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Underwriters Laboratories Inc.®

A not-for-profit organization dedicated to public safety
and committed to quality service

March 8, 1996

Revision pages for

Standard for

Power Supplies for Fire Protective Signaling Systems

UL 1481, Third Edition

Attached to this transmittal notice is a reprinted title page for the third edition of UL 1481.

Attention is directed to the note on the title page of this standard outlining the procedure to be followed to retain the approved text of ANSI/UL 1481-1995.

Revised and/or additional pages may be issued from time to time.

With the inclusion of the accompanying material, the standard consists of pages dated as shown in the following checklist:

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UL 1481

Standard for

Power Supplies for Fire Protective Signaling Systems

First Edition – August, 1978
Second Edition – May, 1987

Third Edition

February 25, 1994

Approval as an American National Standard (ANSI) covers the numbered paragraphs on pages dated February 25, 1994 and May 23, 1995. These pages should not be discarded when revised or additional pages are issued if it is desired to retain the ANSI approved text.

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

Approved as ANSI/UL 1481-1979, December 7, 1979
Approved as ANSI/UL 1481-1986, September 10, 1986
Approved as ANSI/UL 1481-1995, December 13, 1995

Revisions of this standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest published set of revision pages.

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Underwriters Laboratories Inc.®

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October 6, 1995

Revision pages for

Standard for

Power Supplies for Fire Protective Signaling Systems

UL 1481, Third Edition

Attached to this transmittal notice is a revision of the third edition of UL 1481.

A CHANGE ON A PAGE DATED OCTOBER 6, 1995 IS INDICATED BY A SMALL PRINT NOTE FOLLOWING THE AFFECTED ITEM, PRECEDED AND FOLLOWED BY AN ASTERISK.

THIS REVISION IS BEING ISSUED TO CORRECT AN EDITORIAL ERROR IN PARAGRAPH 43.1. THE REQUIREMENTS ARE NOW IN EFFECT.

Revised and/or additional pages may be issued from time to time.

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36.2.4 At the conclusion of the discharge period, maximum rated alarm load is to be applied for 5 minutes. Battery terminal voltage of the discharge battery is then to be measured.

Exception: For an uninterruptible power supply, battery terminal voltage is to be measured at the end of the 15-minute discharge period.

36.3 Battery recharge

36.3.1 The voltage of a battery charged as specified in 36.3.2 shall be at least 95 percent of the voltage measured in 36.2.3.

36.3.2 At the conclusion of the test sequence specified in 36.2.2 – 36.2.4, ac input power is to be reapplied to the product for 48 hours. During charging, the product is to be operated continuously with maximum normal load connected. At the conclusion of the 48-hour recharge time, ac power is to be disconnected and battery-terminal voltage measured after one minute.

36.4 Battery discharge – second trial

36.4.1 The voltage of the battery shall not be less than 85 percent of the marked nominal battery rating after the battery has been discharged as specified in 36.2.3 and 36.2.4 following charging as specified in 36.3.2.

TESTS – BATTERY CHARGERS

37 General

37.1 The battery charger shall isolate the battery from external loads until an ac power loss occurs, at which time the battery is to be connected to these loads by means of a transfer mechanism. This mechanism may be incorporated in the charger unit or may be a part of an external system which utilizes the battery voltage.

38 Input Test – Battery Chargers

38.1 The power input to a battery charger shall not be more than 110 percent of the rated value with:

- a) A fully charged battery, and
- b) A discharged battery of the maximum capacity described by the manufacturer.

The applicable input power measurements are to be the lowest value measured within the period of 3 minutes following energizing of the input circuit.

38.1 revised May 23, 1995

39 Variable Voltage Operation Test – Battery Chargers

39.1 When the voltage to the battery charger input is reduced to 85 percent of its rated value, the battery connected to the charger shall not discharge.

40 Charging Current Test

40.1 The battery charger unit shall comply with the requirements of the Charging Current Tests, Section 36, except that during the recharge cycle, only the discharged battery is intended to be connected to the charger. Any external loading contemplated for the system is to be disconnected.

TESTS — ALL UNITS**41 Variable Ambient Temperature Test**

41.1 A product shall operate as intended following exposure to air at a temperature of 49°C (120°F) and at 0°C (32°F), for a period of 3 hours, or until thermal equilibrium has been reached, whichever occurs first.

41.2 During this test, the input of the power supply is to be connected to a voltage source in accordance with Table 27.1, and the output(s) is to be delivering maximum rated power.

41.3 Following exposure to each of the temperatures in 41.1, and while still in a heated condition, the product shall comply with the requirement of the Variable Voltage Operation Test — Power Supplies, Section 29, the Variable Voltage Operation Test — Power Supplies-Battery Chargers, Section 35, or the Variable Voltage Operation Test — Battery Chargers, Section 39, whichever is applicable.

42 Humidity Test

42.1 A product shall operate as intended during and after exposure for 24 hours to air having a relative humidity of 85 ±5 percent and a temperature of 30 ±2°C (86 ±3°F).

42.2 During this test, the input of the power supply is to be connected to a voltage source and the output circuit(s) is to be delivering maximum rated power.

42.3 Following the 24-hour exposure period, and while still in the humid environment, the product shall comply with the requirements of the Variable Voltage Operation Test — Power Supplies, Section 29, the Variable Voltage Operation Test — Power Supplies-Battery Chargers, Section 35, or the Variable Voltage Operation Test — Battery Chargers, Section 39, whichever is applicable.

43 Electric Shock Current Test

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

- a) Earth ground or
- b) Any other exposed accessible part

exceeds 42.4 volts peak, the part shall comply with the requirements of 43.2 — 43.4, as applicable.

43.1 revised October 6, 1995

43.2 The continuous current flow through a 500-ohm resistor shall not exceed the values specified in Table 43.1 when the resistor is connected between any part that is exposed only during operator servicing and either:

- a) Earth ground or
- b) Any other exposed accessible part.

**Underwriters Laboratories Inc.®**A not-for-profit organization dedicated to public safety
and committed to quality service**May 23, 1995****Revision pages for****Standard for****Power Supplies for Fire Protective Signaling Systems****UL 1481, Third Edition**

Attached to this transmittal notice is a revision of the third edition of UL 1481.

A CHANGE ON A PAGE DATED MAY 23, 1995 IS INDICATED BY A SMALL PRINT NOTE FOLLOWING THE AFFECTED ITEM, PRECEDED AND FOLLOWED BY AN ASTERISK.

THESE NEW AND REVISED REQUIREMENTS ARE NOW IN EFFECT.

The new and revised requirements are substantially in accordance with UL's bulletin on this subject dated February 6, 1995. The bulletin is now obsolete and may be discarded.

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FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction differing from those detailed in the requirements of this Standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

1.1 These requirements cover commercial stationary and fixed power supplies for fire-protective signaling systems, having input and output ratings of not more than 300 volts, direct- and alternating-current, (dc and ac), for use in indoor locations in accordance with the following Standards of the National Fire Protection Association:

NFPA 70
National Electrical Code.

NFPA 72
National Fire Alarm Code.

1.2 These requirements also cover power supply-battery charger combinations used as power supplies, and battery charger units for use as components in fire protective signaling systems.

1.3 These requirements do not cover power supplies or battery chargers integral with control units or amplifiers intended for fire-protective signaling service.

1.4 These requirements do not cover power supplies for use in hazardous locations, as defined in the National Electrical Code, ANSI/NFPA 70.

1.5 These requirements do not cover commercial power supplies covered by the Standard for Power Units Other Than Class 2, UL 1012, or commercial battery chargers covered by the Standard for Battery Chargers for Charging Engine-Starter Batteries, UL 1236.

1.6 A power supply that is not a complete assembly and depends upon installation in an end product for compliance with the requirements of this standard shall be investigated under the requirements of the standard for that end product.

1.6.1 The term "product" as used in this standard refers to all power supplies, battery chargers, power supply-battery charger combinations, and battery charger units or any part thereof covered by this standard unless specifically noted otherwise.

1.6.1 added May 23, 1995

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

2 General

2.1 Components

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

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

- a) Involves a feature or characteristic not needed in the application of the component in the product covered by this standard, or
- b) Is superseded by a requirement in this standard.

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

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

2.2 Units of measurement

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

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

2.3 Undated references

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

3 Glossary

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

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

3.3 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. The storage batteries are intended to provide a secondary source of operating power in response to failure of the primary source of operating power.

3.4 CIRCUITS, ELECTRICAL:

- a) High-Voltage — A circuit involving a potential of not more than 300 volts and having circuit characteristics in excess of those of a low-voltage circuit.
- b) Low-Voltage — A circuit involving a potential of not more than 30 volts alternating current (ac) rms, 42.4 volts direct current (dc) or ac peak.
- c) Power Limited — A circuit wherein the power is limited as described in Power-Limited Circuits, Section 31.

Revised 3.4 effective May 1, 1994

Table 3.1
Power limitations for power limited fire protective signaling
circuits supplied from an inherently limited power source

Table 3.1 deleted effective May 1, 1994

Table 3.2
Power limitations for power limited fire protective
signaling circuits supplied from a power source
with overcurrent protection

Table 3.2 deleted effective May 1, 1994

3.5 Deleted May 23, 1995

3.6 GAGES – Wherever they appear in this standard, the abbreviations MSG, GSG, and AWG mean, respectively, Manufacturers' Standard Gage for Steel Sheets, Galvanized Sheet Gage, and American Wire Gage. Reference to sheet metal by gage number is intended only as auxiliary information. Sheet metal of the indicated gage number may not be used if the forming processes have reduced the thickness of the sheet to a point below the specified minimum thickness.

3.7 LINE REGULATION – The change in steady state output resulting from a change in input line voltage.

3.8 LOAD REGULATION – The change in steady state output voltage resulting from a change in output current.

3.8.1 OPERATOR ACCESS AREA – An area to which, under normal operating conditions, either:

- a) Access can be gained without the use of a tool;
- b) The means of access is deliberately provided to the operator; or
- c) The operator is instructed to enter regardless of whether or not tools are needed to gain access.

3.8.1 added May 23, 1995

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

- a) **Fixed** – A power supply that is intended to be permanently connected to the electrical supply.
- b) **Stationary** – A power supply that is intended to be fastened in place or located in a dedicated space.

3.9 revised May 23, 1995

3.10 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.

3.11 RIPLE – An ac component superimposed on the dc output of a power supply, specified in terms of either its effective value or peak-to-peak value.

INSTRUCTIONS AND DRAWINGS

4 Details

4.1 General

4.1.1 Each product shall include instructions necessary for its intended installation and operation, as described in the following paragraphs.

4.2 Installation drawings

4.2.1 Installation instructions and drawings shall include at least the following information:

- a) Typical installation drawing layouts and complete representative installation wiring diagram for the product, indicating field connections, wiring methods in accordance with the National Electrical Code, ANSI/NFPA 70, and input and output ratings.
- b) A concise description of the operation, testing, and proper maintenance procedures for the product(s). The frequency of testing shall be in accordance with the requirements of the authorities having jurisdiction.
- c) Replacement parts shall be identified in the instructions.

4.2.1 revised May 23, 1995

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

4.2.2 revised May 23, 1995

4.3 Operating instructions

4.3.1 Operating instructions shall include at least the following:

- a) A description of the operation of the product and the function of controls and/or adjustments used during intended operation of the product.
- b) Input and output ratings.
- c) A space for the name, address, and telephone number of the local service representative.
- d) The load with which the product is intended to operate.

4.3.2 With reference to 4.3.1(d), the operating instructions for a power supply-battery charger unit shall include:

- a) The maximum charging current (trickle charge and fast charge), and
- b) The maximum ampere-hour capacity of the battery which the product is intended to charge.

4.3.3 The operating instructions shall appear on the front of the outer enclosure, or on a separate sheet that can be framed and located adjacent to the product.

4.3.4 If provided on a separate sheet in accordance with 4.3.3, the operating instructions shall include the model number (or other specific identification) of the product, and the product marking shall refer to the operating instructions by drawing number, issue number and/or date.

CONSTRUCTION

ASSEMBLY

5 General

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

5.2 The test means shall be constructed and located so as to prevent tampering by unauthorized personnel.

6 Enclosures

6.1 General

6.1.1 The frame and enclosure of a product shall be sufficiently strong and rigid to resist total or partial collapse with attendant reduction of spacings, loosening or displacement of parts and development of other conditions which could impair operation of the product and increase the risk of fire, electric shock, or personal injury.

6.1.2 Electrical parts of a product shall be located or enclosed to provide protection against unintentional contact with uninsulated high-voltage live parts.

6.1.3 Operating parts, such as light-duty relays and similar devices, shall be enclosed to protect against malfunction from dust or other foreign material which may impair their intended operation.

6.1.3 revised May 23, 1995

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

6.1.5 An enclosure containing circuits other than power limited circuits shall not be open to the floor or other support on which the product rests.

6.2 Protection of service personnel

6.2.1 *Revised and relocated as 6A.2 May 23, 1995*

6.2.2 *Revised and combined with 6.2.3 as 6A.3 May 23, 1995*

6.2.3 *Revised and combined with 6.2.2 as 6A.3 May 23, 1995*

6.2.4 *Revised and relocated as 6A.4 May 23, 1995*

6.3 Openings

6.3.1 Openings in the top and sides of an enclosure, excluding openings in operator access areas within an enclosure, shall comply with 6.3.2 – 6.3.6, as appropriate.

6.3.1 revised May 23, 1995

6.3.2 Openings in the top of an enclosure directly over uninsulated live parts at high voltage shall:

- a) Not exceed 0.187 inch (4.75 mm) in any dimension; and
- b) Be constructed so that direct vertical entry of a falling object is prevented from reaching such parts by means of traps or restriction.

See Figure 6.1 for examples of top cover designs that prevent such direct entry.

6.3.2 revised May 23, 1995

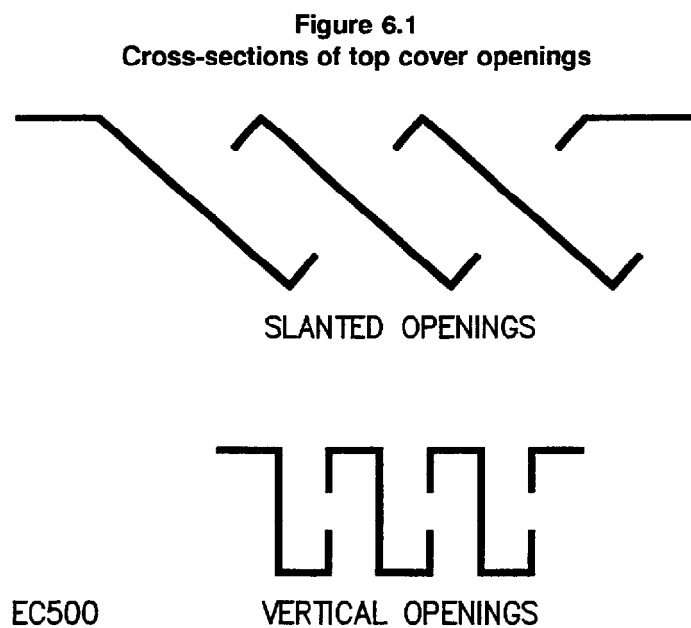


Figure 6.1 revised May 23, 1995

6.3.3 Openings in the sides of an enclosure shall either:

- a) Not exceed 0.187 inch (4.75 mm) in any dimension or
- b) Be provided with louvers that are shaped to deflect outward an external vertically falling object. See Figure 6.2 for examples of louver design.

6.3.3 revised May 23, 1995

6.3.4 Openings in the enclosure shall not give access to any relays, terminals, controls, or related components that might be subject to tampering.

Figure 6.2
Cross-sections of side louvers

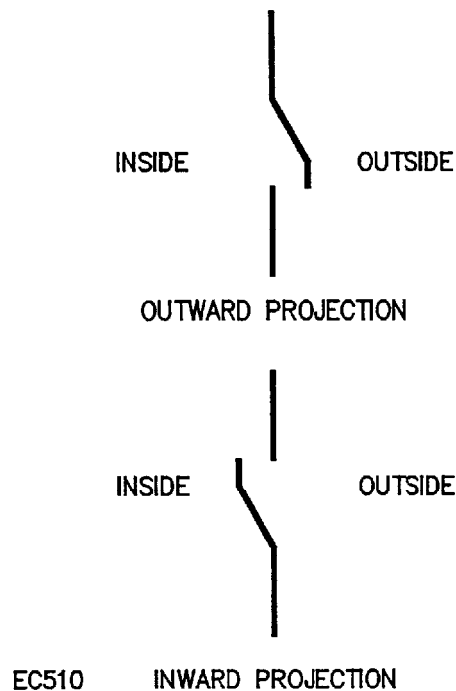


Figure 6.2 revised May 23, 1995

6.3.5 An opening shall not permit entrance of a 3/4 inch (19.1 mm) diameter rod and shall be sized and arranged so that a probe, as illustrated in Figure 6.3, cannot be made to contact any uninsulated live electrical part, other than low-voltage, when inserted through the opening in a straight or articulated position.

6.3.5.1 The probe illustrated in Figure 6.3 is to be applied to any depth that the opening will permit with a force not greater than 1 pound (4.4 N), and is to be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the power supply. The probe is to be applied in any possible configuration and, if necessary, the configuration is to be changed after insertion through the opening.

6.3.5.1 added May 23, 1995

6.3.5.2 A guard, baffle, or cover that can be removed without using a tool is to be removed when determining if a part is accessible to the user. A part that can be contacted by the probe illustrated in Figure 6.3 when inserted through an opening in a permanently attached guard or baffle is considered to be accessible to persons.

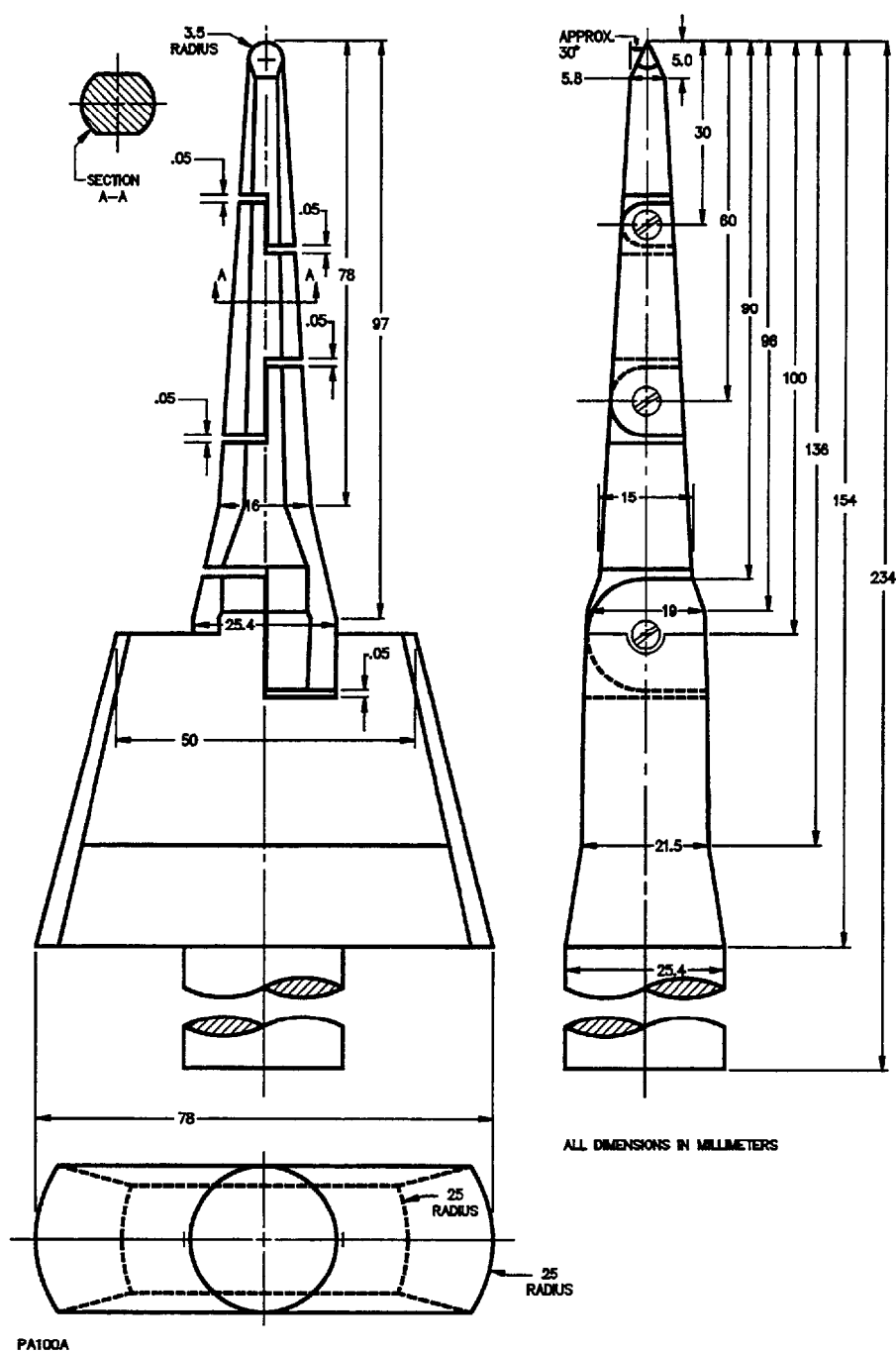
6.3.5.2 added May 23, 1995

6.3.5.3 A part on the back of a component mounting panel and a part located so as to require major disassembly by using a tool are not considered to be accessible to the user.

6.3.5.3 added May 23, 1995

6.3.6 If a power supply is not intended to be installed in a separate cabinet which has provision for connection to a Class 1 wiring system, as defined by the National Electrical Code, ANSI/NFPA 70, the enclosure of the power supply shall have provision for connection to a Class 1 wiring system.

Figure 6.3
Articulate probe with web stop^a



^aAvailable from Underwriters Laboratories Inc.

Figure 6.3 revised May 23, 1995

6.4 Cast metal

6.4.1 The thickness of cast metal for an enclosure shall be as indicated in Table 6.1.

Exception: Cast metal of lesser thickness may be used if, consideration being given to the shape, size, and function of the enclosure, it provides equivalent mechanical strength. See Impact Test for Enclosures, Section 55.

Table 6.1
Cast-metal enclosures

Use, or dimensions of area involved ^a	Minimum thickness, inch (mm)	
	Die-cast metal	Cast metal of other than the die-cast type
Area of 24 square inches (155 cm ²) or less and having no dimension greater than 6 inches (152 mm)	1/16 (1.6)	1/8 (3.2)
Area greater than 24 square inches or having any dimension greater than 6 inches	3/32 (2.4)	1/8 (3.2)
At a threaded conduit hole	1/4 (6.4)	1/4 (6.4)
At an unthreaded conduit hole	1/8 (3.2)	1/8 (3.2)
^a The area limitation for metal 1/16 inch (1.6 mm) in thickness may be obtained by the provision of reinforcing ribs subdividing a larger area.		

6.4.2 Die-cast metal for other than flush boxes may be used if it complies with one of the alloy specifications given in the Standard Specification for Zinc-Alloy Die Castings, ASTM B86-94.

6.4.3 Compliance of a zinc-base alloy die casting with the requirement of 6.4.2 is to be determined by the Standard Specification for Steel Castings, Carbon, for General Application, ASTM A27/A27M-93.

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

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

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

6.5 Sheet metal

6.5.1 The thickness of sheet metal used for the enclosure of a product shall not be less than that indicated in Tables 6.2 and 6.3.

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

Table 6.2
Minimum thickness of sheet metal for electrical enclosures
carbon steel or stainless steel

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

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

- 1) 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 inch (12.7 mm) wide.

Table 6.3
Minimum thickness of sheet metal for electrical enclosures
aluminum, copper, or brass

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

6.5.2 A plate or plug closure for an unused conduit opening or other hole in the enclosure shall have a thickness not less than:

- a) 0.014 inch (0.4 mm) for steel or 0.019 inch (0.5 mm) for nonferrous metal for a hole having a 1/4 inch (6.4 mm) maximum dimension.
- b) 0.027 inch (0.7 mm) for steel or 0.032 inch (0.8 mm) for nonferrous metal for a hole having a 1-3/8 inch (34.9 mm) maximum dimension.

6.5.3 A hole larger than 1-3/8 inch (34.9 mm) diameter shall have a closure whose thickness is not less than that required for the enclosure of the product or shall have a standard knockout seal. Such plates or plugs shall be securely mounted.

6.5.4 A knockout in a sheet metal enclosure shall be secured but shall be capable of being removed without undue deformation of the enclosure.

6.5.5 A knockout shall be provided with a surrounding surface area of sufficient size to permit seating of a conduit bushing, and shall be located so that a bushing used at any knockout likely to be used during installation will not result in spacings between uninsulated live parts and the bushing of less than those indicated under Spacings, Section 25.

6.5.6 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 power supply is mounted as intended.

6.5.7 The requirement in 6.5.6 does not apply to an opening for a mounting screw or nail or for a manufacturing operation (such as paint drainage) provided:

- a) No such opening has a dimension greater than 17/64 inch (6.75 mm) or an area greater than 0.055 square inch (35 mm²), and
- b) There is not more than one mounting screw for each 12 inches (305 mm) of length of mounting surface.

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

- a) 0.032 inch (0.81 mm) if of uncoated steel;
- b) 0.034 inch (0.86 mm) if of galvanized steel; and
- c) 0.045 inch (1.14 mm) if of nonferrous metal.

6.6 Nonmetallic

6.6.1 An electrical enclosure or parts of an electrical enclosure of nonmetallic material shall comply with applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

6.7 Doors and covers

6.7.1 An enclosure cover shall be hinged, sliding, or similarly attached so as to prevent its being removed if:

- a) It gives access to fuses or to any other overcurrent protective device, the intended functioning of which requires renewal; or
- b) It is necessary to open the cover in connection with the intended operation of the unit.

Exception: A hinged cover is not required if the only fuse(s) enclosed is intended to provide protection to portions of internal circuits such as may be used on a separate printed wiring board or circuit subassembly, to prevent excessive circuit damage resulting from a fault. Such a fuse(s) may be used if the following or equivalent marking is indicated on the cover: "Circuit Fuse(s) Inside – Disconnect Power Prior To Servicing."

6.7.2 An unhinged cover shall be securely held in place by screws, or the equivalent.

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

6.8 Transparent covers

6.8.1 Glass covering an observation opening shall be secured in place so that it cannot be readily displaced in service and shall provide mechanical protection for the enclosed parts. The thickness of a glass cover shall not be less than that indicated in Table 6.4.

Table 6.4
Thickness of glass covers

Maximum size of opening				Minimum thickness	
Length or width		Area			
inch	(mm)	Inch ²	(cm ²)		
4	(102)	16	(103)	1/16	(1.6)
12	(305)	144	(929)	1/8	(3.2)
over 12	(305)	over 144	(929)	a	
a 1/8 inch (3.2 mm) or more, depending upon the size, shape, and mounting of the glass panel.					

6.8.2 A glass panel for an opening having an area of more than 144 square inches (928 cm²), or having any dimension greater than 12 inches (305 mm), shall be supported by a continuous groove not less than 3/16 inch (4.8 mm) deep along all four edges of the panel, or an equivalent arrangement.

6.8.3 A transparent material other than glass may be used for the cover of an observation opening provided the material does not increase the risk of fire, distort, nor become less transparent at the temperature to which it may be subjected under intended operating conditions.

6.9 Screens and expanded metal

6.9.1 A screen or expanded metal used as a guard, enclosure, or part of an enclosure, shall comply with the requirements of 6.1.5, or the Exceptions to 6.9.2 and 6A.3.

6.9.1 revised May 23, 1995

6.9.2 Perforated sheet steel and sheet steel used for expanded metal mesh shall not be less than 0.042 inch (1.07 mm) thick [0.045 inch (1.14 mm) if zinc coated] if the mesh openings or perforations are 1/2 square inch (323 mm²) or less in area, and shall not be less than 0.080 inch (2.03 mm) thick [0.084 inch (2.13 mm) if zinc coated] for larger openings. The largest dimension shall not exceed 4 inches (102 mm).

Exception: If the indentation of a guard or the enclosure will not alter the clearance between uninsulated live parts and grounded metal so as to impair intended operation of the product or reduce spacings below the minimum required values, see Spacings, Section 25, 0.020 inch (0.51 mm) expanded metal mesh or perforated sheet metal [0.023 inch (0.58 mm) if zinc coated] may be used, if:

- a) *The exposed mesh on any one side or surface of the protected product has an area of not more than 72 square inches (464 cm²) and has no dimension greater than 12 inches (305 mm), or that*
- b) *The width of a protected opening is not greater than 3-1/2 inches (89 mm).*

6.9.3 The wires of a screen shall not be smaller than No. 16 AWG (1.3 mm²) if the screen openings are 1/2 square inch (323 mm²) or less in area, and shall not be smaller than No. 12 AWG (2.1 mm²) for larger screen openings.

6A Protection of Service Personnel

6A.1 These requirements apply to live parts used in circuits involving a risk of electric shock.

6A.1 added May 23, 1995

6A.2 An uninsulated live part involving a risk of electric shock, and moving parts, sharp corners, and projections that involve a risk of injury to persons shall be formed, located, guarded, or enclosed so as to prevent unintentional contact by persons performing such servicing as fuse replacement, adjusting of controls, and required maintenance, including those performed only at the time of installation or during servicing procedures.

6.2.1 revised and relocated as 6A.2 May 23, 1995

6A.3 If the linear distance from a component requiring servicing to an uninsulated current-carrying part of a high-voltage circuit is less than 6 inches (152 mm), protection shall be provided by insulating tape, barriers, or equivalent.

Exception: In lieu of the minimum 6 inch requirement, an interlock may be provided on the cover to de-energize all live parts in the enclosure, or the word "CAUTION" and the following or equivalent permanent and prominent marking shall be provided on the cover front: "De-Energize Unit Prior to Servicing."

5.2.2 and 6.2.3 revised and combined as 6A.3 May 23, 1995

6A.4 If provision is made for testing the operability of a product, the means provided shall not result in the risk of electric shock or injury to the personnel involved.

6.2.4 revised and relocated as 6A.4 May 23, 1995

6A.5 The following are not considered to be uninsulated live parts:

- a) Coils and windings of relays, solenoids, and transformers that are provided with intended insulating overwraps not less than 1/32 inch (0.8 mm) thick, or the equivalent;
- b) Enclosed motor windings;
- c) Terminals and splices with intended insulation; and
- d) Insulated wire.

6A.5 added May 23, 1995

7 Electric Shock

7.1 Any part that is exposed only during operator servicing shall not present the risk of electric shock. See Electric Shock Current Test, Section 43.

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

- a) Have a maximum resistance of 5.2 megohms,
- b) Have a minimum wattage rating of 1/2 watt, and
- c) Be effective with the power switch in either the on or off position.

Exception: The conductive connection need not be provided if:

- a) *Such a connection is established in the event of electrical breakdown of the antenna isolating means,*
- b) *The breakdown does not result in a risk of electric shock, and*
- c) *In a construction using an isolating power transformer, the resistance of the conductive connection between the supply circuit and chassis does not exceed 5.2 megohms.*

7.3 The maximum value of 5.2 megohms specified in 7.2 is to include the maximum tolerance of the resistor value used; that is, a resistor rated 4.2 megohms with 20 percent tolerance or a resistor rated 4.7 megohms with a 10 percent tolerance may be used. A component comprised of a capacitor with a built-in shunt resistor that complies with the requirements for antenna isolating capacitors may be rated a minimum of 1/4 watt.

8 Corrosion Protection

8.1 Iron and steel parts shall be protected against corrosion by enameling, painting, galvanizing, plating, or other means determined to be equivalent.

Exception No. 1: Bearings, laminations, and other parts of iron or steel such as washers and screws need not comply with this requirement.

Exception No. 2: A part need not be protected against corrosion if the corrosion of the part would not result in a risk of fire, electric shock, or injury to persons.

8.1 revised May 23, 1995

8.2 The requirement of 8.1 applies to all enclosures of sheet steel or cast iron, and to all springs and other parts upon which intended mechanical operation may depend.

8.3 Bearing surfaces shall be of such materials and design as to resist binding due to corrosion.

8.4 Metal shall not be used in combinations such as to cause galvanic action.

8.5 Cabinets and enclosures of corrosion-resistant material may be used without special corrosion protection.

FIELD WIRING CONNECTIONS

9 General

9.1 Wiring terminals or leads shall be provided for connection of conductors of at least the size required by the National Electrical Code, ANSI/NFPA 70, corresponding to the electrical rating of the unit.

9.2 Duplicate terminals or leads, or equivalent means to achieve electrical supervision, shall be provided for each incoming and outgoing alarm-initiating-circuit connection. A common terminal may be used for connection of both incoming and outgoing wires, if the design and construction of the terminal does not permit an uninsulated section of a single conductor to be looped around the terminal and serve as two separate connections, thereby precluding supervision of the connection in the event that the wire becomes dislodged from under the terminal. A notched clamping plate under a single securing screw may be used, if separate conductors of an initiating circuit are intended to be inserted in each notch, but this arrangement shall be supplemented by additional marking in the wiring area or on the installation wiring diagram specifying the intended connections to the terminals.

9.3 A field-wiring terminal shall be prevented from turning.

10 Separation of Circuits

10.1 If the construction of the product is such that the product either requires or permits power-limited fire protective signaling circuit conductors to occupy the same enclosure as electric light, power, Class 1, or nonpower-limited fire protective signaling circuit conductors, both of the following conditions shall be met:

- a) The enclosure shall provide a minimum of two cable entry openings into the enclosure so that the power-limited fire protective signaling conductors may be segregated from electric light, power, Class 1, and nonpower-limited fire protective signaling conductors. The installation document of the product shall completely detail cable entry routing of all conductors into the enclosure.
- b) The product shall be constructed so that with all field installed wiring connected, a minimum of 1/4-inch (6.4-mm) spacing is provided between all power-limited fire protective signaling conductors and all electric light, power, Class 1, or nonpower-limited fire protective signaling conductors. Compliance with this requirement may be achieved by specific wire routing configurations that are detailed in the installation document of the product. If a wire routing scheme will not ensure a separation of 1/4 inch, barriers shall be used to provide the separation.

Added 10.1 effective May 1, 1994

11 Field Wiring Compartment

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

11.2 An outlet box, terminal box, wiring compartment, or the like in which connections to the power supply circuit will be made in the field shall be free from any sharp edge, including screw threads, a burr, a fin, a moving part, or the like, that may abrade the insulation on conductors or otherwise damage the wiring.

11.2 revised May 23, 1995

11.3 An outlet box or compartment in which field wiring connections are to be made shall be located so that the connections may be readily inspected after the product is installed as intended. The removal of screws, or equivalent arrangement, to view the field wiring connections, is considered to comply with this requirement.

11.3 revised May 23, 1995

12 Terminals – General Application

12.1 Either of the following terminal configurations may be used on all circuits to which field wiring connections are made.

- a) Connectors and Lugs – Nonferrous soldering lugs or solderless (pressure) wire connectors shall be used for No. 8 AWG (8.4 mm²) and larger wires. If the connectors or lugs are secured to a plate, the plate thickness shall not be less than 0.050 inch (1.3 mm) thick. Securing screws may be plated steel.
- b) Terminal Plates with Wire Binding Screws [For No. 10 AWG (5.3 mm²) and Smaller Wires] – A terminal plate tapped for a wire binding screw shall be of a nonferrous metal not less than 0.050 inch (1.3 mm) in thickness for a No. 8 (4.2 mm diameter) or larger screw, and not less than 0.030 inch (0.76 mm) in thickness for a No. 6 (3.5 mm diameter) screw. The plate shall 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.

If a wire binding screw is used at a wiring terminal, the screw shall not be smaller than No. 8 (4.2 mm diameter), except that a No. 6 (3.5 mm diameter) screw may be used for the connection of a No. 14 AWG (2.1 mm²) or smaller conductor and a No. 4 (2.8 mm diameter) may be used for No. 19 AWG (0.65 mm²) or smaller conductor. The screws may be plated steel. Other constructions may be used if they provide equivalent strength of the terminal plate and thread security of the wire binding screw. If two or more conductors are intended to be connected by wrapping under the same screw, a nonferrous intervening metal washer shall be used for each additional conductor. A separator washer is not required if two conductors are separated and intended to be secured under a common clamping plate. If the wires protrude above terminal barriers, the nonferrous separator shall include means, such as upturned tabs or sides, to retain the wire.

13 Leads

13.1 Leads provided for field connections shall not be less than 6 inches (152 mm) long, shall be provided with strain relief, shall not be smaller than No. 18 AWG (0.82 mm²) and the insulation, if of rubber or thermoplastic, shall not be less than 1/32 inch (0.8 mm) in thickness.

Exception: The leads may be less than 6 inches in length if it is evident that the use of a longer lead may result in damage to the insulation.

14 Grounding

14.1 In a product intended to be connected to a grounded circuit, one terminal or lead shall be identified for the connection of the grounded conductor. The identified terminal or lead shall be the one which is connected to dead metal parts within the frame or enclosure and to which no primary overcurrent-protective devices of the single-pole type are connected.

14.1 revised May 23, 1995

14.2 The following circuits of a power supply shall be grounded under the indicated conditions:

a) AC circuits less than 50 volts.

- 1) Where supplied by transformers if the transformer supply system exceeds 150 volts to ground.
- 2) Where supplied by transformers if the transformer supply system is ungrounded.
- 3) Where installed as overhead conductors outside of buildings.

b) AC circuits of 50 volts and over.

- 1) Where the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts.
- 2) Where the system is nominally rated 240/120 volt, 3 phase, 4 wire in which the midpoint of one phase is used as a circuit conductor.

c) DC circuits operating at 51 – 300 volts, except for 250 volt dc maximum fire protective signaling power limited circuits having a maximum current of 0.03 ampere as specified in the National Electrical Code, ANSI/NFPA 70.

14.3 The following means for grounding may be used:

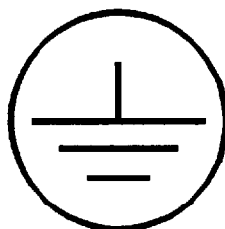
- a) In a product intended to be permanently connected by a metal-enclosed wiring system, a knockout, or equivalent opening in the metal enclosure.
- b) In a product intended to be connected by a nonmetallic-enclosed wiring system, such as nonmetallic-sheathed cable, an equipment grounding terminal or lead.

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

14.5 On an equipment grounding terminal, a wire-binding screw intended for the connection of an equipment grounding conductor shall have a green colored head that is hexagonal, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be plainly marked "G," "GR," "GROUND," "GROUNDING," or the like, or by a marking on a wiring diagram provided on the unit. The wire-binding screw or pressure wire connector shall be located so that it is unlikely to be removed during servicing of the unit. The symbol illustrated in Figure 14.1 may be used to identify the grounding conductor.

14.5 revised May 23, 1995

Figure 14.1
Grounding symbol



UL0005

Figure 14.1 added May 23, 1995

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

INTERNAL WIRING AND ASSEMBLY

15 General

15.1 Unless it is to be evaluated as an uninsulated live part, insulated internal wiring – including an equipment-grounding conductor – shall consist of wire of a type or types intended for the application, when considered with regard to:

- a) The temperature and voltage to which the wiring is likely to be subjected;

- b) Exposure to oil, grease, cleaning fluid, or other substances likely to have a deleterious effect on the insulation; and
- c) Other conditions of service to which it is likely to be subjected.

15.1 revised May 23, 1995

15.2 Leads or a cable assembly connected to parts mounted on a hinged cover shall be of sufficient length to permit the full opening of the cover without applying stress to the leads or their connections. The leads shall be secured or equivalently arranged to prevent abrasion of insulation and jamming between parts of the enclosure.

15.3 *Deleted May 23, 1995*

15.4 Wireways shall be smooth and entirely free from sharp edges, burrs, fins, moving parts, and the like, which may cause abrasion of the conductor insulation.

15.5 All splices and connections shall be mechanically secure and bonded electrically.

15.6 Stranded conductors clamped under wire-binding screws or similar parts shall have the individual strands soldered together or equivalently arranged.

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

15.8 A printed wiring assembly shall comply with the Standard for Printed-Wiring Boards, UL 796.

16 Separation of Circuits

16.1 General

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

16.1 relocated as 16.1.1 May 23, 1995

16.2 Barrier

16.2.1 A metal barrier used to provide separation between the wiring of different circuits shall have a thickness at least equal to that required by Table 16.1 as determined by the size of the barrier. A barrier of insulation material shall not be less than 0.028 inch (0.71 mm) thick and shall be of greater thickness if its deformation may be readily accomplished so as to defeat its purpose. Any clearance between the edge of a barrier and a compartment wall shall be not more than 1/16 inch (1.6 mm).

16.2 relocated as 16.2.1 May 23, 1995

Table 16.1
Thickness of flat sheets of insulating material

Maximum dimensions				Minimum thickness, Inch (mm)	
Length or width, Inches (mm)		Area, Square inches (cm ²)			
24	(610)	360	(2323)	3/8 ^a	(9.5)
48	(1219)	1152	(7432)	1/2	(12.7)
48	(1219)	1728	(11,148)	5/8	(15.9)
over 48	(1219)	over 1728	(11,148)	3/4	(19.1)

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

17 Bonding for Grounding

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

Exception No. 1: Adhesive-attached metal marking plates, screws, handles, and the like, located on the outside of enclosures or cabinets and isolated from electrical components or wiring by grounded metal parts so that they are not likely to become energized, need not be bonded.

Exception No. 2: Isolated metal parts, such as a relay or contactor magnet or armature, small assembly screws, and the like, which are positively separated from wiring and uninsulated live parts need not be bonded.

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

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

Exception No. 5: Power-limited circuitry in accordance with 3.4(c) need not be bonded.

17.1 revised May 23, 1995

17.2 Uninsulated dead metal parts of cabinets, electrical component and cover enclosures, mounting brackets, capacitors, and the like shall be bonded for grounding if they may be contacted by the user or by service personnel.

17.2 revised May 23, 1995

17.3 A bonding means may be used as an electrical conductor. If of ferrous metal, it shall be protected against corrosion by painting, plating, or the equivalent. The conductor shall be of adequate size. A separate bonding conductor shall be installed so that it is protected from mechanical damage.

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

17.5 A bolted or screwed connection that incorporates a star washer or serration under the screwhead may be used for penetrating nonconductive coatings where required for compliance with 17.1.

17.6 Where the bonding means depends upon screw threads, two or more screws to two full threads of a single screw engaging metal is in compliance with 17.1.

17.7 Metal-to-metal hinge-bearing members for doors or covers may be used as a means for bonding the door or cover for grounding providing a multiple bearing-pin type (piano-type) hinge is used.

17.8 A bonding conductor shall be aluminum, copper, or copper clad aluminum. The size of the conductor shall be in accordance with Table 17.1.

17.8 revised May 23, 1995

Table 17.1
Bonding wire conductor size

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

^a Or equivalent cross-sectional area.

Table 17.1 revised May 23, 1995

17.9 A conductor, such as a clamp or strap, used in place of a separate wire conductor may be used, if the minimum cross-sectional conducting area of the bonding means is not less than that of the wire indicated in Table 17.1.

17.10 A splice shall not be employed in a bonding conductor.

17.10 revised May 23, 1995

COMPONENTS – ELECTRICAL

18 General

18.1 Mounting of components

18.1.1 All stationary parts of a product which support moving components, shall be securely mounted in position and prevented from loosening or turning.

18.1.2 Uninsulated live parts shall be secured to the base or mounting surface so that they will be prevented from turning or shifting in position, if such motion may result in a reduction of spacings below the minimum values required. See Spacings, Section 25.

18.1.3 Friction between surfaces shall not be used as a means to prevent turning, loosening, or shifting of apart as required in 18.1.1 and 18.1.2, but a toothed lock washer that provides both spring take-up and an interference lock, or equivalent means may be used.

18.2 Insulating materials

18.2.1 Materials used for a base for the support of live parts shall be nonflammable, moisture-resistant insulating material, such as porcelain, phenolic or cold-molded composition, or the equivalent.

18.2.2 Among the factors to be considered in judging electrical insulation are mechanical and electrical strength, resistance to burning, moisture, arcing, and creep (flow due to stress), and thermal endurance and resistance to temperatures encountered in intended use. Polymeric materials used as an enclosure or for the support of current-carrying parts shall comply with the applicable portions of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

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

18.2.4 Ordinary vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not for the sole support of live parts where shrinkage, current leakage, or warping of the fiber may introduce a risk of fire or electric shock.

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

18.2.6 The thickness of a flat sheet of insulating material, such as impregnated asbestos-cement composition, phenolic composition, or the equivalent, used for panel-mounting of parts shall not be less than that indicated in Table 16.1.

18.3 Current-carrying parts

18.3.1 A current-carrying part shall be of silver, copper, a copper-alloy, or the equivalent.

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

18.4 Bushings

18.4.1 Holes in walls or partitions through which insulated wires pass and on which they may bear shall have smooth, rounded surfaces to prevent abrasion of the insulation. Bushings, if used, shall be ceramic, phenolic, cold-molded composition, fiber, or other equivalent material. Thermoplastic material shall not be clamped in a manner that would cause cold-flow of the material which could result in risk of fire or electric shock.

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

18.4.3 Ordinary vulcanized fiber may be used where it will not be subjected to a temperature higher than 90°C (194°F) under intended operating conditions if the bushing is not less than 3/64 inch (1.2 mm) in thickness and if it will not be exposed to moisture.

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

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

19 Meters

19.1 A battery-charging rectifier shall be provided with readily accessible terminal facilities for the connection of portable meters by which the battery voltage and charging current can be determined. These terminals shall be identified as to their function.

20 Overcurrent Protection

20.1 A battery, other than a primary battery having an open-circuit potential of 30 volts or less, shall be protected by a fuse or other overcurrent protective device rated at not less than 150 percent of the maximum operating load on the battery.

20.2 A fuse or other overcurrent protective device provided in the input supply circuit of a power supply shall have a rating not less than 150 percent of the input rating of the power supply unit.

20.3 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 volts.

21 Semiconductors

21.1 Semiconductors shall be rated for the intended application under all environmental conditions to which they may be exposed in service. See Performance Tests, Sections 26 – 57.

22 Storage Batteries

22.1 A storage battery shall have sealed cells or cells with spray-trap vents.

22.2 Batteries shall be located and mounted so that terminals of cells will be prevented from coming in contact with terminals of adjacent cells or with metal parts of the battery enclosure as a result of shifting of the batteries. The mounting arrangement shall permit ready access to the cell for checking the specific gravity of the electrolyte.

22.3 A conditioning charge shall be limited so that, with the maximum rate of charge which can be obtained, the battery gases will not affect any part of the power supply. The trickle and fast charge rates of a battery shall not exceed the battery manufacturer's recommended rates.

22.4 A compartment for storage batteries shall have a total volume not less than twice the volume occupied by the batteries. Ventilating openings shall be provided and located to permit circulation of air and dispersion of gas while the battery is being charged at the highest rate permitted by the charging circuit.

22.5 The interior of a storage battery compartment shall be protected against the detrimental action of the electrolyte.

22.6 The requirements of 22.4 and 22.5 do not apply to compartments containing only dry electrolyte or permanently sealed batteries.

23 Switches

23.1 A switch shall have current and voltage ratings not less than those of the circuit that it controls when the unit is operated in its intended manner.

23.1 revised and separated into 23.1 and 23.2 May 23, 1995

23.2 If the circuit controlled has a power factor less than 75 percent, the switch shall have:

- a) A horsepower rating (judged on the basis of the ampere equivalent), or
- b) A current rating of not less than 200 percent of the maximum load current.

23.1 revised and separated into 23.1 and 23.2 May 23, 1995

24 Transformers, Relays

24.1 An input supply line voltage transformer shall be of the two-coil or insulated type.

Exception: An autotransformer may be used if the terminal or lead common to both input and output circuits is identified and the output circuits are located within the enclosure containing the autotransformer as described in 14.1.

24.2 Coils shall be treated with an insulating varnish, and baked or otherwise impregnated to exclude moisture.

24.3 Enameled, or equivalently coated wire is not required to be given additional treatment to prevent moisture absorption.

25 Spacings

25.1 Spacings between uninsulated live parts and between uninsulated live parts and dead metal parts shall not be less than those indicated in 25.2 – 25.7 and Table 25.1.

Exception No. 1: The spacing requirements in Table 25.1 do not apply to the inherent spacings within a component, except at wiring terminals. Such spacings shall comply with the requirements for the component in question if they are less than the values specified in Table 25.1. The electrical clearance resulting from the assembly of a component into the complete device, including clearances to dead metal or enclosures, shall be those indicated in Table 25.1.

Exception No. 2: The to-walls-of-enclosure spacings indicated in Table 25.1 shall not be applied to an individual enclosure of a component part within an outer enclosure.

25.1 revised May 23, 1995

Table 25.1
Minimum spacings

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

^a Measurements are to be made with solid wire of adequate ampacity for the applied load connected to each terminal. In no case shall the wire be smaller than No. 18 AWG (0.82 mm²).

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

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

25.2 The spacings between an uninsulated live part and:

- a) A wall or cover of a metal enclosure;
- b) A fitting for conduit or metal-clad cable; and
- c) A metal piece attached to a metal enclosure, where deformation of the enclosure is liable to reduce spacings,

shall not be less than those indicated in Table 25.1.

25.3 The spacings between an uninsulated live part and:

- a) An uninsulated live part of opposite polarity,
- b) An uninsulated grounded part other than the enclosure, and
- c) An exposed dead metal part that is isolated (insulated)

shall not be less than those indicated in Table 25.1.

25.3 revised May 23, 1995

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

25.5 *Deleted May 23, 1995*

25.6 Enamel-insulated wire is considered an uninsulated live part in determining compliance with spacing requirements, but enamel may be used as turn-to-turn insulation in coils.

25.7 An insulating liner or barrier of vulcanized fiber, varnished cloth, mica, phenolic composition, or similar material used where spacings would otherwise be insufficient, shall not be less than 0.028 inch (0.7 mm) in thickness; except that a liner or barrier not less than 0.013 inch (0.3 mm) in thickness may be used in conjunction with an air spacing of not less than one-half of the through-air spacing required. The liner shall be located so that it will not be subjected to the direct effects of arcing.

PERFORMANCE

DETAILS

26 General

26.1 Products fully representative of production units are to be used for each of the following tests unless otherwise specified.

26.2 One sample power supply of each rating is to be supplied for test.