equipment when each of the following conditions occur:

a) Total instantaneous loss of primary power; and

b) Degradation of primary power to the point of transfer to secondary power.

Transfer to the secondary power source shall not occur below 85 nor above 90 % of rated voltage. Restoration of the primary operating source to a value of not more than 90 % of rated voltage shall result in the transfer of product operation to the primary operating source within 30 min.

Exception: A lower transfer cutout voltage is not prohibited when operation of the product is not impaired and compatibility of connected appliances is maintained.

35.2.4 For units employing an uninterruptible power source, a supervisory signal shall be initiated and annunciated as described in 36.1.2 and 36.1.3 when the uninterruptible power source system switches from the primary power source to the secondary power source.

35.3 Secondary power source(s)

35.3.1 All secondary power source(s), other than those used solely to sustain time and date functions or volatile memory, for each RF emitting device and system component shall be monitored for the presence of voltage at the point of connection to the product such that loss of voltage shall result in the annunciation of an audible and visual trouble signal at the dedicated operator interface.

35.3.2 The system shall produce the same operation, excluding the alternating current (AC) power indicator, when powered solely from its secondary power source as when the product is connected to its primary power source.

35.3.3 Standby batteries, other than those used solely to sustain time and date functions or volatile memory, shall be rechargeable.

35.3.4 Each RF emitting device and system component employing rechargeable batteries as the secondary power source shall monitor the integrity of the battery-charging circuit and shall result in the annunciation described in 36.1.2 – 36.1.10.

35.3.5 With regard to 35.3.4, products employing voltage controlled charging methods shall initiate a supervisory signal when the charging voltage decreases below the marked nominal rated battery voltage.

36 Monitoring for Integrity

36.1 General

36.1.1 Emergency Responder Communication Enhancement Systems shall be automatically monitored for the following:

a) Donor antenna(s) malfunction

b) Active radio frequency emitting device failure

c) System component failure which affects system performance

d) Low-battery capacity indication when 70 % of the 12-hour operating capacity has been depleted.

36.1.2 The emergency responder communication enhancement system shall have the capability of automatically signaling an off-normal condition to a fire alarm system for any of the conditions in 36.1.3 (b) – (g) within 200 s of the occurrence of the condition and within 24 hours of the occurrence of the condition indicated in 36.1.3(h). The off-normal signal shall be distinct from the fault condition annunciation indicated in 36.1.5.

36.1.3 A dedicated annunciator shall annunciate the status of all RF emitting devices and emergency responder communication enhancement system components. The following visual and labeled indications are to be provided for each system component and active RF emitting device:

a) Normal AC power.

b) Loss of normal AC power.

c) Battery charger failure.

d) Low battery capacity (to 70 percent depletion).

e) Signal source malfunction.

f) Active RF emitting device malfunction.

g) System component malfunction, other than passive RF component, which affects system performance.

36.1.4 The status changes described in 36.1.3 (b) – (h) shall also be annunciated by distinctive audible signals. When an intermittent signal is used, it shall sound at least once every ten seconds with minimum on-time duration of one-half second. When a common audible signal is to be employed for all trouble annunciation signals, distinction shall be achieved visually.

Exception: The dedicated annunciator is not required to annunciate an audible signal when the interconnected fire alarm system annunciates the audible signal and the dedicated annunciator is intended to be installed in close proximity to the fire alarm control unit.

36.1.5 The communication path between the dedicated annunciator described in 36.1.3 and the emergency responder communication enhancement system is to be monitored for integrity of the interconnecting conductor(s) and/or equivalent path(s) so that the occurrence of a single ground, single open or adverse condition shall automatically result in an audible and visual and labeled indication at the annunciator described in 36.1.3.

Exception: Interconnection between equipment within a common enclosure.

36.1.6 The annunciation of the conditions indicated in 36.1.3, 36.1.4 and 36.1.5 shall occur within 200 s.

Exception: The signal source malfunction annunciation, when caused by a donor antenna malfunction, may be annunciated within 24 hrs.

36.1.7 Cancellation of the off-normal signal is acceptable annunciation for the restoration signal.

36.1.8 The activation of a self-restoring annunciation and its restoration to normal shall be automatically indicated as described in 36.1.3, 36.1.4, 36.1.5 and 36.1.7.

36.1.9 The activation of a latching annunciation at the dedicated annunciator covered in 36.1.3 shall be automatically indicated as described in 36.1.3 and 36.1.4. Restoration of a latching annunciation shall be indicated as described in 36.1.7 after activation of a manual reset.

36.1.10 A means for silencing the audible sounding device described in 36.1.4 shall comply with all of the following:

a) Limiting access by being either:

1) Key operated with the key removable only in the normal position;

2) Located within a locked cabinet;

3) Limited by a software security code providing a minimum of 1000 combinations and with a maximum 30-min time-out feature after the last activity; or

4) Arranged to provide equivalent protection against unauthorized use.

b) A visible trouble indicator remains activated or is simultaneously activated when the sounding device is de-energized.

c) The audible trouble signal shall sound when the means is in the "silence" position and no trouble exists.

d) The visible indicator shall be located and identified so that the user will recognize the signal as soon as it is activated.

36.1.11 An audible trouble signal that has been silenced at the protected premises shall

a) Automatically reactivate the audible trouble signal at the operator interface every 24 hr. or less until trouble signal conditions are restored to normal; and

b) The audible signal shall operate until it is manually silenced or acknowledged.

36.1.12 Conductors for ground detection are not required to be monitored for integrity where a single ground does not prevent the required normal operation of the system;

36.1.13 A short-circuit, an open, or a ground fault on the Interconnections to supplementary system devices/components shall not affect the normal operation of the system except for omission of the supplementary feature (when necessary to comply with the above requirement, overcurrent protective devices provided for supplementary circuit protection shall be non-interchangeable).

36.2 Software

36.2.1 General

36.2.1.1 Any product that is dependent upon software program(s) to achieve proper operation shall meet all the requirements in this section.

36.2.1.2 Where compliance with this standard is dependent upon the proper selection of software features and parameters which are field programmable, one of the following shall be met:

a) The software shall not permit any product operation or contain any programming options that are prohibited by this standard;

b) The software shall be partitioned and identified in the field programming software as complying or not complying with (a); or

c) A summary as described in 54.12 shall be provided in the front of the programming manual describing all programming options and parameters that have the potential for conflicting with the requirements in this standard and stating the proper program selections that would be in accordance with this standard. Additionally, information shall also appear throughout the manual where the specific feature or option appears describing the requirements of this standard.

36.2.1.3 A release level shall identify the executive software of a product. A new release level shall be assigned due to any changes in the executive software.

36.2.1.4 With the executive software or Device Specific Firmware resident in the product, the release level of the software shall be visibly marked on the product or shall be capable of being displayed.

36.2.1.5 All software shall be resident in nonvolatile storage devices that are sealed against atmospheric contaminants and not subject to mechanical wear of the storage medium. Integrated circuits and solid state drives are examples of storage devices that meet this requirement.

Exception: Software and data that is of a supplementary nature or software used to initially program the product.

36.2.1.6 Software and firmware within a product that interfaces to software in another system, such as a fire alarm system, to provide required functions shall be functionally compatible and the compatibility shall be indicated in the installation instructions of one or both of the compatible systems. This does not apply to supplementary functions.

36.2.2 User access and programming

36.2.2.1 The executive program shall not be accessible for change, modification, or addition by the user, nor shall program execution depend upon site specific programming by the user.

36.2.2.2 Site-specific programming of the Device Specific Firmware is not prohibited from being performed at the factory or in the field.

36.2.2.3 A security means shall be provided to restrict unauthorized access to site specific programming. The means shall provide a minimum of 1000 possible combinations. The security means shall not be the same as the access means provided to enable the products operational controls or features. The use of different passwords meets the intent of this requirement.

36.2.2.4 When the proper operation of a product is adversely affected due to actuation of the security means or during any reprogramming, the product shall produce a visual trouble signal. In addition, a protected-premises unit connected to a supervising station receiver shall transmit a trouble signal.

36.2.2.5 Initial site specific programming or any subsequent reprogramming of a unit shall require manual actuation of the security means at the installation.

37 Charging Current Test

37.1 General

37.1.1 This test is to be conducted in conjunction with the Component Temperature Test, Section 42, on products provided with standby batteries.

37.1.2 A product intended to be used with a standby battery shall have sufficient capacity, while connected to rated primary power, to maintain a charged battery under all conditions of intended operation, including sufficient capacity to operate the product with the battery disconnected or fully discharged. In any operating mode, other than when the product is in the transmitting condition, the battery charger shall be capable of maintaining the battery in the charged condition.

37.1.3 A charged battery is defined as a battery having the capacity to maintain 100 percent system operation (transmitting) capacity for the time period required by 37.2.5.

37.2 Discharged battery

37.2.1 The terminal voltage of a battery discharged as specified in 37.2.2 – 37.2.5 shall not be less than 85 % of the marked nominal battery voltage.

37.2.2 The battery is first to be charged by applying AC input power to the product for 48 hr, during which the product is to be operated continuously with normal standby load connected.

37.2.3 The normal standby load shall be the quiescent current of the product plus any specified normal supervisory power supply loads not automatically disconnected upon transfer to secondary power.

37.2.4 With the loading applied as described in 37.2.5, AC input is then to be disconnected, and terminal voltage of the battery is to be measured one min after disconnection.

37.2.5 The battery is then to be discharged by maintaining 100 percent system operation (transmitting) capacity for the applicable period specified in (a), (b), or (c):

a) 2 hr, where secondary (standby) power is intended to be used in conjunction with an automatic-starting engine-driven generator;

b) 12 hr; or

c) A longer than 12-hr period as described in the installation document of the product.

37.3 Charged battery

37.3.1 The terminal voltage of a battery charged as specified in 37.3.2 shall be at least 95 % of the voltage measured in 37.2.4.

37.3.2 At the conclusion of the test sequence described in 37.2.2 – 37.2.5, AC input power is to be reapplied to the product for 48 hr. During charging, the product is to be operated continuously with normal standby load connected. At the conclusion of the 48-hr recharge time, the loading specified in 37.2.5 is to be applied, AC power is to be disconnected and battery terminal voltage measured after one min.

37.4 Discharged battery – second trial

37.4.1 The terminal voltage of a battery shall not be less than 85 % of the marked nominal battery voltage after the battery has been discharged as specified in 37.2.5 following charging as specified in 37.3.2.

38 Electrical Ratings Test

38.1 Power input circuits

38.1.1 With the product energized from rated voltage and connected to 100 percent system operation (transmitting) capacity rated load, the input current of the product shall not exceed the marked rating of the product when the product is operated under all conditions of intended use, including while connected to a discharged battery (as defined in 37.2.1 – 37.2.5).

38.1.2 Where the operating voltage of a product is specified at two or more discrete values, the requirement in 38.1.1 shall be applied at each voltage rating.

38.1.3 Where the input to the product is specified as a voltage range, the input current rating shall be a single value that is equal to or greater than the measured input current obtained at any voltage within the range.

38.2 Other external circuits

38.2.1 All external circuits shall be electrically rated to permit proper installation of the product using wiring methods permitted by the Code indicated below. The actual measured values of any circuit shall not exceed the rating for that circuit.

a) In the United States – National Electrical Code, NFPA 70

b) In Canada – CSA C22.1, Safety Standard for Electrical Installations, Canadian Electrical Code Part I

38.2.2 The electrical rating of a circuit shall indicate the maximum circuit voltage under any operating condition including an open circuit and the maximum circuit current (or wattage for an audio product) under any condition of normal operation.

38.2.3 Where the circuit is not power limited as defined in the Power-Limited Circuits Test, Section 47, and a circuit fault condition will cause a circuit current in excess of the normal current rating, either:

a) The maximum fault current shall be indicated; or

b) The minimum size wire capable of handling the fault current shall be indicated.

There shall be coordination between the maximum fault current and the overcurrent or current limiting protection required in 17.4.

38.2.4 Output current measurements of either half-wave and full-wave rectifier circuits are to be based on the average value of the waveform.

39 Jarring Test

39.1 A product shall withstand jarring resulting from impact and vibration without:

a) Resulting in a risk of shock or fire hazard;

b) Causing false signaling operation of any part; and

c) Impairing the subsequent intended operation.

39.2 The product is to be mounted as intended to the center of a 1.8- by 1.2-m (6- by 4-ft) nominal 19.1-mm (3/4-in) thick plywood board secured in place at four corners. A 4.08 J (3 ft·lb) impact is to be applied to the center of the reverse side of this board by means of a 535 g, 51-mm diameter steel sphere either:

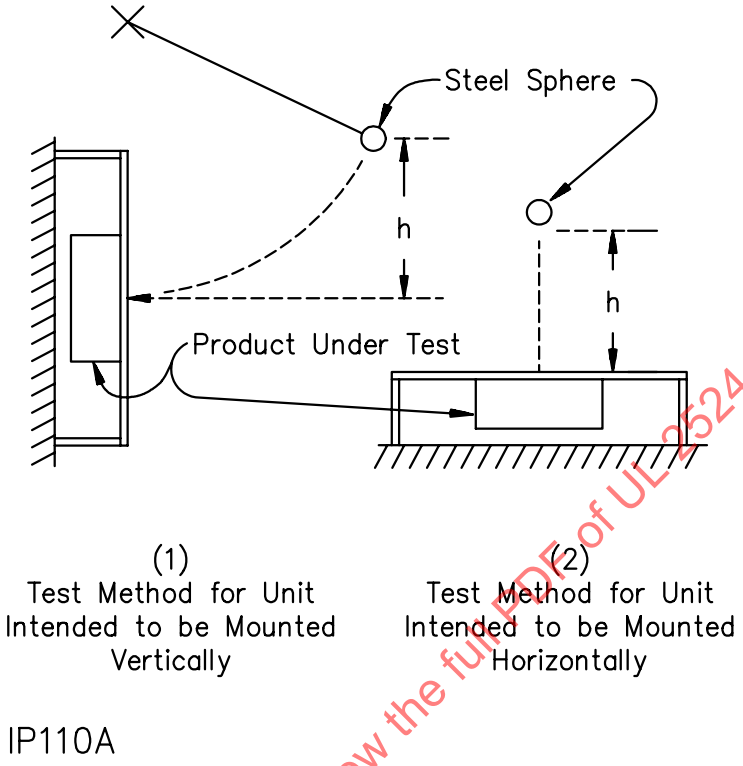
a) Swung through a pendulum arc from a height (h) of 775 mm (2.54 ft) or

b) Dropped from a height (h) of 775 mm depending upon the mounting of the equipment.

See Figure 39.1.

Figure 39.1

Jarring Test



39.3 During this test, products shall be connected to a rated source of supply voltage and tested while in the normal supervisory condition.

40 Dielectric Voltage-Withstand Test

40.1 A product shall withstand for 1 min without breakdown, the application of an essentially sinusoidal AC potential of a frequency within the range of 40 – 70 Hz, or a DC potential, between live parts and the enclosure, between live parts and exposed dead-metal parts (see 40.2), and between live parts of circuits operating at different potentials or frequencies (see 40.3). The test potential is to be:

a) For circuits rated 30 V AC rms (42.4 V DC or AC peak) or less – 500 V AC (707 V, when a DC potential is used);

b) For circuits rated greater than 30 and equal to or less than 150 V AC rms (42.4 and 212 V DC) – 1000 V AC (1414 V, when a DC potential is used);

c) For circuits rated more than 150 V AC rms (212 V DC) – 1000 V AC plus twice the rated voltage (1414 V plus 2.828 times the rated AC rms voltage, when a DC potential is used).

See 40.4 – 40.6.

40.2 Exposed dead-metal parts are non-current-carrying metal parts that are capable of becoming energized and are accessible from outside of the enclosure of a product.

40.3 For the application of a potential between live parts of circuits operating at different potentials or frequencies, the voltage is to be the applicable value specified in 40.1 (a), (b), or (c), based on the highest

voltage of the circuits under test. Electrical connections between the circuits are to be disconnected before the test potential is applied.

40.4 Where the charging current through a capacitor or capacitor-type filter connected across-the-line, or from line-to-earth ground is sufficient to prevent maintenance of the specified AC test potential, the capacitor or filter is to be tested using a DC test potential in accordance with 40.1.

40.5 The test potential shall be obtained from any convenient source having sufficient capacity to maintain the specified voltage. The output voltage of the test apparatus is to be monitored. The method of applying the test voltage is to be such that there are no transient voltages that result in instantaneous voltage being applied to the circuit exceeding 105 % of the peak value of the specified test voltage. The applied potential is to be:

a) Increased from 0 at a uniform rate so as to arrive at the specified test potential in approximately 5 s; and then

b) Maintained at the test potential for 1 min without an indication of a breakdown.

Manual or automatic control of the rate of rise is not prohibited.

40.6 A printed-wiring assembly or other electronic circuit component that is capable of short-circuiting (or being damaged by) the test potential, is to be removed, disconnected, or otherwise rendered inoperative before the test. A representative subassembly is then to be tested instead of an entire unit.

41 Leakage Current Test

41.1 Where a cord-connected product is powered by a source greater than 42.4 V peak, the leakage current at any exposed surface, or between any accessible part and earth ground, or any other accessible part with an open potential of greater than 42.4 V peak shall not be more than the following values when tested in accordance with 41.2 – 41.8:

a) 0.5 mA for an ungrounded (2-wire) portable or stationary;

b) 0.5 mA for a grounded (3-wire) portable product; and

c) 0.75 mA for a grounded (3-wire) stationary.

Exception: Where an electromagnetic radiation suppression filter is necessary for the product to function as intended, the leakage current is to not be more than 2.5 mA when 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 Grounding for Products Containing Circuits with Voltages Exceeding 30 V rms or 42.4 V DC, Section 27;

b) With the filter removed from the product, the leakage current does not exceed the limits specified in 41.1 (b) and (c), as applicable; and

41.2 With regard to the requirements in 41.1, leakage current refers to all currents, including capacitively coupled currents that are capable of being conveyed between exposed conductive surfaces of the equipment and ground, or between exposed conductive surfaces of the equipment.

41.3 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 exposed surface to another where the exposed surfaces are simultaneously accessible. A part is

considered to be an exposed surface unless it is guarded by an enclosure determined to protect against the risk of electric shock. Surfaces that can be readily contacted by one or both hands of a person at the same time are determined to be simultaneously accessible. For the purpose of these requirements, one hand is determined to be able to contact parts simultaneously when the parts are within a 4 by 8 in (102 by 203 mm) rectangle, and two hands of a person are determined to be able to contact parts simultaneously when the parts are no more than 6 ft (1.8 m) apart.

41.4 Where 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 having dimensions of 3.94 by 7.88 in (10 by 20 cm) in contact with the surface. Where the surface is less than 3.94 by 7.88 in, 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.

41.5 The measurement circuit for the leakage current test is to be as illustrated in Figure 41.1. 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. The meter is not required to have all of the attributes of the defined instrument.

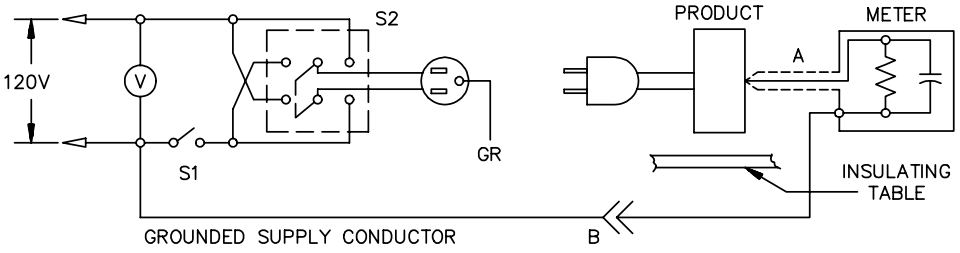
a) The meter is to have an input impedance of 1500 ohm resistive shunted by a capacitance of 0.15 µF;

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 kHz, 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 µF capacitor to 1500 ohm. At an indication of 0.5 or 0.75 mA, the measurement is to have an error of not more than 5 % at 60 Hz.

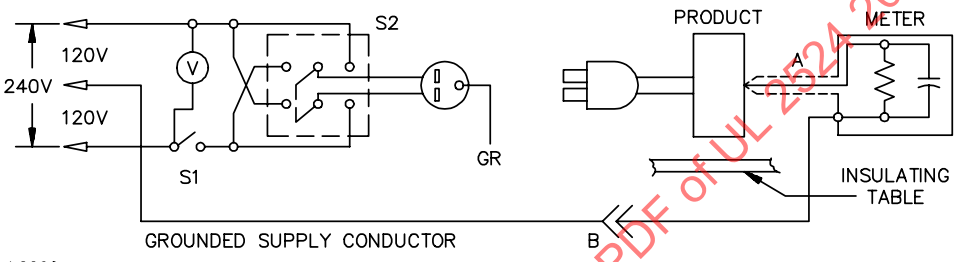
Figure 41.1

Leakage Current Measurement Circuits



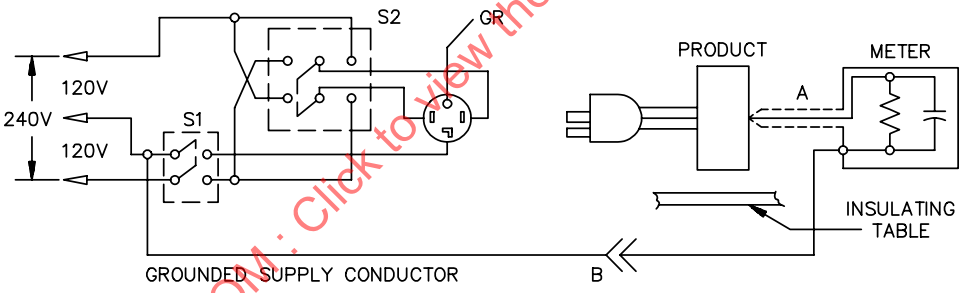
LC100

Product intended for connection to a 120-V power supply.



LC200

Product intended for connection to a 3-wire, grounded neutral 120/240-V power supply, as illustrated above.



LC300

Product intended for connection to a 3-wire, grounded neutral 120/240-V power supply, as illustrated above.

A – probe with shielded lead.
B – Separated and used as clip when measuring currents from one part of product to another.

NOTE – 120/240 V circuit also apply to 208Y/120 V supply.

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

41.7 Systems of interconnected equipment with individual connections to primary power shall have each piece of equipment tested separately. Systems of interconnected equipment with one common connection to primary power shall be treated as a single piece of equipment. Equipment designed for multiple (redundant) supplies shall be tested with only one supply connected.

41.8 A sample of the product is to be tested in the as-received condition initially with all switches indicated below closed, but with its grounding conductor, when provided, open at the attachment plug. A product that has not been energized for a minimum of 48 hr prior to the test, and that is at room temperature, is determined to be in the as-received condition. The supply voltage is to be the maximum voltage marked on the product, in accordance with 32.1.3 or shall be as described in 42.6, but not less than 120 or 240 V. The test sequence (with regard to Figure 41.1) 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 s 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 occurs. 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 Component Temperature Test, Section 42.

42 Component Temperature Test

42.1 A product, when operated under any normal condition of intended use and at maximum rated load, shall not reach a temperature at any point high enough to:

a) Result in a risk of fire or electric shock;

b) Adversely affect any materials in the product; or

c) Exceed the temperature rises at specific points as specified in Table 42.1 and Table 42.2.

Exception: A component with a temperature exceeding that indicated in Table 42.1 is not prohibited from being used when reliability data at the higher temperature is provided by the manufacturer to justify its use.

Table 42.1
Maximum Temperature Rises – Electronic Components

Component or device	Normal standby (i.e. any long term condition of operation or any non-emergency operating condition)		Active condition (i.e. short term operating condition supporting radio communication)	
	°F	(°C)	°F	(°C)
A. COMPONENTS				
1. Capacitors[a]	45	(25)	72	(40)
2. Resistors[b]				
Carbon	45	(25)	90	(50)
Wire-wound	90	(50)	225	(125)
Other	45	(25)	90	(50)
B. SOLID-STATE DEVICES	See note (c)			

[a] In lieu of complying with these temperature limits, the failure rate of the component is equal to or less than 0.5 failures per million hours of operation using Military Handbook Electronic Reliability Design Handbook, MIL-HDBK-338, or equivalent, or component reliability data based on actual performance in a similar application.

[b] In lieu of complying with these temperature limits, a resistor shall not dissipate more than one-half of its maximum power rating under the test conditions specified or component reliability data based on actual performance in a similar application, or the Military Handbook, Electronic Reliability Design Handbook, MIL-HDBK-338, or equivalent, such that the failure rate is equal to or less than 0.5 failures per million hours of operation.

[c] The temperature of a solid-state device (such as a transistor, SCR, or integrated circuit) shall comply with one of the following:

1) Not exceed the temperature limits specified in both (a) and (b):

a) 50 % of its rated junction temperature, or storage temperature when not rated for junction temperature, during the normal standby condition and during any non-fire or emergency signaling condition.

b) 75 % of its rated junction temperature, or storage temperature when not rated for junction temperature, under the alarm condition or any other short term condition of operation which produces the maximum temperature dissipation of the component.

For reference purposes, 32 °F (0 °C) shall be determined as 0 %. For integrated circuits, the loading factor shall not exceed 50 % of its rating under the normal standby condition and 75 % under any condition of operation.

2) Not exceed 100 % of its rating under any condition of normal use and the component is subjected to one of the following:

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

b) Component reliability data based on actual performance in a similar application, or the Military Handbook "Electronic Reliability Design Handbook, MIL-HDBK-338" or equivalent, such that the failure rate is equal to or less than 0.5 failures per million hours of operation.

Table 42.2
Maximum Temperature Rises – Materials and Component Parts

Materials and component parts	°F	(°C)
1. Varnished cloth insulation	108	(60)
2. Fuses:		
a) Class G, J, L, and CC:		
Tube	180	(100)
Ferrule or blade	153	(85)
b) Others	117	(65)

Table 42.2 Continued on Next Page

Table 42.2 Continued

Materials and component parts	°F	(°C)
3. Fiber used as electrical insulation	117	(65)
4. Wood and similar combustible material	117	(65)
5. Any point on or within a terminal box on a permanently wired unit (see 53.1.8)	117	(65)
6. A surface upon which a permanently wired unit is mounted in service, and surfaces that are adjacent to the unit when it is so mounted	117	(65)
7. Enclosure surfaces:		
a) Surfaces subject to contact during intended use or maintenance:		
Metallic	63	(35)
Nonmetallic	108	(60)
b) Other surfaces:		
Metallic	81	(45)
Nonmetallic	126	(70)
8. Class 105 (formerly Class A) insulation systems on windings of relays, solenoids, magnets, transformers, and similar parts:		
Thermocouple method	117	(65)
Resistance method	153	(85)
9. Class 130 (formerly Class B) insulation systems on windings of relays, solenoids, magnets, transformers, and similar parts:		
Thermocouple method	153	(85)
Resistance method	189	(105)
10. Class 155 insulation systems on windings of relays, solenoids, magnets, transformers, and similar parts:		
Thermocouple method	198	(110)
Resistance method	216	(120)
11. Class 180 insulation systems on windings of relays, solenoids, magnets, transformers, and similar parts:		
Thermocouple method	225	(125)
Resistance method	243	(135)
12. Phenolic composition used as electrical insulation or as a part whose malfunction is capable of resulting in a risk of fire, electric shock, injury to persons or risk from electrical-energy/high-current levels[a].	225	(125)
13. Insulated conductors, appliance wiring material	see note b	
14. Sealing compound	72 °F (22 °C) less than melting point	
15. Printed-wiring board	see note c	

[a] The limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to compounds that have been investigated and determined to meet the requirements for use at higher temperatures.

[b] 77 °F (25 °C) less than the established temperature rating of the wire.

[c] Temperatures on the surface of any printed-wiring board shall not exceed the temperature limits of the board.

42.2 All values for temperature rise apply to equipment intended for use with ambient temperatures normally prevailing in occupiable spaces which usually are not higher than 77 °F (25 °C). When equipment is intended specifically for use with a prevailing ambient temperature constantly more than 77 °F, the test of the equipment is to be made with the higher ambient temperature, and the allowable temperature rises specified in Table 42.1 and Table 42.2 are to be reduced by the amount of the difference between that higher ambient temperature and 77 °F.

42.3 Temperature measurements on equipment intended for recessed mounting are to be made with the unit installed in the intended manner on or against the black painted surface of an enclosure of 3/4 in (19.1 mm) wood such that the walls of the enclosure make a close fit with the product and extending approximately 2 in (50.8 mm) on the top, sides and rear, and the front extended to be flush with the product cover.

42.4 A product shall be connected to a supply circuit of rated voltage. A product having a single frequency rating is to be tested at that frequency. A product rated AC/DC or DC – 60 Hz is to be tested at both direct current and 60-Hz alternating current. A product rated 25 – 60 Hz or 50 – 60 Hz is to be tested on 50-Hz alternating current.

42.5 A product that is rated for use at more than one voltage or for a range of voltages shall be tested at each supply voltage.

42.6 A product that is rated for use at more than one voltage, or a range of voltages, and contains a tapped transformer or other means of being adapted to different supply voltages shall be tested at the most unfavorable combination of supply voltage and voltage adjustment.

Exception: The product is to be tested while connected according to the manufacturer's instructions when the product is marked according to 53.1.17.

42.7 For the purpose of prescreening, thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2), and an infrared temperature probe or the equivalent, are not prohibited from being employed to identify those components and/or materials in which compliance with 42.1 is questionable and, therefore, requiring the measurements indicated in 42.8.

42.8 Temperatures are to be measured by thermocouples except the change-of-resistance method shall be used for coil and winding temperatures where the coil is inaccessible for mounting of thermocouples (for example, a coil immersed in sealing compound) or where the coil wrap includes thermal insulation or more than two layers [1/32 in (0.8 mm) maximum in total thickness] of cotton, paper, rayon, or the like.

42.9 Whenever temperature measurements by thermocouples are necessary, thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wire and a potentiometer-type instrument are to be used. The thermocouple wire is to conform with the requirements in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ASTM E230/E230M.

42.10 The temperature of a copper coil winding is determined by the change-in-resistance method, wherein the resistance of the winding at the temperature to be determined is compared with the resistance at a known temperature by means of the formula:

$$T = \frac{R}{r}(234.5 + t) - 234.5$$

in which:

T is the temperature to be determined in °C;

R is the resistance in ohms at the temperature to be determined;

r is the resistance in ohms at the known temperature; and

t is the known temperature in °C.

42.11 As it is generally necessary to de-energize the winding before measuring *R*, the value of *R* at shutdown is to be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown. A curve of the resistance values and the time is to be plotted and extrapolated to give the value of *R* at shutdown.

42.12 The circuit of a current-regulating resistor or reactor provided as part of a product is to be adjusted for the maximum resistance or reactance at rated load.

42.13 Component temperature is to be determined while the product is operated under the following conditions:

a) Normal supervisory condition (i.e. any long term operating condition of supporting radio communication) until constant temperatures occurs. If the product is intended to charge standby batteries, this test shall be conducted while connected to a discharged battery (as defined in 37.2.1 – 37.2.5).

b) Active condition (i.e. any short term operating condition of supporting radio communication which produces the maximum component temperature dissipation) under maximum rated load conditions until constant temperatures occur.

42.14 A temperature is determined to be constant when three successive readings taken at intervals of 10 % of the previously elapsed duration of the test, but not less than 5-min intervals, indicate no change.

43 Abnormal Operation Tests

43.1 General

43.1.1 When the conditions of intended operation are not representative of all conditions possible in service, a product shall not present a risk of fire, electric shock, or injury to persons when operated under such abnormal conditions.

43.1.2 Continuous operation, malfunction of components, shorting of output circuits, failure of cooling fans, and likely misuses of the product are examples of conditions to be simulated during the tests in this section.

43.1.3 During the tests, a single layer of bleached cheesecloth, fabricated at 14 – 15 yd^2 to the pound (26 – 28 m^2/lb) and having a thread count of 28 by 32, is to be draped loosely over the entire unit. The product is to be connected to a power supply as indicated in 32.1.3 and connected in series with a non-time-delay fuse of the maximum current rating of the branch circuit. Opening of the fuse before any condition of risk of fire or electrical shock results is considered as meeting the intent of the requirements. The enclosure, when metallic or employing dead-metal parts, shall be connected to ground either through a fuse rated to correspond to the input rating of the unit or 3 amp, whichever is less. Only one abnormal condition is to be simulated at a time.

43.1.4 During these tests, all fuses which are field-renewable by the user and are of an interchangeable type shall be replaced by a fuse of the same size and voltage rating using the highest available current rating for that size. Opening of the fuse before any condition of risk of fire or electrical shock results satisfies the requirement of the test.

Exception: Fuses need not be replaced when the product employs marking identifying the need for using the indicated fuse(s) located so that it is obvious as to which fuse or fuseholder(s) the marking applies and where readily visible during replacement of the fuse(s). A single marking is acceptable for a group of fuses. The marking shall comply with 53.1.20 and shall consist of the word "CAUTION" and the following or equivalent text: "For continued protection against risk of fire, replace only with same type and rating of fuse".

43.1.5 All abnormal conditions are to be continued until ultimate results are obtained, such as burnout or stabilization of temperatures.

43.1.6 Compliance with the tests specified in this section is met when all of the following occurs:

a) There is no ignition or charring of the cheesecloth indicator (charring is deemed to have occurred when the structural integrity of the threads has been destroyed due to the temperature rise);

b) The fuse from the enclosure to ground does not open;

c) Immediately following these tests, the product complies with:

1) The Dielectric Voltage-Withstand Test, Section 40, within 1 min of the conclusion of the test, or

2) The Leakage Current Test, Section 41, when it is not practical to conduct the dielectric voltage-withstand test due to numerous components electrically connected to the product chassis or ground.

43.2 Operation

43.2.1 A product that normally would only be operated for a limited time shall be capable of operating continuously in any condition of normal use possible without risk of fire, electric shock, or injury to persons.

43.3 Field-wiring circuits

43.3.1 Each output circuit of the product to which field wiring is intended to be connected is to be individually opened or shorted.

43.3.2 The test condition in 43.3.1 shall be applied one at a time. The abnormal condition shall be introduced while the equipment is operating in any condition of normal use.

43.4 Electronic components

43.4.1 All circuit components located in a circuit with voltages exceeding 30 V rms or 42.4 V DC shall be examined using the equipment circuit diagrams and component specifications to determine those faults that can occur. Examples are short-circuits and open-circuits of transistors, rectifiers, diodes, and capacitors, faults causing continuous dissipation in resistors designed for intermittent dissipation, and internal faults in integrated circuits causing excessive dissipation. The product shall then be operated during each of the fault conditions until constant temperature or burnout occurs.

Exception No. 1: Components do not require testing when located in circuits meeting one of the following conditions:

a) Where the circuit current is limited by 10,000 ohm or more of series impedance in a circuit in which the voltage is 125 V or less;

b) Where the circuit current is limited by 20,000 ohm or more of series impedance in a circuit in which the voltage is greater than 125 V but is not greater than 250 V;

c) In the United States – When the power source supplying the circuit is power limited as specified in Table 47.1 or Table 47.2; or

d) Circuits or devices that have been evaluated for use in circuits with voltages exceeding 30 V rms or 42.4 V DC, such as EMI Line Filters.

Exception No. 2: A resistor, an inductor, or an optical isolator is not required to be subjected to this test.

43.4.2 The faults referenced in 43.4.1 shall be applied one at a time. Short circuits shall be applied only between two terminals of a multi-terminal device at one time. Simulated circuits are also capable of being used for abnormal tests for circuits with voltages exceeding 30 V rms or 42.4 V DC. But when the tests performed on simulated circuits indicate likely damage to other parts of the equipment to the extent that the safety of the equipment is capable of being affected, the tests shall be repeated in the equipment. The abnormal condition shall be introduced while the equipment is operating under intended conditions. This is to be accomplished by jumper leads and remote switches with consideration given to the effect these devices have on the test.

43.4.3 Three tests of each combination, using untested components for each test, shall be conducted.

Exception: If analysis of the test results and circuit indicate that the result obtained is the only one likely to occur, the test need be conducted only once.

43.4.4 When the circuit is interrupted by opening of a component, the test is to be repeated twice, using new components when required. When a printed wiring board trace opens, the gap is to be electrically shorted and the test continued until ultimate results occur, and the procedure is to be repeated for each occurrence of a trace opening.

Exception: After opening of an internal overcurrent protective device, the test is not required to be repeated.

43.4.5 The test of 43.4.2 is to be continued for 1 hr or until one of the following conditions occurs:

a) Ignition or charring of the cheesecloth indicator (charring is deemed to have occurred when the structural integrity of the threads has been destroyed due to the temperature rise); or

b) Fuse from the enclosure to ground does opens.

When, at the end of 1 hr, no condition described below has occurred, and it is indicated that such a condition is imminent, the test is to be continued until ultimate results are obtained (usually 7 hr).

43.4.6 Immediately following each fault described in 43.4.2, within one min of the conclusion of the test, the product shall be subjected to the Dielectric Voltage-Withstand Test, Section 40.

43.5 Cooling fans and blowers

43.5.1 The product shall be operated under the condition which produces the greatest power dissipation until constant temperature or burnout occurs with all cooling fans and blowers disabled.

43.5.2 The locked-rotor test is to be conducted on the product and operated with the rotor of each cooling fan and blower motor locked.

Exception: Where a means of limiting the current is inherent in or provided as part of the device, these features are to be given consideration when conducting the locked-rotor test. These features may be external to the fan or motor and include, but are not limited to, the following:

a) Nonresettable thermal elements that are integral with fan or motor windings;

b) Wire-wound, or other types of resistors that limit the load current;

c) Positive temperature coefficient (PTC) resistors;

d) Inherent limitation due to impedance of the fan or motor windings; and

e) Nonreplaceable fusing elements soldered into the product.

43.5.3 When the fan or motor indicated in 43.5.2 is connected directly to the branch circuit a circuit representing the branch circuit supplying the motor or fan under test is to be protected by a circuit breaker rated at least ten times the primary current rating of the fan or motor, but not less than 15 amps. Opening of the circuit breaker is acceptable when the installation instructions for the product specify the maximum overcurrent protection rating to be used for the branch circuit.

43.6 Transformer burnout

43.6.1 A transformer shall be operated under one of the following conditions:

a) A transformer supplying a circuit involving a potential of not more than 30 V alternating current (AC) rms, 42.4 V direct current (DC) shall be tested with the secondary circuit shorted.

b) A power transformer supplying a circuit with voltages exceeding 30 V rms or 42.4 V DC shall be tested with the secondary circuit shorted or while connected to a resistive load drawing three times the full rated current, whichever results in the greater current value.

Exception: Where a means of limiting the secondary circuit current is inherent in or provided as part of the device, these features are to be given consideration and the burnout test conducted at the maximum load permitted by the limiting features. These features may be external to the transformer and include, but are not limited to, the following:

a) Nonresettable thermal elements that are integral with transformer windings;

b) Wire-wound, or other types of resistors that limit the load current;

c) Positive temperature coefficient (PTC) resistors;

d) Inherent limitation due to impedance of the transformer windings; and

e) Non-replaceable fusing elements soldered into the product.

43.6.2 A circuit representing the branch circuit supplying the transformer under test is to be protected by a circuit breaker rated at least ten times the primary current rating of the transformer, but not less than 15 amps. Opening of the circuit breaker is acceptable when the installation instructions for the product specify the maximum overcurrent protection rating to be used for the branch circuit.

43.6.3 The test shall be conducted until constant temperature or burnout occurs.

43.7 Communications circuits

43.7.1 In the United States – Where a product has provisions for connection to a telephone, telegraph, or outside wiring as covered by Article 800 in the National Electrical Code, NFPA 70, the product shall comply with the requirements for protection against overvoltage from power line crosses described in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1.

43.7.2 In Canada – Where a product has provisions for connection to a telephone, telegraph, or outside wiring as covered by CSA C22.1, Safety Standard for Electrical Installations, Canadian Electrical Code Part I, the product shall comply with the requirements for protection against overvoltage described in CSA C22.2 No. 60950-1 / UL 60950-1, Information Technology Equipment – Safety – Part 1: General Requirements.

43.8 Evaluation of reduced spacings on printed-wiring boards

43.8.1 In accordance with the Exception of 19.1, printed-wiring board traces of different potential having reduced spacings shall comply with:

a) The dielectric voltage-withstand test described in 43.8.2 and 43.8.3; or

b) The shorted trace test described in 43.8.4 and 43.8.5.

43.8.2 A printed-wiring board, as specified in 43.8.1(a), shall withstand for 1 min without breakdown the application of a dielectric withstand potential between the traces having reduced spacings, in accordance with 40.1, as appropriate.

43.8.3 Power-dissipating component parts, electronic devices, and capacitors connected between traces having reduced spacings, are to be removed or disconnected so that the spacings and insulations, rather than these component parts, are subjected to the full dielectric voltage-withstand test potential.

43.8.4 Printed-wiring board traces, as specified in 43.8.1(b), are to be short-circuited, one location at a time, and the test is to be conducted as described in 43.1. As a result of this test:

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

b) A wire shall not open.

When the circuit is interrupted by opening of a component, the test is to be repeated twice, using new components when required. When a printed wiring board trace opens, the gap is to be electrically shorted and the test continued until ultimate results occur, and the procedure is to be repeated for each occurrence of a trace opening.

Exception: After opening of an internal overcurrent protective device, the test is not required to be repeated.

43.8.5 The test of 43.8.4 is to be continued for 1 hr or until one of the conditions described below occurs. When, at the end of 1 hr, no condition described below has occurred, and it is indicated that such a condition is imminent, the test is to be continued until ultimate results are obtained (usually 7 hr).

a) Ignition or charring of the cheesecloth indicator (charring is deemed to have occurred when the structural integrity of the threads has been destroyed due to the temperature rise; or

b) Fuse from the enclosure to ground does opens.

43.8.6 Immediately following each fault described in 43.8.4, within one min of the conclusion of the test, the product shall be subjected to the Dielectric Voltage Withstand Test, Section 40.

44 Tests on Special Terminal Assemblies

44.1 General

44.1.1 To determine its suitability as a field-wiring connection in compliance with 15.5.1 and 15.5.2, representative samples of the terminal assembly shall comply with all of the tests specified in 44.2.1 – 44.5.2.

44.2 Mechanical secureness test

44.2.1 A terminal connection shall withstand the application of a straight pull of 5 lb (22.2 N), applied for 1 min to the wire in the direction which would most likely result in pullout, without separating from the terminal.

44.2.2 Six samples of the terminal are to be connected to the wire sizes with which they are intended to be used, in accordance with the manufacturer's instructions. When a special tool is required to assemble the connection, it is to be used. Each sample is to be subjected to a gradually increasing pull on the wire until the test pull of 5 lb (22.2 N) is reached.

44.3 Flexing test

44.3.1 The wire attached to a terminal shall be capable of withstanding an average of 5 right-angle bends without breaking.

44.3.2 Six terminal assemblies using the maximum wire size and six with the minimum wire size shall be subjected to this test. The terminal shall be rigidly secured so as to prevent any movement. With the wire in 3-lb (1.4-kg) tension and held at a point 3 in (41.2 mm) from the terminal-to-wire juncture, the wire shall be bent at a right angle from the nominal wire position. The wires shall be assembled to the terminals using any special tool required as specified in the manufacturer's instructions. The tension on the wire shall be sufficient to hold the wire in a rigid position during the flexing trials.

44.4 Millivolt drop test

44.4.1 The millivolt drop across a terminal connection, using the maximum and minimum wire sizes intended to be used, shall not be greater than 300 mV with the maximum current of the circuit flowing through the terminal connection at the rated voltage of the circuit.

44.4.2 Six terminal assemblies using the maximum wire sizes and six assemblies using the minimum wire sizes shall be subjected to this test. The wires shall be assembled to the terminals using any special tool, when required, according to the manufacturer's instructions. The millivolt drop shall then be measured using a high-impedance millivoltmeter with the maximum current, as specified by the manufacturer, flowing through the connection.

44.5 Temperature test

44.5.1 The maximum temperature rise on a terminal junction with the maximum or minimum wire sizes with which the terminal is used, shall not be greater than 86 °F (30 °C) based on an ambient temperature of 77 °F (25 °C).

44.5.2 Six terminal assemblies using the maximum wire size and six using the minimum wire size are to be subjected to this test. The wire is to be assembled to the terminals using any special tools, when required, according to the manufacturer's instructions. The maximum current is then to be passed through the terminal connection to which the wire will be subjected in service. After temperatures have stabilized, the maximum temperature rise is to be measured by the thermocouple method in accordance with the Component Temperature Test, Section 42.

45 Strain-Relief Test

45.1 Each lead used for field connections, including a battery clip lead assembly, shall withstand for 1 min a pull of 10 lbf (44.5 N) without any evidence of damage or of transmittal of stress to internal soldered connections. The means of affording strain relief does not meet the requirement when, at the point of

connection of the conductors, there is movement of the wire indicating stress has been transmitted to the soldered connections.

45.2 When the strain relief is dependent upon a polymeric material, the requirement in 45.1 is to be completed after the mold stress-relief distortion test specified is conducted:

a) In the United States, Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C

b) In Canada, CSA C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials

46 Polarity Reversal Test

46.1 A product intended to be connected to a DC supply or primary battery shall not present a risk of fire or electric shock when connected to rated voltage when each supply connection is of the incorrect polarity. The incorrect polarity is to be applied until ultimate conditions occur. Opening of a protective fuse is not prohibited during this test.

46.2 One sample is to be subjected to this test.

47 In the United States – Power-Limited Circuits Test

47.1 General

47.1.1 All field-wiring circuits that derive energy from power sources connected to a product shall be classified as a power-limited or non-power-limited circuit. A circuit shall be considered non-power-limited unless otherwise identified in the installation documentation and marking on the product.

47.1.2 The power source (or sources) supplying a power-limited circuit shall be either inherently limited requiring no overcurrent protection, or limited by a combination of a power source and overcurrent protection devices such that a power-limited circuit has electrical characteristics as described in Table 47.1 for AC circuits or Table 47.2 for DC circuits.

Table 47.1
Power Limitations for AC Circuits

Circuit voltage V_{max} [a]		Inherently limited power source (overcurrent protection not required)			Not inherently limited power source (overcurrent protection required)		
		0 – 20	over 20 – 30	over 30 – 100	0 – 20	over 20 – 100	over 100 – 150
Power limitations VA_{max} [b] (volt-amps)		–	–	–	250[d]	250	–
Current limitations I_{max} [c] (amps)		8.0	8.0	$150/V_{max}$	$1000/V_{max}$	$1000/V_{max}$	1.0
Maximum overcurrent protection (amps)		–	–	–	5.0	$100/V_{max}$	1.0
Power source maximum nameplate ratings	VA (volt-amps)	$5.0 \times V_{max}$	100	100	$5.0 \times V_{max}$	100	100
	Current (amps)	5.0	$100/V_{max}$	$100/V_{max}$	5.0	$100/V_{max}$	$100/V_{max}$

[a] V_{max} is the maximum output voltage regardless of load with rated input applied.

Table 47.1 Continued on Next Page

Table 47.1 Continued

Circuit voltage V_{max} [a]	Inherently limited power source (overcurrent protection not required)			Not inherently limited power source (overcurrent protection required)		
	0 – 20	over 20 – 30	over 30 – 100	0 – 20	over 20 – 100	over 100 – 150

[b] VA_{max} is the maximum volt-ampere output after 1 min of operation regardless of load and with overcurrent protection bypassed if used. Current-limiting impedance shall not be bypassed when determining I_{max} and VA_{max}.

[c] I_{max} is the maximum output current under any noncapacitive load, including short circuit, and with overcurrent protection bypassed if used. If a transformer limits the output current, I_{max} limits apply after 1 min of operation. If a current-limiting impedance, determined to be suitable for the purpose, is used in combination with a nonpower-limited transformer or a stored energy source, such as a storage battery to limit the output current, the limits apply after 5 s of operation.

[d] If the power source is a transformer, VA_{max} is 350 or less when V_{max} is 15 or less.

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Table 47.2
Power Limitations for DC Circuits

Circuit voltage V_{max} [a]		Inherently limited power source (overcurrent protection not required)				Not inherently limited power source (overcurrent protection required)		
		0 – 20	over 20 – 30	over 30 – 100	over 100 – 250	0 – 20	over 20 – 100	over 100 – 150
Power limitations VA_{max} [b] (volt-amps)		–	–	–	–	250[d]	250	–
Current limitations I_{max} [c] (amps)		8.0	8.0	$150/V_{max}$	0.030	$1000/V_{max}$	$1000/V_{max}$	1.0
Maximum overcurrent protection (amps)		–	–	–	–	5.0	$100/V_{max}$	1.0
Power source maximum nameplate ratings	VA (volt-amps)	$5.0 \times V_{max}$	100	100	$0.030 \times V_{max}$	$5.0 \times V_{max}$	100	100
	Current (amps)	5.0	$100/V_{max}$	$100/V_{max}$	0.030	5.0	$100/V_{max}$	$100/V_{max}$

[a] V_{max} is the maximum output voltage regardless of load with rated input applied.

[b] VA_{max} is the maximum volt-ampere output after 1 min of operation regardless of load and with overcurrent protection bypassed if used. Current-limiting impedance shall not be bypassed when determining I_{max} and VA_{max}.

[c] I_{max} is the maximum output current under any noncapacitive load, including short circuit, and with overcurrent protection bypassed if used. If a transformer limits the output current, I_{max} limits apply after 1 min of operation. If a current-limiting impedance, determined to be suitable for the purpose, is used in combination with a nonpower-limited transformer or a stored energy source, such as a storage battery to limit the output current, I_{max} limits apply after 5 s of operation.

[d] If the power source is a transformer, VA_{max} is 350 or less when V_{max} is 15 or less.

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47.1.3 Relative to 47.1.2, acceptable means for current limiting include:

a) Transformer winding impedance,

b) Thermal link embedded within the winding overwrap of a transformer,

c) Circuit components (resistors, regulators, transistors, and similar devices) which comply with the temperature test under Imax condition, and

d) Suitable current-limiting impedances (positive temperature coefficient varistor, and the like).

47.1.4 Relative to 47.1.2, the following are not acceptable means of current-limiting:

a) Circuit component burnout;

b) Permanent or replaceable fuses;

c) Opening of conductors on printed-wiring boards; and

d) Opening of internal wiring conductors.

47.1.5 The overcurrent protection device specified in 47.1.2 shall be of the non-interchangeable type such that it cannot be renewed in the field with an overcurrent device having a higher current rating.

47.1.6 When conducting I_{max} and VA_{max} measurements, all overcurrent protection devices of the control unit are to be short-circuited. However, current-limiting devices are not to be bypassed and are to be allowed to remain functional.

47.1.7 Where the product contains a float battery charger, V_{max}, I_{max}, and VA_{max} measurements are to be conducted with both AC and battery connected to the product. If the product contains a battery transfer relay or contains a trickle charge battery circuit, measurements of V_{max}, I_{max}, and VA_{max} are to be conducted with the product first energized only from the AC power source and then repeated with the product energized solely from the battery. The battery used during these measurements is to have the largest capacity as specified in the manufacturer's installation document.

47.1.8 The loads referenced in 47.2.1 – 47.4.1 shall be resistive.

47.2 Maximum voltage

47.2.1 With the product energized only from its rated primary power source, the output voltage of the circuit under test is to be measured while the circuit is connected to full rated load and under open circuit conditions. The maximum voltage recorded under these two conditions is to be considered V_{max}. Where the product incorporates a secondary source of supply, the test is to be repeated with the product energized solely from the secondary power source and with the primary power source disconnected. The V_{max} value obtained from each power source is to be considered separately when applying the requirements of Table 47.1 or Table 47.2.

47.3 Maximum current

47.3.1 In order to determine compliance with the I_{max} limitation, a variable load resistor initially set to draw rated current is to be connected across the circuit. The current through the load resistor is to be noted and the load removed. The resistance of the load shall then be incrementally decreased, momentarily reconnected across the circuit while noting the current, and then removed. The method is to be repeated until a short-circuit condition is obtained. The load resistor is then to be readjusted to a value capable of producing and maintaining a current equal to the maximum permitted in Table 47.1 and Table 47.2. The load resistor is then to be connected to the circuit and the current through the load resistor measured after 1 min or after 5 s as determined from Table 47.1 or Table 47.2.

47.3.2 The maximum current measurement is to be the rms value for circuits that are constantly energized and the peak value for circuits that pulse the output. The measurement of the time period starts when the output is initially energized with the load specified in 47.3.1, and continues until the current is continuously below the I_{max} value indicated in Table 47.1 or Table 47.2. The time period is to include any momentary period where the output current temporarily drops below the required I_{max} value limit.

47.3.3 Where a transformer limits the value of I_{max}, and when I_{max} cannot be maintained for 1 min due to transformer burnout, a plot of current versus time is to be generated and the graph extrapolated to 1 min.

The results satisfy the requirement of the test when the extrapolated value of I_{max} at 1 min does not exceed the I_{max} limitations as indicated in Table 47.1 or Table 47.2.

47.3.4 Where a transformer does not limit the current of I_{max}, and when the maximum current through the load resistor cannot be maintained for 5 s due to current-limiting devices (opening of thermal link power supply foldback, PTC varistor effect, and similar devices) the current load resistor shall be adjusted to a value which will produce a current just above the I_{max} value indicated in Table 47.1 or Table 47.2. The results are in compliance when the I_{max} value stated in Table 47.1 or Table 47.2 cannot be maintained for more than 5 s.

47.4 VA_{max} (not inherently limited circuits only)

47.4.1 In order to determine VA_{max}, the product is to be energized from a rated source of supply and the circuit under test open-circuited. A variable load resistor, initially set to draw rated circuit current, is then to be connected across the circuit, the circuit voltage and current recorded, and the load removed. The resistance of the load is then to be incrementally decreased, momentarily reconnected across the circuit while recording the voltage and current, and then removed. This procedure is to be repeated until the load resistance has been reduced to a short circuit. Using the recorded voltage and current, the volt-ampere output under each load condition is to be calculated. The load resistor is then to be adjusted to that value which produced the maximum volt-ampere calculated and then connected to the circuit. After 1 min, the voltage and current are again to be measured. The results of this test are acceptable if the calculated volt-ampere output of the circuit after 1 min does not exceed the value specified in Table 47.1 or Table 47.2, as appropriate.

48 Variable Voltage Operation Test

48.1 The product, when connected to maximum rated load as described in 32.2.2 and subjected to the input voltage conditions described in 48.2 – 48.5, shall operate as intended and without risk of fire or electric shock during all conditions of intended use. At each input voltage, all conditions of intended use are to be maintained until constant temperatures of its parts are reached, or a minimum of two hours.

48.2 The product is to be subjected to the following variable voltage conditions:

a) 110 % of the rated primary input voltage specified in Table 32.1. The secondary power source is to be connected to rated voltage.

b) 110 % of the marked rated nominal standby battery voltage or rated secondary power input voltage specified in Table 32.1. The primary input voltage is to be disconnected.

c) 85 % of rated primary input voltage specified in Table 32.1 or at some lower level of transfer voltage as specified in 35.2.3. The standby battery or, when provided, a secondary power source shall be disconnected.

d) 85 % of the marked rated nominal standby battery voltage or rated secondary power input voltage specified in Table 32.1. The primary input voltage is to be disconnected.

48.3 In conducting the reduced voltage test, the voltage is to be reduced by a means that will maintain a stable potential of the required value under the most severe conditions of normal loading.

48.4 The reduced voltage tests are to be made with the maximum line impedance as indicated in the installation wiring diagram connected to all external circuit(s).

48.5 In those cases where different components or units of a system obtain power from separate sources, each source is to be independently varied while the system is tested for its normal operation.