UL 1730

STANDARD FOR SAFETY

Smoke Detector Monitors and Accessories for Individual Living Units of Multifamily Residences and Hotel/Motel Rooms

UL Standard for Safety for Smoke Detector Monitors and Accessories for Individual Living Units of Multifamily Residences and Hotel/Motel Rooms, UL 1730

Fourth Edition, Dated December 29, 2006

Summary of Topics

This revision of ANSI/UL 1730 dated April 11, 2022 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

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

The requirements are substantially in accordance with Proposal(s) on this subject dated February 11, 2022.

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Standard for Smoke Detector Monitors and Accessories for Individual Living Units of Multifamily Residences and Hotel/Motel Rooms

First Edition – September, 1987
Second Edition – September, 1994
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Fourth Edition

December 29, 2006

This ANSI/UL Standard for Safety consists of the Fourth Edition including revisions through April 11, 2022.

The most recent designation of ANSI/UL 1730 as a Reaffirmed American National Standard (ANS) occurred on April 11, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover electrically operated smoke detector monitors intended to be used in ordinary indoor locations in accordance with the National Electrical Code, NFPA 70; the Life Safety Code, NFPA 101; and Chapter 2 of the National Fire Alarm Code, NFPA 72.

1.2 As covered by these requirements, a smoke detector monitor is a unit that provides for the connection and supervision of initiating circuits which are, in turn, to be connected to smoke detectors. The smoke detectors may be single station or multiple station and are installed within individual living units of multifamily residences or hotel or motel rooms. The monitor provides alarm or trouble indications at an attended central monitoring location as a supplement to the signal indication provided at the location of the smoke detector. These units are not intended for use as fire protective signaling control units.

1.3 In addition to smoke detector monitoring, a monitor covered by these requirements may provide for manual activation of alarm signals within the individual living units (whether integral with the smoke detectors or not) on either an individual or zone basis.

1.4 An installation wiring diagram attached to the monitor, or referenced in the markings on the monitor, indicates the devices and circuits acceptable for connection to it in the field.

1.5 These requirements do not cover automatic fire detectors or alerting devices not provided as part of the monitor, nor do they cover units intended for connection to smoke detectors that:

a) Do not have integral sounding devices or

b) Are installed in common areas of multifamily dwellings.

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

2 General

2.1 Components

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

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

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

b) Is superseded by a requirement in this standard.

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

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

2.2 Units of measurement

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

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

2.3 Undated references

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

3 Glossary

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

3.2 ALARM SIGNAL – An audible and visual signal indicating an emergency fire condition that requires immediate action.

3.3 ALERTING DEVICE – Any device that provides an audible signal to the attendant to indicate a fire or trouble condition. Examples of audible signal devices are bells, horns, sirens, electronic horns, buzzers, and chimes.

3.4 ALERTING DEVICE CIRCUIT – A circuit to which alerting devices are connected.

3.5 END-OF-LINE RESISTOR – A resistor installed at the end of an initiating or alerting device circuit to limit the amount of supervisory current.

3.6 FAULT – An open or ground condition on any line extending from a monitor or monitoring accessory.

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

3.8 GROUNDING CONDUCTOR – A conductor used to connect noncurrent carrying parts of equipment, raceways, and enclosure to a grounding electrode at the service. The grounding electrode is, in turn, connected to earth ground or to some conducting body that serves in place of earth ground.

3.9 INITIATING DEVICE – An automatically operated smoke detector, the operation of which results in a fire alarm indication at the monitor.

3.10 INITIATING DEVICE CIRCUIT – A circuit to which initiating devices are connected.

3.11 MONITOR – An electrically-operated visual and audible alerting device containing or having provision for connection to remote alarm and trouble alerting devices. This device is used to indicate the presence of alarm and faults on the circuit extending from the unit.

3.12 MONITOR ACCESSORY – A device or appliance that is externally connected to a monitor and employed to provide supplementary signaling indication. Such accessories include end-of-line resistors or diodes, auxiliary relays, remote switches, and living area interface units.

3.13 PROGRAM-CONTROLLED UNIT – A unit for which the intended operation is controlled or influenced by a stored program. As used here, the word "program" refers to a set of instructions that is carried out in a sequential and repetitive manner and that determines the system output signal resulting from a specific system input signal. "Stored" refers to the action provided by memory devices in which the memory may be either transient or permanent and that are used for retaining information, instruction, status, and the like.

3.14 SIGNALING LINE CIRCUIT – A circuit over which signals are transmitted between a monitor and its accessories.

3.15 SUPPLEMENTARY SIGNALING CIRCUIT – A circuit to which room status or housekeeping equipment, or the like, may be connected.

3.16 TROUBLE SIGNAL – A visual and audible signal indicating a fault condition of any nature, such as an open or ground, or other trouble condition that has occurred in the device or connected wiring.

3.17 VOLTAGE CLASSIFICATIONS:

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

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

c) Power-Limited Circuit – A circuit in which the power is limited as specified in Power-Limited Circuits, Section 36.

INSTRUCTIONS AND DRAWINGS

4 General

4.1 Installation wiring diagram

4.1.1 An installation wiring diagram shall be provided with each monitor illustrating the field connections to be made. The drawing may be attached to the unit or, if separate, shall be referenced in the marking on the unit by the name or trademark of the manufacturer, drawing number, and issue number or date.

4.1.2 The drawing shall show a pictorial view of the installation terminals or leads to which field connections are to be made as they would appear when viewed during an installation. The terminal numbers on the unit shall agree with the numbers on the drawing.

4.1.3 The following marking information shall appear on the installation wiring diagram for the applicable circuits to which field connections are made. In addition, each circuit shall be marked to indicate that the circuit is "SUPERVISED" or "NOT SUPERVISED."

a) Main Supply Circuit – Volts, frequency, and maximum current input or specific power supply with which the unit is intended to be used. A terminal for the connection of a grounded conductor shall be properly identified. If the input current can vary appreciably with the extent of output circuit loading and will affect the size of the supply circuit wire used, more than one current rating may be shown in conjunction with a marking on the unit indicating the limitations of loading.

b) Trouble Supply Circuit – Voltage, frequency, and maximum current input.

c) Battery Circuit – DC voltage and the maximum current input. For a storage battery intended to be charged by the unit, the maximum charging currents (trickle and fast charge) shall be indicated as well as the capacity in ampere-hours.

d) Initiating Device Circuit – Reference by manufacturer's name and model number to the intended smoke detectors and the intended connection. Smoke detectors shall be shown connected in an initiating device circuit such that a trouble signal emanating from a particular detector (for example, the beacon lamp in a photoelectric detector) will not prevent operation for alarm signals from other initiating devices on the same circuit. The maximum line impedance shall be indicated unless the unit can operate with a 100 ohm impedance in each circuit.

e) Alerting Device Circuit – The type of signaling devices and their intended connection. If the circuit is intended for the connection of a polarized appliance, the field connections to which the appliance is to be wired shall be marked with plus or minus (+, −) symbols, or symbols that have been determined to be equivalent, to indicate the intended field connection.

f) Supplementary Signaling Circuits – Maximum current, voltage, and frequency. If the circuit provides relay contact operation, the position of the contacts and the condition of the circuit (supervisory, alarm, or trouble) shall be indicated.

g) Signaling Line Circuit – Maximum line impedance, voltage, current, and frequency. The current operating range shall also be indicated if a field adjustment of current is indicated.

h) Accessory Circuits – Reference to the name of manufacturer, model number, and connection to the accessory.

i) Power-Limited Circuits – Connections to circuits that may be connected to power-limited cable shall be identified by the marking "Power-Limited Circuit" or a marking determined to be equivalent.

j) Aluminum Connections – The following shall be marked on the wiring diagram: "Do Not Use Aluminum Conductors."

k) Wiring Terminals – Where extra terminals are provided to which field connections are not intended, the marking "NC" or a marking determined to be equivalent shall be used.

4.1.4 The output parameters indicated in accordance with 4.1.3 (d) – (g) shall be stated as specified in Table 4.1, or in a format determined to be equivalent.

Table 4.1
Output parameters

		Current (or wattage)		
Designation	**Type voltage**	**Normal maximum standby (alarm)**	**Frequency**	**Ripple voltage**
Alternating current	AC			
Half-wave	HW			
Full-wave	FW			
Direct current	DC			

4.1.5 For a unit provided with field-wiring terminals as described in 14.3.1:

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

b) The range of wire sizes shall be indicated on the installation wiring diagram.

c) If means for testing for an open and a ground fault on the circuit to which the wiring is connected is not incorporated into the unit, the means shall be indicated on the installation wiring diagram.

4.2 Operating instructions

4.2.1 A monitor shall be provided with understandable operating instructions. These instructions shall appear on the cabinet front or on a separate sheet that can be framed and located adjacent to the unit.

4.2.2 If separate from the unit, the instructions shall include the model number of the unit and be referenced in the marking on the unit by number and issue number or date.

4.2.3 The instructions shall include a capsule description of pertinent conditions applicable to the particular monitor. Examples of typical conditions are as follows:

a) Normal standby;

b) Alarm;

c) Alarm test;

d) Alarm reset;

e) Trouble;

f) Off-normal position of switches;

g) Function of lights, switches, and meters;

h) Periodic testing recommendations;

i) Fuse replacement; and

j) Alarm silencing procedure.

4.2.4 In addition to the description specified in 4.2.3, a blank space shall be provided on the instruction sheet to fill in the name, address, and telephone number of the local service representative to contact in the event of trouble.

4.2.5 If the instructions appear on a separate sheet a notation shall be added on the bottom that the instructions should be framed and placed adjacent to the unit for ready reference.

CONSTRUCTION

ASSEMBLY

5 Protection of Service Personnel

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

5.2 During the examination of a unit in connection with the requirements in 5.1, a part of the outer enclosure that may be removed without the use of tools, or part of the outer enclosure that may be

removed by the user to allow access for making intended operating adjustments, shall be disregarded; it will not be assumed that the part in question affords protection against electric shock.

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

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

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

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

c) Insulated wire.

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

Exception No. 1: A unit need not comply with this requirement if either:

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

b) The cover is marked in accordance with 53.8.

Exception No. 2: This requirement does not apply to uninsulated high-voltage parts if the current is limited in accordance with the Electric Shock Current Test, Section 43.

6 Enclosures

6.1 General

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

6.1.2 Uninsulated high-voltage electrical parts of a unit shall be located or enclosed to provide protection from unintentional contact.

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

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

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

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

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

Exception No. 3: The material used to form a gear, cam, belt, bearing, strain-relief bushing applied over a PVC-jacketed cord, or other small part that contributes negligible fuel to a fire need not be investigated if the part is isolated from uninsulated electrical parts that are not power-limited either by:

a) At least 0.5 inch (12.7 mm) of air or

b) A solid barrier of material classified V-2 or less flammable.

Exception No. 4: Tubing for air or fluid systems, and foamed plastic, need only be classified HB or HBF, if the tubing or foamed plastic is isolated for uninsulated electrical parts that are not power-limited either by:

a) At least 0.5 inch (12.7 mm) of air or

b) A solid barrier of material classified V-2 or less flammable.

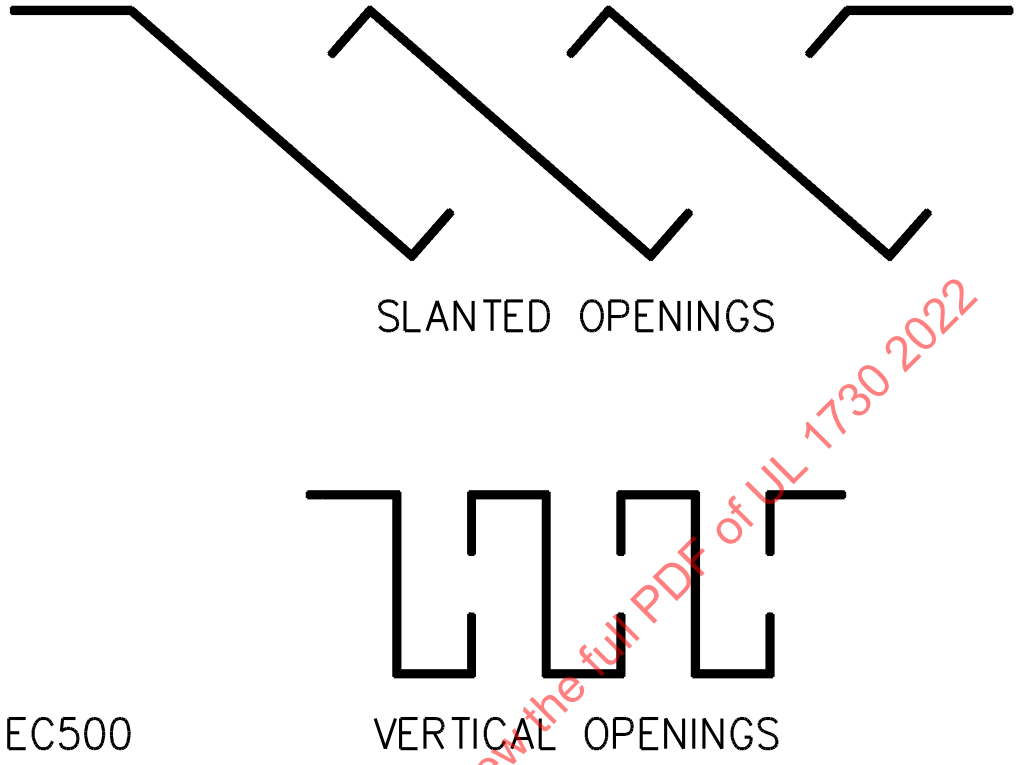
6.1.6 If a monitor is not intended to be installed in a separate cabinet that has provision for connection to a Class I wiring system, as defined by the National Electrical Code, ANSI/NFPA 70, the enclosure of the unit shall have provision for connection to a Class I wiring system.

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

6.1.8 To comply with the requirements in 6.1.7, an opening directly over an uninsulated live part shall not exceed 0.187 inch (4.75 mm) in any dimension unless the configuration of the opening prevents direct entry of uninsulated high-voltage parts. See Figure 6.1 for examples of acceptable top cover constructions.

Figure 6.1

Cross sections of top cover designs



6.1.9 An opening in the side of the enclosure shall be located and sized to reduce the likelihood of:

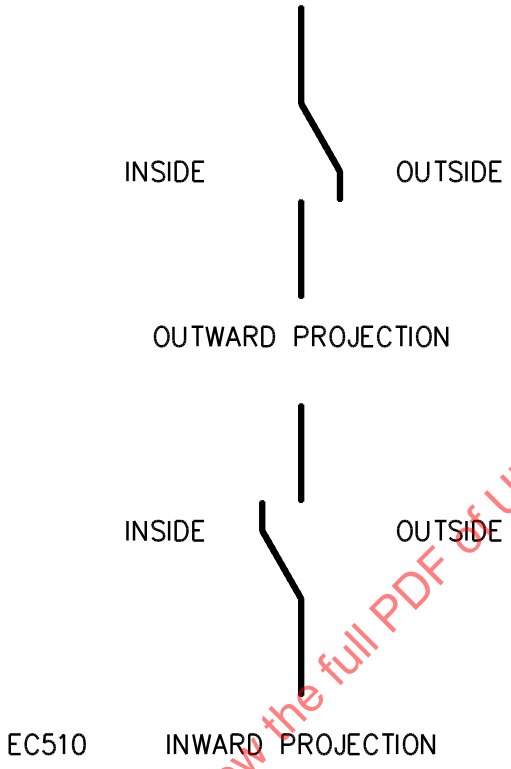
a) Entry of a foreign object and

b) Contact with internal parts by persons.

Louver openings may be used if shaped to deflect external falling objects outward. See Figure 6.2 for examples of louver constructions that may be used.

Figure 6.2

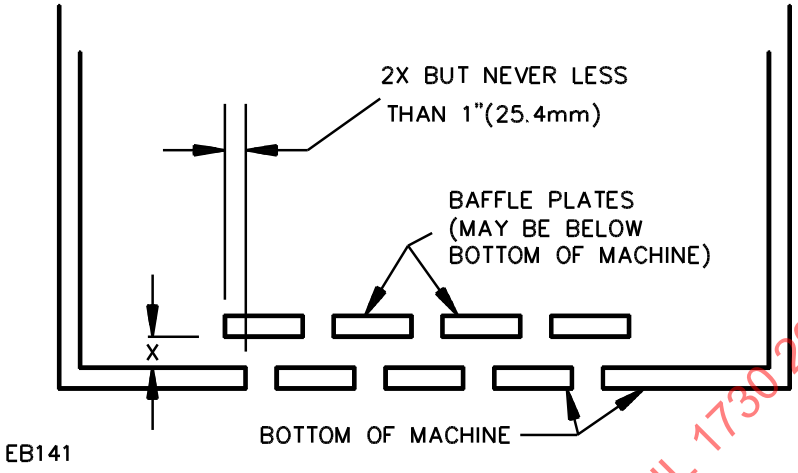
Louvers



6.1.10 Openings shall not be provided in the bottom panels or protective pans under areas containing materials not classified V-1 or less flammable, in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, unless constructed in a manner that prevents materials from falling directly from the interior of the unit onto the supporting surface or onto any other location under the unit. Figure 6.3 illustrates a type of baffle that complies with this requirement. A second construction that complies with this requirement is a 0.040 inch (1.02 mm) thick sheet steel bottom panel in which round holes of 5/64 inch (2.0 mm) maximum diameter are spaced no closer together than 1/8 inch (3.2 mm) center-to-center. See the Abnormal Operation Tests, Section 49.

Figure 6.3

Bottom panel baffles



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

6.1.12 Openings may be used without limitation on the size or number in areas that contain only:

a) CTFE, FEP, PVC, TFE, and neoprene-insulated wire cable and

b) Plugs and receptacles.

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

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

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

a) A nonfunctional opening or

b) Openings that vent into concealed spaces of a building structure, such as into hollow spaces in the wall, when the unit is mounted as intended.

Exception: The requirement in (b) does not apply to an opening for a mounting screw or nail or for a manufacturing operation (such as paint drainage) if the opening has no dimension greater than 17/64 inches (6.75 mm) or an area greater than 0.055 square inch (35.48 mm^2), and there is no more than one mounting screw hole for each 12 inches (305 mm) of length of mounting surface, or fraction thereof.

6.2 Cast metal

6.2.1 The thickness of cast metal for an enclosure shall be at least the applicable value specified in Table 6.1.

Exception: Cast metal of lesser thickness may be used if it provides equivalent mechanical strength considering the shape, size, and function of the enclosure.

Table 6.1
Cast-metal electrical enclosures

Use, or dimensions of area involved[a]	Minimum thickness			
	Die-cast metal,		Cast metal of other than the die-cast type,	
	inch	(mm)	inch	(mm)
Area of 24 square inches (155 cm^2) or less having no dimension greater than 6 inches (152 mm)	1/16	1.6	1/8	3.2
Area greater than 24 square inches (155 cm^2) or having any dimension greater than 6 inches (152 mm)	3/32	2.4	1/8	3.2
At a threaded conduit hole	1/4	6.4	1/4	6.4
At an unthreaded conduit hole	1/8	3.2	1/8	3.2

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

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

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

6.3 Sheet metal

6.3.1 The thickness of sheet metal used for the enclosure shall be at least the applicable value specified in Table 6.2 or Table 6.3.

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

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,		Minimum thickness metal coated,	
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,					
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inch	(mm)	inch	(mm)
4.0	10.2	Not limited		6.25	15.9	Not limited					
4.75	12.1	5.75	14.6	6.75	17.1	8.25	21.0	0.020	0.51	0.023	0.58
6.0	15.2	Not limited		9.5	24.1	Not limited					
7.0	17.8	8.75	22.2	10.0	25.4	12.5	31.8	0.026	0.66	0.029	0.74
8.0	20.3	Not limited		12.0	30.5	Not limited					
9.0	22.9	11.5	29.2	13.0	33.0	16.0	40.6	0.032	0.81	0.034	0.86
12.5	31.8	Not limited		19.5	49.5	Not limited					
14.0	35.6	18.0	45.7	21.0	53.3	25.0	63.5	0.042	1.07	0.045	1.14
18.0	45.7	Not limited		27.0	68.6	Not limited					
20.0	50.8	25.0	63.5	29.0	73.7	36.0	91.4	0.053	1.35	0.056	1.42
22.0	55.9	Not limited		33.0	83.8	Not limited					
25.0	63.5	31.0	78.7	35.0	88.9	43.0	109.2	0.060	1.52	0.063	1.60
25.0	63.5	Not limited		39.0	99.1	Not limited					
29.0	73.7	36.0	91.4	41.0	104.1	51.0	129.5	0.067	1.70	0.070	1.78
33.0	83.8	Not limited		51.0	129.5	Not limited					
35.0	88.9	47.0	119.4	54.0	137.2	66.0	167.6	0.080	2.03	0.084	2.13
42.0	106.7	Not limited		64.0	162.6	Not limited					
47.0	119.4	59.0	149.9	68.0	172.7	84.0	213.4	0.093	2.36	0.097	2.46
52.0	132.1	Not limited		80.0	203.2	Not limited					
60.0	152.4	74.0	188.0	84.0	213.4	103.0	261.6	0.108	2.74	0.111	2.82
63.0	160.0	Not limited		97.0	246.4	Not limited					
73.0	185.4	90.0	228.6	103.0	261.6	127.0	322.6	0.123	3.12	0.126	3.20

[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. Constructions that are 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. Constructions considered to be without supporting frame include:

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,	
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,			
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inch	(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. Constructions that are 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. Constructions considered to be without supporting frame include:

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.

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

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

6.3.4 A knockout shall be provided with a surrounding surface area of sufficient size to permit seating of a conduit bushing, and shall be located so that a bushing used at any knockout likely to be used during installation will not reduce spacings between uninsulated live parts and the bushing to values less than those specified in Spacings, Section 29.

6.3.5 A sheet metal member to which a wiring system is to be connected in the field shall be at least:

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

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

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

6.4 Nonmetallic

6.4.1 An enclosure or part of an enclosure of nonmetallic material shall have sufficient mechanical strength and durability and shall be formed so that operating parts will be protected against damage. The mechanical strength of the enclosure shall be at least equivalent to a sheet metal enclosure of the minimum thickness specified in Table 6.2.

6.4.2 Among the factors to be taken into consideration when evaluating the acceptability of a nonmetallic enclosure or parts are flammability, mechanical strength, resistance to impact, moisture absorption properties, dielectric strength, insulation resistance, resistance to arc tracking, and resistance to distortion at temperatures to which the material may be subjected under conditions of anticipated use. All these factors are to be considered with regard to aging. See the Polymeric Materials Tests, Section 38.

6.4.3 A wooden enclosure shall be solid or laminated wood, at least 3/8 inch (9.5 mm) thick with no edges exposed to internal electrical parts, and shall be spaced at least 1/2 inch (12.7 mm) from live or arcing parts and potential sources of ignition. All electrical parts shall be mounted to a metal chassis. A metal liner, at least 0.010 inch (0.25 mm) thick, shall be provided. The liner shall completely cover the bottom of the enclosure. All high-voltage circuits and nonpower-limited low-voltage circuits shall be completely enclosed by metal not less than 0.010 inch thick.

6.5 Doors and covers

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

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

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

Exception: A tamper switch may be used in lieu of an attachment, if only overcurrent protective devices are located within the unit.

6.5.2 Intended operation, as mentioned in 6.5.1, is considered to include operation of a switch for testing or for silencing an audible signal device or operation of any other component of a unit that requires such action in connection with its intended performance.

6.5.3 A hinged cover is not required if the only fuses enclosed are intended to provide protection to portions of internal circuits such as may be used on a separate printed wiring board or circuit subassembly, to reduce the risk of circuit damage resulting from a fault. See 53.9 for circuit fuse marking specification.

6.5.4 A hinged or sliding cover shall be provided with a lock, latch, or catch.

6.5.5 An unhinged cover shall be securely held in place by screws or by securement means determined to be equivalent.

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

Table 6.4
Thickness of glass covers

Maximum size of opening					
Length or width,		Area,		Minimum thickness,	
inches	(mm)	inches^2	(cm^2)	inch	(mm)
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. See 37.2.1 and 37.2.2.

6.5.7 A glass panel for an opening having an area of more than 144 square inches (929 cm^2), 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 by an arrangement determined to be equivalent.

6.5.8 A transparent material other than glass may be used for the cover of an observation opening if the material does not introduce a risk of fire, distort, or become less transparent at the temperature to which it may be subjected under either normal or abnormal service conditions.

6.6 Screens and expanded metal

6.6.1 A screen and expanded metal used as a guard, enclosure, or part of an enclosure, shall comply with the requirements in 6.6.2 and 6.6.3.

6.6.2 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 mm^2) or less in area, and shall not be less than 0.080 inch (2.03 mm) thick [0.084 inch (2.13 mm) if zinc coated] for larger openings. The largest dimension shall not exceed 4 inches (102 mm).

Exception: If the indentation of a guard or the enclosure will not alter the clearance between uninsulated live parts and grounded metal so as to impair intended operation of the unit or reduce spacings below the minimum required values (see Spacings, Section 29), 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 unit has an area of not more than 72 square inches (465 cm^2) and has no dimension greater than 12 inches (305 mm) or

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

6.6.3 The wires of a screen shall not be smaller than 16 AWG (1.3 mm^2) if the screen openings are 1/2 square inch (323 mm^2) or less in area, and shall not be smaller than 12 AWG (3.3 mm^2) for larger screen openings.

6.7 Battery compartments

6.7.1 A compartment for vented storage batteries shall have a total volume not less than twice the volume occupied by the batteries. Ventilating openings shall be located so 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 unit.

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

7 Electric Shock

7.1 Shock current

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

7.2 Antenna terminals

7.2.1 Each terminal provided for the connection of an external antenna shall be conductively connected to the supply circuit grounded conductor. The conductive connection shall have a maximum resistance of 5.2 megohms, a minimum wattage rating of 1/2 watt, 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 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.

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

7.2.2 The maximum value of 5.2 megohms mentioned in 7.2.1 is to include the maximum tolerance of the resistor value used; that is, a resistor rated 4.2 megohms with 20 percent tolerance or a resistor rated 4.7 megohms with a 10 percent tolerance may be used.

7.3 Circuit element replacement

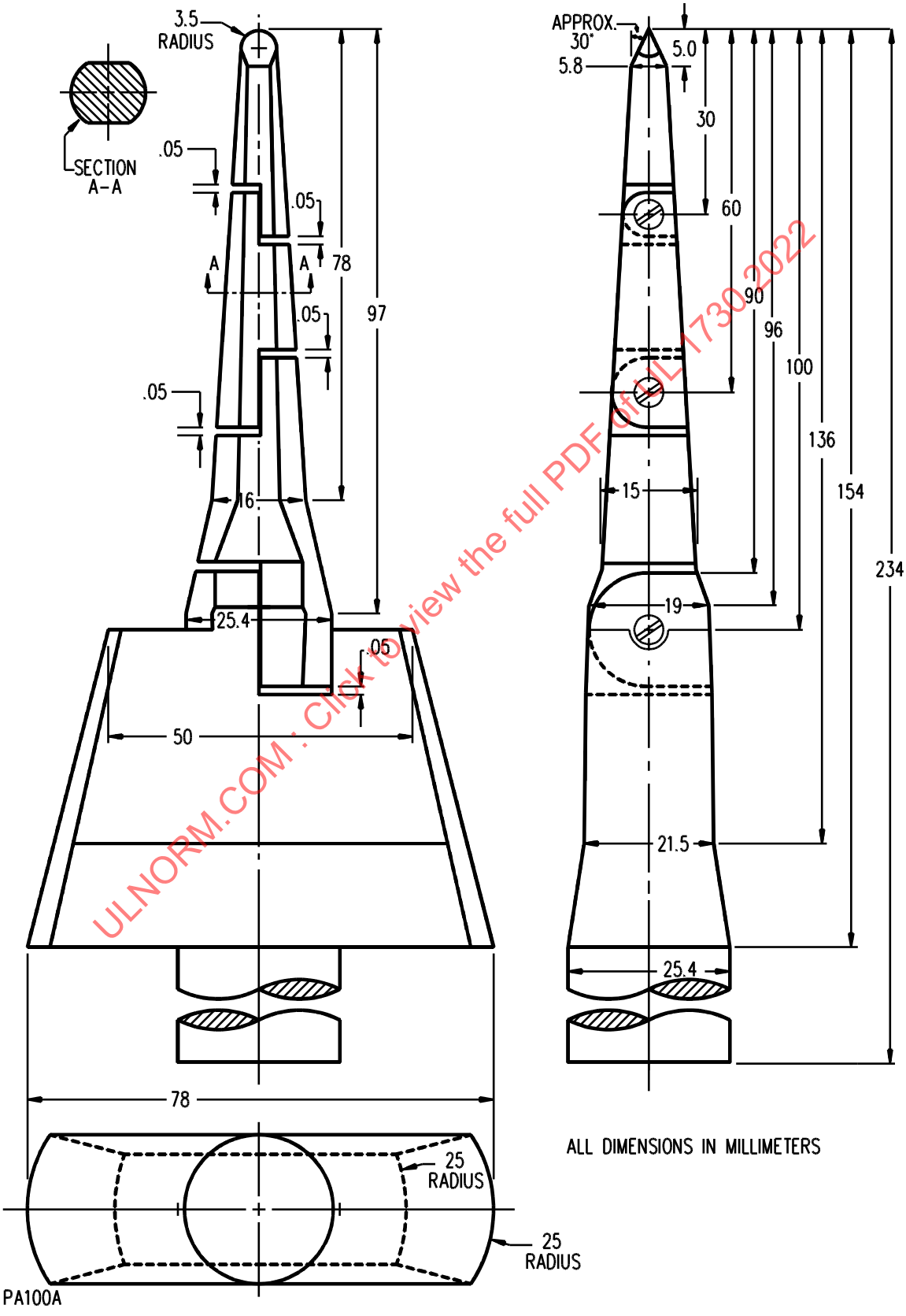
7.3.1 The insertion in any socket of any semiconductor, or similar replaceable circuit element shall not result in a risk of electric shock.

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

8.1 To reduce the likelihood of unintentional contact that may involve a risk of electric shock from an uninsulated live part or film-coated wire, or injury to persons from a moving part, an opening in an enclosure shall have a minor dimension less than 3/4 inch (19.1 mm) diameter and such a part or wire shall not be contacted by the probe illustrated in Figure 8.1.

Figure 8.1

Articulate probe with web stop



8.2 Before determining compliance with the requirements in 8.1, a part of the enclosure that may be opened or removed by the user without using a tool (to attach an accessory, to make an operating adjustment, or for other reasons) is to be opened or removed.

8.3 The probe specified in 8.1 is to be applied to any depth that the opening will permit; and is to be rotated or angled before, during, and after insertion through the opening to any position that is necessary in order to examine the enclosure. The probe is to be applied in any possible configuration. If necessary, the configuration may be changed after insertion through the opening.

8.4 The probe specified in 8.1 is to be used as a measuring instrument to judge the accessibility provided by an opening, and not as an instrument to judge the strength of a material; it is to be applied with the minimum force necessary to determine accessibility.

9 Protection Against Corrosion

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

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

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

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

9.2 The requirement in 9.1 applies to an enclosure of sheet steel or cast iron and to a spring or other part upon which intended mechanical operation may depend.

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

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

FIELD-WIRING CONNECTIONS

10 General

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

11 Supply Connections

11.1 A unit shall have provision for connection of conduit.

Exception: An enclosure without provision for the connection of conduit may be used if furnished with definite instructions identifying the section(s) of the unit intended to be drilled in the field for the connection.

12 Field-Wiring Compartment

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

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

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

12.4 Field-wiring areas shall not have sharp edges that may abrade wire insulation. If field wiring is intended for routing in one of several areas to comply with this requirement, the compartment interior shall be marked as specified in 53.10.

13 Power-Limited Circuits

13.1 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 openings into the enclosure or, when a single opening is provided, a continuous and firmly fixed nonconductor such as flexible tubing. These are to provide segregation of the power-limited conductors 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 product.

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

1) A minimum of 6.4 mm (1/4 inch) is provided between all power limited conductors and all electric light, power, Class 1, or nonpower-limited fire protective signaling conductors; or

2) For circuit conductors operating at 150 volts or less to ground and where the power limited conductors are installed using Types FPL, FPLR, FPLP, (or permitted substitute cables as described in Article 760 of the NEC); a minimum 6.4 mm (1/4 inch) separation is provided between the power limited cable conductors extending beyond the jacket and all electric light, power, and Class 1, and nonpower-limited fire protective signaling conductors.

Specific wire routing configurations detailed in the installation document achieves compliance with this requirement. When a wire routing scheme does not maintain the required separation, barriers or nonconductive sleeving shall be used to assure separation.

14 Field-Wiring Terminals

14.1 General

14.1.1 A field-wiring terminal shall be prevented from turning or shifting in position. This may be accomplished by means such as two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; or by a connecting strap or clip fitted into an adjacent part. Friction between surfaces shall not be used to prevent movement of the terminal.

14.2 General application

14.2.1 A nonferrous soldering lug or solderless (pressure) wire connector shall be used for 8 AWG (8.4 mm^2) and larger wire. If the connector or lug is secured to a plate, the plate shall not be less than 0.050 inch (1.27 mm) thick. A securing screw may be of plated steel.

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

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

14.2.3 A terminal plate tapped for a wire binding screw 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 wire in position. Other constructions may be used if they provide equivalent security of the wire binding screw threads.

b) Be of a nonferrous metal not less than 0.050 inch (1.27 mm) thick for a No. 8 (4.2 mm diameter) or larger screw, and not less than 0.030 inch (0.76 mm) thick for a No. 6 (3.5 mm diameter) screw.

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

14.3 Qualified application

14.3.1 Any of the following terminal configurations may be used on a circuit to which field wiring connections are made, within the limitations specified in 14.3.2:

a) Telephone-Type Terminals – Nonferrous terminal plates employing a narrow V-shaped slot for securing a conductor in a post. A tool specifically intended for this purpose is required for connection.

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

c) Push-In Terminals – Nonferrous (screwless) push-in terminals of the type used on some switches and receptacles, wherein solid conductors are pushed into slots containing spring-type contacts. The leads can be removed by means of a tool inserted to relieve the spring tension on the conductor.

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

e) Solder Terminals – Conventional nonferrous solder terminals.

f) Other Terminals – Other terminal connections and materials may be employed if determined to be equivalent to those specified in (a) – (e) and limited to the same restrictions.

14.3.2 A unit using a terminal of any of the configurations described in 14.3.1 for connection of field wiring shall comply with all of the following:

a) The wire size to be used shall be acceptable for the current-carrying capacity of the circuit application. The minimum wire size to be used shall not be smaller than 18 AWG (0.82 mm^2) for single conductors, and shall not be smaller than indicated in Article 760 of the National Electrical Code, ANSI/NFPA 70, for power-limited multiple-conductor cables.

b) Except for connections described in 14.3.1 (b) and (c), removal of a lead for testing or routine servicing, including detection, location, and correction of installation wiring faults shall not be required.

c) Instructions in accordance with 4.1.5 shall be provided.

15 Field-Wiring Leads

15.1 A lead provided for field connections shall not be less than 6 inches (152 mm) long, provided with strain relief, and not smaller than 18 AWG (0.82 mm^2). The insulation, if of rubber or thermoplastic, shall not be less than 1/32 inch (0.8 mm) thick.

16 Grounding

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

16.2 The following circuits of a unit shall be grounded under the indicated conditions:

a) AC circuits less than 50 volts if supplied by a transformer, the supply system of which exceeds 150 volts to ground; if supplied by a transformer, the supply system of which is ungrounded; or if installed as overhead conductors outside of buildings.

b) AC circuits of 50 volts and over if the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts; or if the system is nominally rated 240-/120-volt, 3-phase, 4-wire, in which the midpoint of one phase is used as a circuit conductor.

c) Direct current circuits operating at 51 – 300 volts, except for 250 volts DC, maximum fire protective signaling power-limited circuits having a maximum current of 0.03 ampere as specified in Article 760 of the National Electrical Code, ANSI/NFPA 70.

16.3 The following may be used as means for grounding:

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

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

16.4 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 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 gray color and shall be readily distinguishable from the other leads.

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

16.6 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

17 General

17.1 Internal wiring shall have insulation rated for the potential involved and the temperature to which it may be subjected. The wiring shall be routed away from moving parts and sharp projections and held in place with clamps, string ties, or the equivalent, unless of sufficient rigidity to retain a shaped form.

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

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

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

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

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

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

18 Separation of Circuits

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

18.2 A metal barrier used to provide separation between the wiring of different circuits shall have a thickness at least equal to the applicable minimum value specified in Table 6.2. A barrier of insulation material shall not be less than 0.028 inch (0.71 mm) thick and shall be of greater thickness if its deformation may be readily accomplished so as to defeat its purpose. The clearance between the edge of a barrier and a compartment wall shall not be more than 1/16 inch (1.6 mm).

19 Bonding for Grounding

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

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

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

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

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

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

19.3 A bonding means may be used as an electrical conductor. If of ferrous metal, it shall be protected against corrosion by painting, plating, or a means determined to be equivalent. A separate bonding conductor shall be installed so that it is protected from mechanical damage.

19.4 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.

19.5 A bolted or screwed connection that incorporates a star washer or serrations under the screwhead may be used for penetrating nonconductive coatings as required in 19.4.

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

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

Exception: Slip-joint or similar hinge-bearing members need not comply with this requirement if the resistance between the two parts connected by the bonding element is not more than 0.1 ohm.

19.8 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 unit will be protected. The size of the conductor shall be as specified in Table 19.1.

19.9 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 specified in Table 19.1.

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

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

Table 19.1
Bonding wire conductor size

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

[a] Or equivalent cross-sectional area.

COMPONENTS – ELECTRICAL

20 General

20.1 Mounting of components

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

20.1.2 An uninsulated live part shall be secured to the base or mounting surface so that it will be prevented from turning or shifting in position, if such motion may result in a reduction of spacings below the required minimum values. See Spacings, Section 29.

20.1.3 Friction between surfaces may not be used as a means to prevent turning, loosening, or shifting of a part as required in 20.1.1 and 20.1.2, but a toothed-lock washer that provides both spring take-up and an interference lock or equivalent means may be used.

20.2 Insulating materials

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

20.2.2 Among the factors to be considered in judging electrical insulation are:

a) Mechanical and electrical strength;

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

c) Thermal endurance at temperatures encountered in intended use.

See the Polymeric Materials Tests, Section 38.

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

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

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

20.2.6 The thickness of a flat sheet of insulating material, such as phenolic composition, or the equivalent, used for panel-mounting of parts, shall not be less than the applicable value specified in Table 20.1.

Table 20.1
Thickness of flat sheets of insulating material

Maximum dimensions				Minimum thickness,[a]	
Length or width,		Area,			
inches	(cm)	inches^2	(cm^2)	inch	(mm)
24	60.9	360	2,322	3/8	9.5
48	122.0	1152	7,432	1/2	12.7
48	122.0	1728	11,148	5/8	15.9
Over 48	122.0	Over 1728	Over 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) thick 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 of internal wiring, resistors, and other components.

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

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

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

20.3 Current-carrying parts

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

20.3.2 A bearing, hinge, or the like, shall not be for use as a current-carrying part.

20.4 Bushings

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

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

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

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

20.4.5 If a soft rubber bushing is used in a hole in metal, the hole shall be free from sharp edges, burrs, projections, and the like, that could cut into the rubber.

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

21 Switches

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

21.2 A switch shall be prevented from turning in accordance with 20.1.1 – 20.1.3.

Exception: A switch need not be prevented from turning if:

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

b) The means of mounting the switch makes it unlikely that operation will loosen the switch; and

c) The spacings are not reduced below the minimum required values if the switch does rotate.

22 Lampholders and Lamps

22.1 A lampholder and lamp shall be rated for the circuit in which they are used when the unit is operated under any condition of intended service.

22.2 A lampholder in a high-voltage circuit 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.

22.3 With reference to 20.1.1 – 20.1.3, a lampholder of a type in which the lamp cannot be replaced, such as a neon pilot or indicator light in which the lamp is sealed in by a nonremovable jewel, need not be prevented from turning if rotation cannot reduce spacings below the minimum required values.

22.4 An indicator lamp shall be color coded as follows:

a) Red for alarm;

b) Yellow or amber for trouble; and

c) White or green for power on.

Exception: Color coding need not be provided if a marking adjacent to the indicator lamp identifies the lamp function.

23 Transformers and Relays

23.1 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 for connection to a grounded conductor and the input circuits are located within the enclosure containing the autotransformer. See 17.1 for further internal wiring specifications.

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

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

24 Printed-Wiring Boards

24.1 A printed wiring board shall comply with the applicable requirements in the Standard for Printed-Wiring Boards, UL 796. The securing of components to the board shall be made in the intended manner and the spacings between circuits shall comply with the requirements for Spacings, Section 29. The board shall be securely mounted so that deflection of the board during servicing will not result in damage to the board or in development of a risk of fire or electric shock.

24.2 A printed-wiring board shall comply with the flammability requirements in 6.1.5.

25 Protective Devices

25.1 A fuseholder shall be of either the cartridge enclosed or plug-fuse type. A plug fuse shall not be used in a unit rated at more than 125 or 125/250 volts.

25.2 A fuseholder, fuse, or circuit breaker shall be rated for the application.

26 Overcurrent Protection

26.1 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.

26.2 If a fuse or other overcurrent protective device is provided in the supply circuit of a unit, the device shall have a rating not less than 150 percent of the rating of the unit.

27 Storage Batteries

27.1 A battery 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 access to the cells for checking the specific gravity of the electrolyte.

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

28 End-of-Line Devices

28.1 An end-of-line device intended for connection to a circuit by conduit or metal-clad cable shall be arranged for mounting inside a metal box to which such connection can be made. Mounting on an outlet box together with provision of field-wiring terminals or leads or an equivalent arrangement may be performed.

28.2 A device intended for installation inside a detector base shall be provided with splice leads, spade type terminals with upturned lugs, or the equivalent, for making field connections. The exposed live parts of the assembly, except for the connection portion of the terminal, shall be covered with insulating tubing at least 0.013 inch (0.33 mm) thick, or the equivalent.

29 Spacings

29.1 The spacings between an uninsulated live part and:

a) A wall or cover of a metal enclosure;

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

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

shall not be less than the applicable value specified in Table 29.1.

Table 29.1
Minimum spacings

Point of application	Voltage range, volts	Minimum spacings through air, inch[a]	Minimum spacings through air, (mm)	Minimum spacings over surface, inch[a]	Minimum spacings over surface, (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,b]					
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:[c]					
100 volt-amperes maximum[d]	0 – 30	1/32[d]	0.8	1/32[d]	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

Table 29.1 Continued on Next Page

Table 29.1 Continued

Point of application	Voltage range, volts	Minimum spacings through air, inch[a]	(mm)	Minimum spacings over surface, inch[a]	(mm)
	151 – 300	1/4	6.4	3/8	9.5

[a] Measurements are to be made with solid wire having rated 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] Spacing requirements apply also to solder-type terminals described in 14.3.1(e).

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

[d] 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).

29.2 The spacings between an uninsulated live part and:

a) An uninsulated live part of opposite polarity;

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

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

shall not be less than the applicable value specified in Table 29.1. See also 29.4 and 29.6.

29.3 If a short circuit between uninsulated live parts of the same polarity would prevent the intended signaling operation of the unit without simultaneously producing an alarm signal, the spacings between such parts shall not be less than the applicable value specified for "Other Parts" in Table 29.1.

29.4 The spacings within a snap switch, lampholder, or similar device supplied as part of a unit are judged under other requirements for such devices and need not comply with the requirements in Table 29.1.

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

29.6 Minimum values of spacings are not specified for a socket or similar related component part, such as a potentiometer, and the like, used in an electronic circuit. However, if the spacings in such a component do not comply with the requirements in 29.2 – 29.5, the circuit shall comply with the requirements in the Dielectric Voltage-Withstand Test, Section 48.

29.7 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 (0.71 mm) thick.

Exception: A liner or barrier not less than 0.013 inch (0.33 mm) thick may be used in conjunction with an air spacing of not less than one-half of the through air spacing required, if the liner is located so that it will not be subjected to the direct effects of arcing.

OPERATING COMPONENTS

30 General

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

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

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

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

INTERCONNECTION OF UNITS

31 General

31.1 Cords and plugs

31.1.1 A time stamp or similar device supplied as a part of a unit and that is not intended to be stationary, may be provided with a cord and cord connector for connection of the combination.

31.1.2 The investigation of such a feature is to include consideration of the utility of the device and the necessity of its being readily detachable.

31.2 Strain relief

31.2.1 Strain relief shall be provided so that a mechanical stress on a flexible cord or cable will not be transmitted to terminals, splices, or interior wiring. See the Strain Relief Tests, Section 50.

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

31.2.3 Means shall be provided to prevent a flexible cord from being pushed into the unit through the cord-entry hole if such displacement is likely to:

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

b) Is likely to reduce spacings, such as to metal strain relief clamp, below the minimum required values.

PERFORMANCE

32 General

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

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

32.3 The alerting devices (bells, horns, and the like) used for testing are to be those specified by the wiring diagram of the unit, except that substitute devices may be used if they produce equivalent signal indication and circuit loading. Substitute load devices are considered to be those found by investigation to provide the same load conditions as those obtained with the devices intended to be used with the unit in service.

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

32.5 Unless specifically noted otherwise, the test voltage for a unit is to be as specified in Table 32.1, at rated frequency.

Table 32.1
Test voltages

Nameplate voltage rating[a]	Test voltage
110 to 120	120
220 to 240	240
Other	Marked nameplate rating
Battery circuit	Nominal battery voltage

[a] Products rated at frequencies other than 60 hertz are to be tested at their rated nameplate voltage and frequency.

33 Normal Operation Test

33.1 A monitor shall operate for all conditions of its intended performance when used in conjunction with initiating devices, alerting devices, and power supplies to form a combination of the type indicated by the installation wiring diagram.

33.2 Initiating devices, alerting devices, and power supply circuits are to be connected to the unit as specified by the installation wiring diagram to form a typical combination, and the unit is then to be operated for each condition of its intended performance.

33.3 Initially, the unit is to be in the normal-standby condition. A visual "power on" indication is to be present.

33.4 An alarm in any initiating circuit of 5 or more continuous seconds shall be indicated at the monitor within 90 seconds of initiation by an audible and visual signal. The audible signal shall persist until manually silenced.

33.5 The visual signal required in 33.4 may be by a lamp, display on a CRT, presentation on a printer, or the like. If the status of the initiating device circuit is not shown at all times, means shall be available to obtain a display of all circuits that are in alarm or trouble. Initiating circuit alarm and trouble signals shall be visually distinct from each other.

33.6 A common audible signal may indicate both alarm and trouble conditions. If a silencing feature is provided, operation of the feature in conjunction with one status change shall not prevent the audible signal from reenergizing due to any subsequent status change.

33.7 If a monitor oversees supplementary functions, such as room status, housekeeping, or the like, a fire alarm signal shall take precedence or be clearly recognizable over any other signal, even if the nonfire-alarm signal is initiated first.

33.8 If the "off-normal" position of any normally preset mechanism or similar part of a unit requires manual restoration in order to permit signaling performance of the unit, such position shall be indicated by a visual or audible trouble signal.

34 Electrical Supervision Test

34.1 The circuits and functions of a monitor and related accessories specified in (a) – (h) shall be electrically supervised to indicate the occurrence of any of the following fault conditions by means of a visual and audible trouble signal at the unit. The trouble signal shall be given within 24 hours from the occurrence of the fault. The trouble signal shall be distinctive from an alarm signal and shall identify the location of the fault.

a) A ground fault that prevents operation or an open circuit in any initiating or signaling circuit.

b) Loss of primary operating power to the unit or accessory.

c) Loss of primary operating power to any smoke detector, except at a detector that utilizes a primary battery and provides a low battery signal.

d) Rupture of any fuse, if the rupture prevents normal operation.

e) For a program-controlled unit, failure to execute its program cycle.

f) A ground fault that prevents operation or an open circuit in an alarm alerting device circuit, other than at an alerting device included as part of the unit or intended to be installed in the same area as the unit, and the interconnecting wiring for which it is intended to be installed in conduit.

g) A short circuit, a break, or a ground fault in a circuit for supplementary signals unless the fault in no way affects the normal operation of the unit except for omission of the supplementary feature. An overcurrent protective device provided for supplementary circuit protection and relied upon for compliance with this requirement shall be noninterchangeable.

h) Failure of a cooling fan motor that would result in temperatures exceeding those specified in Table 39.1.

34.2 A single break or a single ground fault in any external circuit or interruption and restoration of any source of electrical energy connected to a unit shall not cause an alarm signal.

34.3 A multiple ground fault or short circuit fault on conductors extending from a circuit intended for connection to limited energy cable and that would prevent proper alarm operation shall result in either a trouble signal or an alarm signal.

34.4 Failure of electronic components, such as opening or shorting of capacitors, shall either have no adverse effect on normal operation or be indicated by a trouble or alarm signal.

34.5 If it is not practical to have a component failure indicated, a reliable component shall be used. The reliability of the component may be based on derating or on reliability data recorded for the particular component. See the Temperature Test, Section 39.

35 Input and Output Characteristics Test

35.1 The input or output current of each circuit of a monitor shall not exceed the marked rating of the unit by more than 10 percent when the unit is operated under the conditions of intended use.

35.2 The measured voltages at the output circuits, with the minimum or maximum (rated) loads applied and while the unit is energized at 85 to 110 percent of rated voltage, shall be compatible with the rating of the device or appliance intended to be connected to the circuit.

35.3 The power supplied by a power-limited circuit shall comply with the requirements in Power-Limited Circuits, Section 36.

36 Power-Limited Circuits

36.1 General

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

36.1.2 The power source(s) 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 such that a power-limited circuit shall have electrical characteristics as described in Table 36.1 for AC circuits or Table 36.2 for DC circuits.

Table 36.1
Power limitations for alternating-current fire protective signaling circuits

		Inherently limited power source (overcurrent protection not required)			Not inherently limited power source (overcurrent protection required)		
Circuit voltage V_{max} [a]		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	NA
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.

[b] $(VA)_{max}$ is the maximum volt-ampere output after 1 minute 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 minute 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 seconds 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 36.2
Power limitations for direct-current fire protective signaling circuits

		Inherently limited power source (overcurrent protection not required)				Not inherently limited power source (overcurrent protection required)		
Circuit voltage V_{max}[a]		0 – 20	Over 20 – 30	Over 30 – 100	Over 100– 200	0 – 20	Over 20 – 100	Over 100 – 150
Power limitations $(VA)_{max}$[b] (volt-amps)		–	–	–	–	250[d]	250	NA
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 minute 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 minute 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 seconds 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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36.1.3 With regard to 36.1.2, means for current limiting that may be used include:

a) Transformer winding impedance;

b) A thermal link embedded within the winding overwrap of a transformer;

c) Circuit components (resistors, regulators, transistors, and the like) that comply with the temperature test under I_{max} condition; and

d) Current limiting impedances determined to be suitable for the application (positive temperature coefficient varistor, and the like).

36.1.4 With regard to 36.1.2, the following means of current limiting shall not be used:

a) Circuit component burnout,

b) Permanent (soldered-in and the like) or replaceable fuses,

c) Opening of conductors on printed circuit boards, or

d) Opening of internal wiring conductors.

36.1.5 The overcurrent protection device specified in 36.1.2 shall be of the noninterchangeable type such that it cannot be renewed in the field with an overcurrent device having a higher current rating.

36.1.6 If 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.

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

36.2 Maximum voltage

36.2.1 When the product is 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}. If the product incorporates a secondary source of supply, this test is to be repeated with the control unit 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 specified in Table 36.1 or Table 36.2.

36.3 Maximum current

36.3.1 In order to determine compliance with the I_{max} limitation, a variable load resistor is to be connected across the circuit. While monitoring the current through the load resistor, the load resistor is to be adjusted from open circuit to short circuit as quickly as possible and the highest current reading noted. The load resistor is then to be readjusted to produce the highest current obtained. This load is to be maintained and the current through the load resistor is to be measured after 1 minute or 5 seconds as determined in Table 36.1 or Table 36.2.

36.3.2 If the maximum current through the load resistor cannot be maintained for 5 seconds due to current limiting devices (opening of thermal link, power supply foldback, PTC varistor affect, and the like), the circuit load resistor is to be adjusted to a value that will produce a current just above the I_{max} value indicated in Table 36.1 or Table 36.2. The results are in compliance if the I_{max} value stated in Table 36.1 or Table 36.2 cannot be maintained for more than 5 seconds.

36.3.3 If a transformer limits the value of I_{max}, and if I_{max} cannot be maintained for 1 minute due to transformer burnout, a plot of current versus time is to be generated and the graph extrapolated to 1 minute. The results are in compliance if the extrapolated value of I_{max} at 1 minute does not exceed the I_{max} limitations as indicated in Table 36.1 or Table 36.2.

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

36.4.1 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 are to be recorded and the load is to be removed. The resistance of the load is then to be 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 connected to the circuit. After 1 minute, the voltage and current are again to be measured. The results of this test are in compliance if the calculated volt-ampere output of the circuit after 1 minute does not exceed the values specified in Table 36.1 or Table 36.2, as appropriate.

37 Mechanical Strength Tests

37.1 Jarring – complete unit

37.1.1 A monitor shall withstand jarring resulting from impact and vibration without causing signaling operation of any part and without impairment of its intended operation.

37.1.2 The unit (and associated equipment, if any) is to be mounted as intended to the center of a 6- by 4-foot (1.83- by 1.23-m), nominal 3/4-inch (19.1-mm) thick plywood board which is to be secured in place at four corners. A 3 foot-pound (4.07 J) impact is to be applied to the center of the reverse side of this board by means of a 1.18-pound (0.54-kg), 2-inch (51-mm) diameter steel sphere either:

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

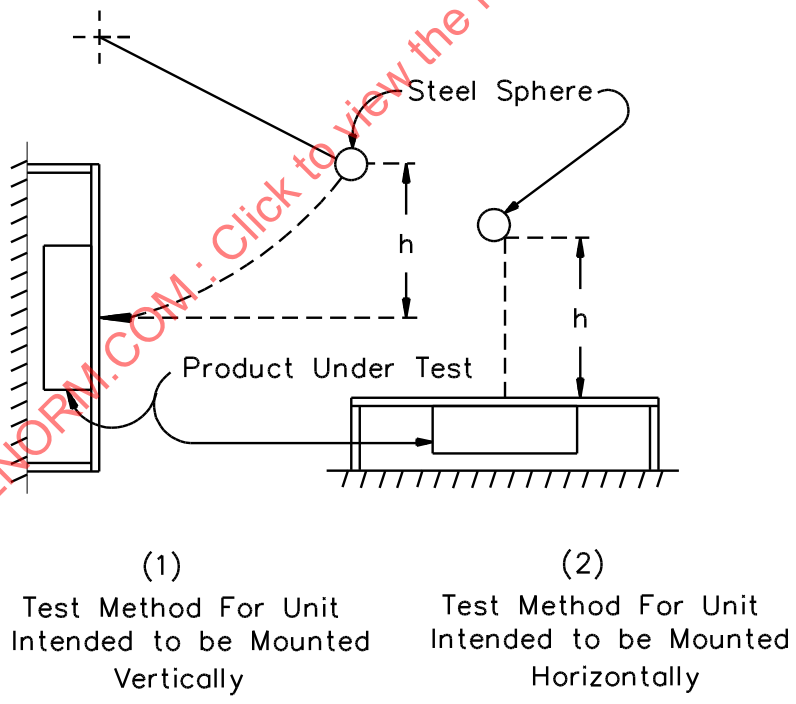
b) Dropped from a height of 2.54 feet, depending upon the intended mounting of the unit.

See Figure 37.1.

37.1.3 The unit is to be in the supervisory condition during the test.

Figure 37.1

Jarring test



37.2 Impact – glass parts

37.2.1 A decorative glass part mounted as intended that has:

a) An area greater than 1 square foot (0.093 m^2) or

b) A major dimension greater than 18 inches (457 mm),

shall withstand an impact as described in 37.2.2 without displacement, breakage, or shattering (either partial or total) that may result in the risk of an injury to persons.

37.2.2 The impact required in 37.2.1 is to be delivered by a 1.18 pound (0.54 kg), 2-inch (51-mm) diameter steel sphere either:

a) Swung through a pendulum arc from a height of 25-1/2 inches (648 mm) or

b) Dropped from a height of 25-1/2 inches, directly on or near the center of the glass part.

38 Polymeric Materials Tests

38.1 Polymeric material used as an enclosure, or for the support of current-carrying parts, shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

39 Temperature Test

39.1 The materials used in the construction of a monitor or accessory shall not attain a temperature rise greater than that specified in Table 39.1 under any condition of intended operation.

Table 39.1
Maximum temperature rises

Device or material	Normal standby (continuous), °C	Normal standby (continuous), (°F)	Alarm condition (short term), °C	Alarm condition (short term), (°F)
A. MOTORS				
1. Class A insulation systems on coil windings of alternating-current motors:				
a) In open motors and on vibrator coils				
Thermocouple or resistance method	75	135	75	135
b) In totally enclosed motors				
Thermocouple or resistance method	80	144	80	144
2. Class B insulation systems on coil windings of alternating-current motors:				
a) In open motors:				
Thermocouple or resistance method	95	171	95	171
b) In totally enclosed motors:				
Thermocouple or resistance method	100	180	100	180
B. COMPONENTS				
1. Capacitors[a]	25	45	40	72
2. Fuses	25	45	25	45
3. Rectifiers – at any point:				
a) Germanium	25	45	50	90
b) Selenium	25	45	50	90

Table 39.1 Continued on Next Page

Table 39.1 Continued

Device or material	Normal standby (continuous), °C	Normal standby (continuous), (°F)	Alarm condition (short term), °C	Alarm condition (short term), (°F)
c) Silicon	25	45	75	135
4. Relays and other coils with:				
a) Class 105 insulated windings:				
Thermocouple method	65	117	65	117
Resistance method	75	135	75	135
b) Class 130 insulated windings:				
Thermocouple method	85	153	85	153
Resistance method	95	171	95	171
5. Resistors[b]:				
a) Carbon	25	45	25	45
b) Wire wound	50	90	325	585
6. Sealing compounds	See note (e)			
7. Solid-state devices	See note (a) or (c)			
C. INSULATED CONDUCTORS[d]				
1. Appliance wiring material	25°C (77°F) less than the established temperature rating of the wire			
2. Flexible cord – Types SJD, SJT	35	63	35	63
D. ELECTRICAL INSULATION – GENERAL				
1. Fiber used as electrical insulation or cord bushings	25	45	65	117
2. Phenolic composition used as electric insulation or as parts where failure will result in a risk of fire, electric shock, or injury to persons	25	45	125	225
3. Printed wiring boards	Based on maximum use temperature rating of printed-wiring board material			
E. GENERAL				
1. Mounting	25	45	65	117
2. Wood or other combustible material	25	45	65	117
3. Enclosure surfaces	40	72	40	72

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

[b] In lieu of complying with these temperature limits, a resistor may be used if it dissipates no more than one-half of its maximum power rating under the test condition specified.

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

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

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

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

Table 39.1 Continued on Next Page

Table 39.1 Continued

Device or material	Normal standby (continuous), °C	(°F)	Alarm condition (short term), °C	(°F)
[d] For standard insulated conductors other than those mentioned, reference should be made to the National Electrical Code, ANSI/NFPA 70, the maximum allowable temperature rise in any case is 25°C (77°F) less than the temperature limit of the wire in question.				
[e] Unless a thermosetting material, the maximum sealing compound temperature, when corrected to a 25°C ambient temperature shall be 15°C (27°F) less than the softening point of the compound as determined by the Standard Test Methods for Softening Point by Ring-and-Ball Apparatus, ASTM E28.				

39.2 All values for temperature rises apply to a unit intended for use with ambient temperatures normally prevailing in occupiable spaces, and that usually are not higher than 25°C (77°F). If a unit is intended specifically for use with a prevailing ambient temperature constantly more than 25°C (77°F), the test of the unit is made with such higher ambient temperature, and the maximum temperature rises specified in Table 39.1 are to be reduced by the amount of the difference between that higher ambient temperature and 25°C (77°F). A temperature is considered to be constant when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 5 minutes, indicate no change.

39.3 Temperature measurements on a unit intended for recessed mounting are to be made with the unit installed in an enclosure of 3/4 inch (19.1 mm) thick wood having clearances of 2 inches (50.8 mm) on the top, sides, and rear, and with the front extended to be flush with the unit cover.

39.4 Except at coils, temperatures are to be measured by means of thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2). The temperature of a coil may be measured by either the thermocouple or resistance method, except that the thermocouple method is not to be employed for a temperature measurement at any point where supplementary thermal insulation is used.

39.5 Thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a potentiometer-type alerting instrument are to be used whenever referee temperature measurements by thermocouples are necessary.

39.6 In determining the temperature of a coil winding by the resistance method, the resistance of the winding at the temperature to be determined is to be compared with the resistance at a known temperature by means of the equation:

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

in which:

Δt is the temperature rise in degrees C;

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

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

k is 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum (values of k for other grades must be determined);

t_1 is the room temperature at the end of the test in degrees C; and

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

39.7 As it is generally necessary to de-energize the winding before measuring R, the value of R at shutdown may 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 may be plotted and extrapolated to give the value of R at shutdown.

39.8 The circuit of a current-regulating resistor or reactor provided as a part of a unit is to be adjusted for the maximum resistance or reactance at normal current.

39.9 For this test, the unit is to be operated:

a) Until constant temperatures are attained in the normal supervisory condition and

b) If the unit is intended to produce a continuous signal, for 1 hour in the alarm signaling condition until an actuating device is restored to normal, or a circuit-resetting device is operated manually.

39.10 For a unit having provision for multiple zones, 10 percent of the total number of zones, but in no case less than three zones, are to be energized during the alarm condition.

39.11 The unit is to be operated continuously under representative service conditions that are likely to produce the highest temperatures.

39.12 If, during this test, the temperature on a lead intended to be field-installed, or on a surface of the wiring compartment which the lead might contact, is more than the 60°C (140°F), the unit shall be marked in accordance with 53.3.

40 Overvoltage and Undervoltage Operation Test

40.1 A monitor shall withstand 110 percent of its rated supply voltage continuously without damage during the normal supervisory condition, and the unit shall operate as intended during an alarm signaling condition at the increased voltage. It shall also operate as intended at 85 percent of its rated voltage.

40.2 For operation at 110 percent of rated voltage, the unit is to be subjected to the increased voltage during the normal supervisory condition until constant temperature of its parts is reached, and then tested for alarm-signaling conditions. For this test, zero line impedance in the initiating device circuit, and minimum circuit loads, are to be used.

40.3 For operation at 85 percent of rated voltage, the unit is to be subjected to the reduced voltage during the supervisory condition until constant temperature of its parts is reached and then tested for the alarm-signaling condition at the reduced voltage. In making 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. The reduced voltage value is to be computed on the basis of the rated nominal voltage if a storage battery is intended to be used with the unit.

40.4 If the maximum impedance of an initiating circuit extended from a unit is required to be less than 100 ohms in order to obtain successful operation, the reduced voltage test is to be made with the maximum impedance connected to the circuit. If no impedance limitation is indicated in the marking, 100 ohms is to be used in the initiating device circuit. For a signaling line circuit of a unit, the maximum impedance indicated on the installation wiring diagram is to be used.

41 Variable Ambient Temperature Test

41.1 A monitor shall operate as intended following exposure to ambient air at temperatures of 49° and 0°C (120° and 32°F).

41.2 The unit is to be maintained at each temperature until thermal equilibrium has been reached. The unit then is to be tested to verify intended operation.

42 Humidity Test

42.1 A monitor shall operate as intended after exposure for 24 hours to moist air having a relative humidity of 85 ±5 percent at a temperature of 30 ±2°C (86 ±3°F). The performance is to be verified with the unit in the humid ambient.

43 Electric Shock Current Test

43.1 If the open circuit potential between any part that is exposed only during operator servicing and either earth ground, or any other exposed accessible parts, exceeds 42.4 volts peak, the part shall comply with the requirements in 43.2 – 43.4, as applicable.

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 earth ground, or any other exposed accessible part.

Table 43.1
Maximum current during operator servicing

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

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

43.3 The duration of a transient current flowing through a 500-ohm resistor connected as described in 43.2 shall not exceed the value determined by the following equation:

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

in which:

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

I is the peak current in milliamperes.

The current shall not exceed 809 milliamperes, regardless of duration. The interval between occurrences shall be equal to or greater than 60 seconds if the current is repetitive. Typical calculated values of maximum transient current duration are shown in Table 43.2.

Table 43.2
Maximum transient current duration

Maximum peak current (I) through 500-ohm resistor, milliamperes	Maximum duration (T) of waveform containing excursions greater than 7.1 milliamperes peak
7.1	7.26 seconds
8.5	5.58
10.0	4.42
12.5	3.21
15.0	2.48
17.5	1.99
20.0	1.64
22.5	1.39
25.0	1.19
30.0	919 milliseconds
40.0	609
50.0	443
60.0	341
70.0	274
80.0	226
90.0	191
100.0	164
150.0	92
200.0	61
250.0	44
300.0	34
350.0	27
400.0	23
450.0	19
500.0	16
600.0	13
700.0	10
809.0	8.3

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

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

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

in which:

C is the maximum capacitance of the capacitor in microfarads and

E is the potential in volts across the capacitor measured 5 seconds after the capacitor terminals are made accessible, such as by the removal or opening of an interlocked cover or the like.

Typical calculated values of maximum capacitance are shown in Table 43.3.

Table 43.3
Electric shock – stored energy

Potential in volts, across capacitance prior to discharge	Maximum capacitance in microfarads
1000	0.868
900	1.02
800	1.22
700	1.50
600	1.90
500	2.52
400	3.55
380	3.86
360	4.22
340	4.64
320	5.13
300	5.71
280	6.40
260	7.24
240	8.27
220	9.56
200	11.2
180	13.4
160	16.3
140	20.5
120	26.7
100	36.5
90	43.8
80	53.8
70	68.0
60	89.4
50	124.0
45	150.0
42.4	167.0

43.5 With reference to the requirements in 43.2 and 43.3, the current is to be measured while the resistor is connected between ground and:

a) Each accessible part individually and

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

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

43.6 With reference to the requirements in 43.5, parts are considered to be simultaneously accessible if they can be contacted by one or both hands of a person at the same time. For the purpose of these

requirements, one hand is to be considered to be able to contact parts simultaneously if the parts are within a 4 by 8 inch (102 by 203 mm) rectangle; and two hands of a person are considered to be able to contact parts simultaneously if the parts are not more than 6 feet (1.83 m) apart.

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

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

43.9 Current measurements are to be made:

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

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

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

44 Leakage Current Test

44.1 If the open circuit potential is greater than 42.4 volts peak as measured between any accessible part and earth ground or any other accessible part, the leakage current at any accessible part shall not be more than the following values when tested in accordance with 44.2 – 44.7:

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

b) 0.5 milliampere for a grounded (3-wire) portable unit; and

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

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

a) A grounding means is provided;

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

c) The unit is marked in accordance with 53.15.

44.2 With reference to the requirements in 44.1, leakage current refers to all currents, including capacitively coupled currents, that may be conveyed between exposed conductive surfaces of the unit and ground, or between exposed conductive surfaces of the unit.

44.3 Leakage currents from all exposed surfaces are to be measured to the grounded supply conductor individually, as well as collectively, if exposed surfaces are simultaneously accessible, and from one exposed surface to another, if the exposed surfaces are simultaneously accessible. A part is considered to be an exposed surface unless it is guarded by an enclosure considered to protect against the risk of electric shock. Surfaces that can be readily contacted by one or both hands of a person at the same time are considered to be simultaneously accessible. For the purpose of these requirements, one hand is considered to be able to contact parts simultaneously if the parts are within a 4 by 8 inch (102 by 203 mm) rectangle; and two hands of a person are considered to be able to contact parts simultaneously if the parts are not more than 6 feet (1.83 m) apart.

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

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

44.6 The measurement circuit for the leakage current test is to be as illustrated in Figure 44.1. The measurement instrument is defined in (a) – (c). The meter used for a measurement need only indicate the same numerical value for the particular measurement as would the defined instrument; it need not have all of the attributes of the defined instrument.

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

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

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

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