UL 680

STANDARD FOR SAFETY

Emergency Vault Ventilators and Vault-Ventilating Ports

UL Standard for Safety for Emergency Vault Ventilators and Vault-Ventilating Ports, UL 680

Eighth Edition, Dated November 26, 2002

Summary of Topics

This revision to ANSI/UL 680 dated June 26, 2023 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 ULSE'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 April 28, 2023.

No Text on This Page

NOVEMBER 26, 2002
(Title Page Reprinted: June 26, 2023)

UL 680

Standard for Emergency Vault Ventilators and Vault-Ventilating Ports

First Edition – June, 1959
Second Edition – September, 1970
Third Edition – August, 1972
Fourth Edition – September, 1977
Fifth Edition – October, 1985
Sixth Edition – September, 1991
Seventh Edition – April, 1996

Eighth Edition

November 26, 2002

This ANSI/UL Standard for Safety consists of the Eighth Edition including revisions through June 26, 2023.

The most recent designation of ANSI/UL 680 as a Reaffirmed American National Standard (ANS) occurred on June 26, 2023. 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 ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PERFORMANCE

MANUFACTURING AND PRODUCTION TESTS

APPENDIX A

INTRODUCTION

1 Scope

1.1 These requirements cover emergency vault ventilators and vault-ventilating ports for installation in a wall.

1.2 Emergency vault ventilators are intended to provide fresh air to persons locked in the vault by accident or during a robbery.

1.3 Vault-ventilating ports are intended for connection to an outside ventilating system that provides circulating air while the vault is open.

1.4 These requirements are intended to evaluate the integrity of electrical wiring and components and to establish burglary resistant ratings. The ratings, based on the net working time to effect entry, are as follows:

a) Class M – 1/4 hour;

b) Class 1 – 1/2 hour;

c) Class 2 – 1 hour; and

d) Class 3 – 2 hours.

1.5 When installed in either a vault door or modular panel that complies with the requirements in the Standard for Burglary Resistant Vault Doors and Modular Panels, UL 608; or a reinforced concrete wall according to the manufacturer's instructions and the Standard Classification for Bank and Mercantile Vault Construction, ASTM F 1090, the products covered by these requirements do not affect the burglary resistance of the vault wall.

1.6 These requirements do not cover protection against entry by attacks with a burning bar (thermal lance) or explosives.

1.7 These units are intended to be installed in accordance with the provision of the National Electrical Code, NFPA 70. However, it is intended that inspection authorities having jurisdiction be consulted before installation of electrical connections.

1.8 Products covered by these requirements are intended for installation in vaults that are used for the storage of valuables, and that are protected by special security measures that cannot be forced using normal rescue equipment, and require waiting for a time-lock or similar device to release entrapped individuals.

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 used in the products covered by this standard.

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

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

b) Is superseded by a requirement in this standard.

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

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

2.2 Units of measurement

2.2.1 When a value for measurement is followed by a value in other units in parentheses, the first stated value is the requirement.

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 Instructions

3.1 A copy or draft of the operating and installation instructions intended to accompany each product as produced is to be used as a reference in the examination and test of the product.

3.2 The instructions shall include such directions and information as deemed by the manufacturer of the product to be required for proper and safe installation, maintenance, operation, and use of the product.

3.3 The instructions shall specify that conduit used for electrical connections shall not form a direct path through the wall, and shall be offset at least once and preferably twice.

CONSTRUCTION

4 General

4.1 A unit shall be constructed so that it is not capable of readily being rendered mechanically inoperative from outside the vault.

4.2 A vault-ventilating port shall be provided with a visual indicator that will indicate when the port is in the closed position. An emergency vault ventilator shall incorporate a visual indication that indicates the location of the unit to a person inside the vault.

4.3 Direct communication shall be provided through an emergency vault ventilator for voice communication and passage of small tools, food, and similar items, from outside the vault.

4.4 An emergency vault ventilator shall be capable of delivering not less than 10 cubic feet per minute (4.7 dm^3/s) of air into the vault and expelling an equal amount of air simultaneously.

4.5 An emergency vault ventilator shall provide a minimum opening of 2 square inches (12.9 cm^2) for natural ventilation, should the electric power fail.

5 Electric Shock

5.1 Any part that is exposed only during operator servicing shall not present the risk of electric shock. See Electric Shock Current Test, Section 30.

6 Frames and Enclosures

6.1 A unit shall be provided with one or more enclosures to afford protection against accidental contact with uninsulated live parts and reduction of spacings, loosening, or displacement of electrical parts.

6.2 Operating parts, such as gear mechanisms, light-duty relays, and similar devices, shall be protected against fouling by dust or other material which affects their intended operation.

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

Table 6.1
Cast-metal 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 and 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) in thickness shall be obtained by the provision of reinforcing ribs subdividing a larger area.

6.4 The thickness of sheet metal for an enclosure shall not be less than indicated in Table 6.2 and Table 6.3. At any point where conduit or metal-clad cable is to be attached, sheet metal shall be of such thickness or shall be formed or reinforced so that it has the stiffness at least equivalent to that of an uncoated flat sheet of steel having a minimum thickness of 0.053 inch (1.35 mm).

6.5 Ventilating openings in an enclosure, including perforated holes, louvers, and openings protected by means of wire screening, expanded metal, or perforated covers, shall be of such size or shape that no opening permits passage of a rod having a diameter of 33/64 inch (13.1 mm).

Exception: When the distance between uninsulated live parts and the enclosure is greater than 4 inches (102 mm), larger openings are permitted provided that no opening permits passage of a rod having a diameter of 49/64 inch (19.4 mm).

6.6 An enclosure housing fuses or any other overload protective device and provided with ventilating openings shall provide protection against the emission of flame or molten metal.

6.7 Perforated sheet metal and sheet metal used for expanded-metal mesh shall be at least:

a) 0.042 inch (1.07 mm) thick, [0.046 inch (1.17 mm) for zinc-coated] when the mesh openings or perforations are 1/2 square inch (323 mm^2) or less in area and

b) 0.080 inch (2.03 mm) thick, [0.084 inch (2.13 mm) for zinc-coated] for larger openings.

Exception: If the indentation of a guard or enclosure will not alter the clearance between uninsulated live parts and grounded metal so as to impair intended operation of the product or reduce spacings below the minimum values required, 0.021-inch (0.53-mm) expanded-metal mesh or perforated sheet metal [0.024-inch (0.61-mm) if zinc-coated] may be used, provided that:

a) The exposed mesh on any side or surface of the device so protected has an area of not more than 72 square inches (4.6 dm^2) and has no dimension greater than 12 inches (305 mm) or

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

6.8 The wires of a screen shall not be smaller than:

a) 16 AWG [0.051 inch (1.29 mm) diameter] when the screen openings are 1/2 square inch (323 mm^2) or less in area and

b) 12 AWG [0.081 inch (2.05 mm) diameter] for larger screen openings.

6.9 A compartment enclosing electrical parts shall not be open to the support on which the unit rests.

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

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

Table 6.2 Continued on Next Page

Table 6.2 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness			
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,		Uncoated,		Metal coated,	
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inch [MSG]	(mm)	inch [GSG]	(mm)
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123	(3.12)	0.126	(3.20)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)	[10]		[10]	

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

1) Single sheet with single formed flanges (formed edges);

2) A single sheet which is corrugated or ribbed; and

3) An enclosure surface loosely attached to a frame, for example, with spring clips.

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

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

[d] Sheet metal for an enclosure intended for outdoor use shall comply with 6.7 and 6.8.

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

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness,	
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,			
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	63.4	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

Table 6.3 Continued on Next Page

Table 6.3 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,		Minimum thickness,
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inch (mm)

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

1) Single sheet with single formed flanges (formed edges);

2) A single sheet which is corrugated or ribbed; and

3) An enclosure surface loosely attached to a frame, for example, with spring clips.

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

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

[d] Sheet metal for an enclosure intended for outdoor use shall comply with 6.7 and 6.8.

7 Mounting of Parts

7.1 All parts shall be mounted in position and prevented from loosening or turning when such motion adversely affects the operation of the equipment.

7.2 Uninsulated live parts shall be secured to their supporting surfaces so as to prevent turning or shifting in position of the part if such motion results in a reduction of spacings to less than minimum required values.

7.3 Friction between surfaces shall not be used as a means to prevent turning, loosening, or shifting of a part as required in 7.1 and 7.2. A toothed-lock washer that provides both spring take-up and an interference lock or equivalent means is capable of being used for this purpose.

8 Protection Against Corrosion

8.1 Except as indicated in 8.2, iron and steel parts, other than bearings or similar parts, where such protection is impracticable, shall be protected against corrosion by enameling, galvanizing, sherardizing, plating, or equivalent means.

8.2 The requirement of 8.1 applies to all enclosing cases of sheet steel or cast iron, and to all springs and other parts upon which intended mechanical operation may depend. It does not apply to minor parts, such as washers, screws, bolts, and similar parts, when corrosion of such unprotected parts does not result in a risk of fire or electric shock or in the unit not operating as intended. Bearing surfaces shall be of materials and design that resist binding due to corrosion.

Exception: Parts made of stainless steel (polished or treated, if necessary), do not require additional protection against corrosion.

9 Insulating Materials

9.1 Material used for a base that supports live parts shall be of nonflammable, moisture-resistant insulating material, such as porcelain, phenolic, or cold-molded composition.

9.2 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.

9.3 Vulcanized fiber is not prohibited from being used for insulating bushings, washers, separators, and barriers. It shall not be used as the sole support for live parts when shrinkage, current leakage, or warping of the fiber introduces a risk of fire or electric shock.

9.4 A countersunk sealed live part shall be covered with a waterproof-insulating compound that does 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 the sealing compound shall not be less than 1/8 inch (3.2 mm).

9.5 The thickness of a flat sheet of insulating material, such as impregnated asbestos-cement composition, phenolic composition, or the equivalent, used for panel-mounting of parts shall not be less than that indicated in Table 9.1.

Table 9.1
Thickness of flat sheets of insulating material

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

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

10 Mechanical Assembly

10.1 A switch (other than a through-cord switch), a lampholder, an attachment-plug receptacle, a motor-attachment plug, or similar component shall be mechanically secured and, except as noted in 10.2 (a) and (b), shall be prevented from turning.

Exception: A lampholder of the type in which the lamp cannot be replaced (such as a neon pilot or indicator light in which the lamp is sealed in a nonremovable jewel) is not required to be prevented from turning when turning cannot reduce spacings below the minimum required values.

10.2 The requirement that a switch be prevented from turning may be waived when all four of the following conditions are met:

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

b) The means for mounting the switch shall prevent loosening of the switch as the result of operation.

c) The spacings shall not be reduced below the minimum required values when the switch rotates.

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

10.3 The means for preventing the turning as required in 10.1 shall consist of more than friction between surfaces. A toothed-lock washer that provides both spring take-up and an interference lock is capable of being used as the means for preventing the turning of a small stem-mounted switch or other device having a single-hole mounting means.

11 Current-Carrying Parts

11.1 A current-carrying part shall be of silver, copper, a copper alloy, or aluminum.

11.2 Bearings, hinges, and similar parts, shall not be used for carrying current between fixed and moving parts.

12 Motors

12.1 A unit using a motor rated at 1 horsepower (746 W output) or less shall incorporate thermal or overcurrent protection that prevents the motor from attaining temperatures higher than those indicated in 12.2 and 35.1. The motor shall not burn out, nor shall there be other evidence of a risk of fire as a result of these tests.

12.2 When the motor is running under the maximum overload condition that it can carry without causing the protective device to operate, the maximum temperature on a Class A (Class 105) insulated motor winding shall not exceed 140°C (284°F) and the maximum temperature on a Class B insulated motor winding shall not exceed 165°C (329°F).

Exception: This requirement does not apply to the motor of a direct-drive fan or blower intended only to move air.

12.3 A thermal or overcurrent-protective device shall not open the circuit during the Temperature Test, Section 26.

12.4 The intended functioning of a motor-protective device provided as part of the unit (whether such device is required or not) shall not result in a risk of fire or injury to persons.

12.5 Impedance protection may be used for motors, provided that the motor will not overheat under locked-rotor conditions or when tested according to these requirements.

13 Installation Wiring Methods

13.1 General

13.1.1 A unit shall be provided with field-wiring terminals or leads and shall have provision for connection of one of the wiring systems that, in accordance with the National Electrical Code, ANSI/NFPA 70, is required for the unit.

13.1.2 If a unit is constructed so that it is capable of being connected to either of two different supply voltages (for example, 120 volts, 2-wire or 120/240 volts, 3-wire), it shall be provided with means by which the appropriate connections shall be made without changing or disrupting internal wiring or connections other than at the point of field-connection.

13.2 Terminal compartments

13.2.1 A terminal compartment intended for connection of a supply raceway shall be attached to the unit so that it is prevented from turning.

13.2.2 An outlet or terminal box in which connections to the power-supply circuit are made shall be located so that, after the unit has been installed as intended, connections are accessible for inspection.

13.2.3 The compartment shall be located so that, during conduit connections, internal wiring and electrical components are not subjected to mechanical damage or stress.

13.3 Terminals

13.3.1 For 6 AWG (13.3 mm^2) and larger wires, soldering lugs or solderless (pressure) wire connectors shall be used. For 8 AWG (8.4 mm^2) and smaller wires, the parts to which wiring connections are made shall consist of clamps or binding screws with terminal plates having upturned lugs or the equivalent to hold the wires in position.

13.3.2 A wiring terminal shall be prevented from turning or shifting in position. This shall 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 for preventing movement of the terminals.

13.3.3 A wire-binding screw at a wiring terminal shall not be smaller than No. 8 (4.2 mm diameter).

Exception: A No. 6 (3.5 mm diameter) screw is permitted to be used at a terminal intended only for the connection of one 14 AWG (2.1 mm^2) conductor, and a No. 4 (2.8 mm diameter) screw is permitted to be used for the connection of one 16 or 18 AWG (1.3 or 0.82 mm^2) conductor in a control circuit.

13.3.4 A wire-binding screw shall thread into metal.

13.3.5 Except as noted in 13.3.6, a terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 inch (1.27 mm) thick. However, a plate not less than 0.030 inch (0.76 mm) thick is permitted to be used when the tapped threads have equivalent physical strength. There shall not be less than two full threads in the metal.

13.3.6 A terminal plate may have the metal extruded at the tapped hole to provide two full threads, if the thickness of the unextruded metal is not less than the pitch of the thread.

13.4 Leads

13.4.1 A lead that is intended to be spliced in the field to a high-voltage circuit conductor in accordance with the National Electrical Code, ANSI/NFPA 70, shall not be smaller than 18 AWG (0.82 mm^2) and the insulation, when of rubber or thermoplastic, shall not be less than 1/32 inch (0.8 mm) thick. For low-voltage circuits, leads not smaller than 22 AWG (0.32 mm^2) may be used.

13.4.2 The surface of an insulated lead intended for connection of an equipment-grounding conductor shall be green, or green with one or more yellow stripes, and no lead other than an equipment-grounding conductor shall be so identified.

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

13.5 Polarity identification

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

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

13.5.3 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.

14 Termination of Raceways

14.1 Except as indicated in 14.2, an enclosure shall have provision for the connection of metal-clad cable, conduit, or nonmetallic sheathed cable.

14.2 An enclosure without provision for the connection of metal-clad cable or conduit shall be used when instructions are furnished with it indicating the sections of the unit that are intended to be drilled in the field for the connection of raceways.

15 Strain Relief

15.1 Strain relief shall be provided so that a mechanical stress or twist on a cord or cable is not transmitted to terminals, splices, or interior wiring.

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

16 Bushings

16.1 At a point where a cord or cable passes through an opening in a barrier or enclosing case, there shall be a bushing or the equivalent that shall provide a smooth, rounded surface against which the cord or cable may bear.

16.2 If the cord hole is in phenolic composition or other nonconducting material, a smooth, rounded surface is deemed to be the equivalent of a bushing.

16.3 Ceramic materials and some molded compositions are permitted to be used for insulating bushings. Bushings of wood and of hot-molded shellac shall not be used.

16.4 Fiber is permitted to be used where it is not 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 when it is not exposed to moisture.

16.5 A soft-rubber bushing is permitted to be used when the bushing is not less than 3/64 inch (1.2 mm) thick, and when the bushing is located so that it is not exposed to oil, grease, oily vapor, or other substances that have a deleterious effect on rubber. When a soft-rubber bushing is used in a hole in metal, the hole shall be free from sharp edges, burrs, or projections that could cut into the rubber.

16.6 An insulating metal grommet may be provided 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.

17 Internal Wiring

17.1 General

17.1.1 Internal wiring shall have thermoplastic or rubber insulation not less than 1/32 inch (0.8 mm) thick, rated 600 volts. Other thinner insulating materials are permitted to be used if determined to be equivalent.

17.1.2 A lead connected to parts mounted on a hinged cover shall be of length enough to permit the full opening of the cover without applying stress to the lead or its connections. The lead shall be secured or equivalently arranged to prevent abrasion of insulation and jamming between parts of the enclosure and shall be of an acceptable flexible type.

17.1.3 Insulation, such as coated fabric and extruded tubing, shall not be affected physically or electrically by the temperature or other environmental conditions to which it is subjected in service.

17.1.4 A wireway shall be smooth and free from sharp edges, burrs, fins, or moving parts that cause abrasion of the conductor insulation. A hole in a sheet-metal wall through which insulated wires pass shall be provided with a bushing when the wall is 0.042 inch (1.07 mm) thick or less. A hole in a wall thicker than 0.042 inch shall have smooth, rounded edges.

17.1.5 A joint or connection shall be mechanically secure without stress on connections and terminals.

17.1.6 A stranded conductor clamped under wire-binding screws or similar parts shall have the individual strands soldered together or equivalently arranged.

17.1.7 A splice shall be provided with insulation equivalent to that required for the wires involved.

17.2 Separation of circuits

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

17.2.2 When a barrier is used to provide separation between the wiring of different circuits, it shall be of metal or insulating material complying with the requirements of Insulating Materials, Section 9. A barrier of insulating material shall not be less than 0.028 inch (0.71 mm) thick.

18 Grounding

18.1 An exposed dead-metal part that is capable of being energized shall be conductively bonded to the part to which metal-clad cable, conduit, or nonmetallic sheathed cable is to be connected.

18.2 A terminal intended solely for connection of a grounding conductor shall be capable of securing a conductor of the size required for the particular application, in accordance with the National Electrical Code, ANSI/NFPA 70.

18.3 A wire-binding screw intended for the connection of an equipment-grounding conductor shall have a green-colored head that is hexagonal-shaped, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be identified by being marked "G," "GR," "Ground," "Grounding," or

by a marking on a wiring diagram provided with the equipment. The wire-binding screw or pressure wire connector shall be located so that it is unlikely to be removed during servicing of the equipment.

19 Electrical Components

19.1 Capacitors

19.1.1 A capacitor provided as a part of a capacitor motor and a capacitor connected across the line, such as a capacitor for radio-interference elimination, shall be housed within an enclosure or container that protects the plates against mechanical damage and prevents the emission of flame or molten material resulting from malfunction of the capacitor. The container shall be of sheet steel at least 0.020 inch (0.51 mm) thick, or shall be constructed so as to afford equivalent protection.

Exception No. 1: The container of a capacitor may be of sheet steel thinner than 0.020 inch, or of other material, when the capacitor is mounted in an enclosure that houses other parts, and when such enclosure used is capable of enclosing live parts.

Exception No. 2: The individual enclosure of an electrolytic capacitor provided as part of a capacitor motor and having means for venting may be of sheet metal thinner than 0.020 inch (0.51 mm) when it provides equivalent protection against mechanical damage.

Exception No. 3: The individual sheet metal enclosure of an electrolytic capacitor not having means for venting, and provided as part of a capacitor motor, may be less than 0.020 inch (0.51 mm) thick, when there is a space of more than 1/16 inch (1.6 mm) between the capacitor enclosure and the motor, and the capacitor complies with the requirements of the Capacitor Overvoltage Test, Section 34.

19.2 Lampholders

19.2.1 A lampholder supplied as part of the unit shall be wired so that the screw shell is connected to the conductor identified as the grounded conductor of the power-supply circuit.

19.3 Switches

19.3.1 A switch provided as part of a device shall have a current and voltage rating not less than that of the circuit it controls when the device is operated under conditions of intended service. When the circuit controlled has a power factor less than 75 percent, the switch shall have either horsepower rating based on the ampere equivalent, or a noninductive current rating of at least 200 percent of the maximum load current.

20 Transformers, Coils, and Relays

20.1 Except as noted in 20.2, a transformer shall be of the two-coil or insulated type.

20.2 An autotransformer may be used if the terminal or lead connected to the autotransformer winding that is common to both input and output circuits is identified, and the output circuits are located only within the enclosure containing the autotransformer. See 17.2.2.

20.3 A coil shall be treated with an insulating varnish and baked or otherwise impregnated to exclude moisture.

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

21 Overcurrent Protection

21.1 The assembly shall be arranged so that an overcurrent protective device, such as a fuse, is capable of being replaced and manual-reset devices are capable of being reset without removing parts other than a service cover(s) or panel(s).

21.2 A fuseholder shall be constructed, installed, or protected so that adjacent uninsulated high-voltage parts, other than the screw shell of a plug fuseholder, cartridge fuse clips, or wiring terminals to the fuseholder, are not exposed to contact by persons removing or replacing fuses. An insulating barrier of vulcanized fiber or similar material used for this purpose shall not be less than 1/32 inch (0.8 mm) thick.

21.3 The door or cover of an enclosure shall be hinged or pivoted where it accesses fuses or any motor-overload protective device, or when it is required to open the cover in connection with the operation of the protective device.

21.4 A hinged cover is not required for a device in which the only fuses enclosed are:

a) Supplementary control-circuit fuses rated 2 amperes or less, provided that the fuses and control-circuit loads (other than a fixed control-circuit load, such as a pilot lamp) are within the same enclosure;

b) Extractor-type fuses, each with its own enclosure; or

c) Fuses in low-voltage circuits.

21.5 Hinged covers, where required, shall not depend solely upon screws or similar means requiring the use of the tools to hold them closed, but shall be provided with a spring latch or catch that retains the cover in the closed position.

21.6 A door or cover directly accessing a fuse in other than a low-voltage circuit shall close against a 1/4-inch (6.4-mm) rabbet or the equivalent, or shall have either turned flanges for the full length of four edges or angle strips fastened to it. Flanges or angle strips shall fit closely with the outside of the box and shall overlap the edges of the box by not less than 1/2 inch (12.7 mm). A construction that affords equivalent protection, such as a construction in which the fuse enclosure is located within an outer enclosure, or a combination of flange and rabbet, is capable of being used for this purpose.

21.7 A fuse shall not be used as a motor-overload protective device unless the motor is protected by the time-delay fuse of largest ampere rating that can be inserted in the fuseholder. See Mechanical Assembly, Section 10.

22 Spacings

22.1 General

22.1.1 Spacings shall not be less than indicated in Table 22.1 between an uninsulated live part and the following:

a) An uninsulated live part of opposite polarity;

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

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

Table 22.1
Minimum spacings

Point of application	Voltage range[a], AC	Minimum spacings[b]			
		Through air,		Over surface,	
		inch	(mm)	inch	(mm)
To walls of enclosure[c]:					
Cast metal enclosures	0 – 300	1/4	6.4	1/4	6.4
Sheet metal enclosures	0 – 300	1/2	12.7	1/2	12.7
Installation wiring terminals[b]:					
With barriers	0 – 30	1/8	3.2	1/8	3.2
	31 – 150	1/8	3.2	1/4	6.4
	151 – 300	1/4	6.4	1/4	6.4
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[d]:					
100 volt-amperes maximum[e]	0 – 30	1/32	0.8	1/32	0.8
Other parts except motors	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

[a] These are rms values. Equivalent direct current or peak voltages are 42.4 volts for 30 volts rms, 212 volts for 150 volts rms, and 424 volts for 300 volts rms.

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

[c] The spacings specified in "To walls of enclosure," apply between an uninsulated live part and a:

1) Wall or cover of a metal enclosure,

2) Fitting for conduit or metal-clad cable, and

3) Metal piece attached to a metal enclosure, where deformation of the enclosure could reduce spacings.

They are not to be applied to an individual enclosure of a component part within an outer enclosure.

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

[e] Spacings less than those indicated, but not less than 1/64 inch (0.4 mm), shall 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).

22.1.2 All uninsulated live parts connected to different line- or low-voltage circuits shall be spaced from one another as though they were parts of opposite polarity in accordance with the requirements in Table 22.1, and shall be evaluated on the basis of the highest voltage involved.

22.2 High-voltage spacings

22.2.1 When an uninsulated live part is not fixed in position by means other than friction between surfaces, or when a movable dead-metal part is in proximity to an uninsulated live-metal part, the construction shall maintain the minimum required spacing.

22.2.2 The spacings within a motor shall comply with the spacing requirements in the Standard for Electric Motors, UL 1004.

22.2.3 The spacings within snap switches, lampholders, and similar wiring devices supplied as part of a device shall comply with the requirements for that component and need not comply with the requirements of Table 22.1.

22.2.4 An insulating lining or barrier of vulcanized fiber or similar material used where spacings are otherwise inadequate shall not be less than 1/32 inch (0.8 mm) thick, and shall be located or of such material so that it is not affected by arcing.

Exception: Vulcanized fiber not less than 1/64-inch (0.4-mm) thick may be used in conjunction with an air spacing of not less than 50 percent of the through-air spacing required.

22.2.5 Film-coated wire is considered to be an uninsulated live part in determining compliance of a product with the spacing requirements, but film coating is acceptable as turn-to-turn insulation in coils.

PERFORMANCE

23 Resistance to Entry Test

23.1 When installed in either a vault door or modular panel that complies with the requirements in the Standard for Burglary Resistant Vault Doors and Modular Panels, UL 608; or a reinforced concrete wall according to the manufacturer's directions and the Standard Classification for Bank and Mercantile Vault Construction, ASTM F-1090, the ventilator or ventilating port shall not affect the burglary-resistance of the vault wall.

23.2 To determine compliance with 23.1, a ventilator or port shall resist removal or creation of a 96-square-inch (619-cm^2) opening through the entire product whose smallest dimension exceeds 6 inches (150 mm), or both, using the tools described in 23.3 for the net working time specified in 1.4. The net working time is the time during which an attack is actively in progress on the sample, excluding the time required for test preparation, safety precautions, and delays.

23.3 The attack tools are to include any of the following:

a) Common Hand Tools – Chisels, punches, wrenches, screwdrivers, and pliers; hammers and sledges not to exceed 8 pounds (3.6 kg) in head size; and pry bars and ripping tools not to exceed 5 feet (1.6 m) in length.

b) Cutting Torch – A heavy-duty, commercially available oxy-fuel cutting torch. See 23.4.

c) Fluxing Rod – Low carbon steel or similar type material rods, such as concrete reinforcing rods, to aid in torch cutting.

d) Hydraulic Tools – Portable, hydraulic-operated jacks, wedges, and similar pressure-applying devices not to exceed 100,000 pounds (444,820 N) of force.

e) Impact Tools – Portable, electric or pneumatic impact hammers and hammer drills, not to exceed 1 inch (25.4 mm) in chuck size.

f) Portable, Electric Drills and Tools – Electric hand drills accommodating drill bits not larger than 1 inch in diameter, and coring drills.

g) Power Saws – Circular saws not exceeding 8 inches (203 mm) in diameter; hole saws not exceeding 12 inches (305 mm) in diameter; or reciprocating saws.

h) Pressure-Applying Devices – Portable drill presses, portable drilling jigs, or other types of drill-holding mechanisms.

23.4 The quantity of gas consumed (combined total of oxygen and fuel gas) in any one test is to be limited as follows:

a) Class M and Class 1 rated product – 1000 cubic feet (28.3 m^3);

b) Class 2 rated product – 2000 cubic feet (56.6 m^3);

c) Class 3 rated product – 4000 cubic feet (113.3 m^3).

23.5 The testing party shall consist of two skilled operators.

23.6 With regard to 23.2, examples of a 96-square-inch (619-cm^2) opening are: a rectangular-shaped opening with the smallest dimension 6 inches (152 mm); a circular opening 11.06 inches (281 mm) in diameter; or an isosceles (right) triangle-shaped opening with a hypotenuse of 19.6 inches (497 mm).

24 Starting Current Test

24.1 A unit shall be capable of starting and operating as intended on a circuit protected by an ordinary (not time-delay) fuse with a current rating corresponding to that of the branch circuit to which the unit is to be connected.

24.2 To determine compliance with the requirement of 24.1, the unit is to be started three times, with the unit at room temperature at the beginning of the test. Each start is to be made under conditions representing the beginning of an operating cycle and the motor is to be allowed to come to rest between successive starts. The fuse shall not open nor shall any overload protector provided as part of the unit trip.

25 Input Test

25.1 The input to a unit shall not exceed 110 percent of the nameplate current, power, or volt-ampere value when the unit is operated under the continuous load conditions while connected to a supply circuit in accordance with the requirements in 25.2.

25.2 The test voltage for this test is to be the maximum rated voltage for the product. For a product having a single voltage rating, such as 115 volts, maximum rated voltage is to be that single voltage. When the voltage is given in terms of a range of voltages, such as 110 – 120 volts, the maximum rated voltage is the highest value of the range.

26 Temperature Test

26.1 While tested under continuous load conditions, a unit shall not exceed the temperature rises specified in Table 26.1 at the specific points designated therein.

26.2 The values for temperature in Table 26.1 are based on an assumed ambient temperature of 25 ±15°C (77 ±27°F), and tests are to be conducted at an ambient temperature within that range.

26.3 Thermocouples are to be used for determining the temperature of a coil or winding when they can be mounted, without removal of encapsulating compound or similar material, either on integrally-applied insulation of a coil without a wrap, or on the outer surface of a wrap that is not more than 1/32 inch (0.8 mm) thick and consists of cotton, paper, rayon, or similar material (but not of impregnated asbestos or similar thermal insulation). The change-in-resistance method is to be used when the thermocouple measurement is not capable of being conducted in accordance with the foregoing considerations. For a thermocouple-measured temperature of a motor coil as specified in Item A of Table 26.1, the thermocouple is to be mounted on the integrally-applied insulation on the conductor.

Table 26.1
Maximum temperature rises

Materials and components	°C	°F
A. MOTORS[a,b]		
1. Class A insulation systems on coil windings of alternating-current motors 7 inches (178 mm) or less in diameter (not including universal motors):		
a) In open motors:		
Thermocouple or resistance method	75	135
b) In totally enclosed motors:		
Thermocouple or resistance method	80	144
2. Class A insulation systems on coil windings of alternating-current motors more than 7 inches (178 mm) in diameter and of direct-current and universal motors:		
a) In open motors:		
Thermocouple method	65	117
Resistance method	75	135
b) In totally enclosed motors:		
Thermocouple method	70	126
Resistance method	80	144
3. Class B insulation systems on coil windings of alternating-current motors 7 inches (178 mm) or less in diameter (not including universal motors):		
a) In open motors:		
Thermocouple or resistance method	95	171
b) In totally enclosed motors:		
Thermocouple or resistance method	100	180
4. Class B insulation systems on coil windings of alternating-current motors more than 7 inches (178 mm) in diameter and of direct-current motors and universal motors:		
a) In open motors:		
Thermocouple method	85	153
Resistance method	95	171
b) In totally enclosed motors:		
Thermocouple method	90	126
Resistance method	100	180
B. COMPONENTS		
1. Capacitors:[c,d]		
a) Electrolytic type	40	72
b) Other types	65	117
2. Rectifiers – at any point:		
a) Germanium	50	90
b) Selenium	50	90
c) Silicon	75	135
3. Relay, solenoid, transformer and other coils with:		
a) Class 105 insulation system:		
Thermocouple method	65	117
Resistance method	85	153
b) Class 130 insulation system:		

Table 26.1 Continued on Next Page

Table 26.1 Continued

Materials and components	°C	°F
Thermocouple method	85	153
Resistance method	105	189
c) Class 155 insulation system:		
(1) Class 2 transformers:		
Thermocouple method	95	171
Resistance method	115	207
(2) Power transformers:		
Thermocouple method	110	198
Resistance method	115	207
d) Class 180 insulation system:		
(1) Class 2 transformers:		
Thermocouple method	115	207
Resistance method	135	243
(2) Power transformers:		
Thermocouple method	125	225
Resistance method	135	243
4. Resistors:[e]		
a) Carbon	25	45
b) Wire wound	125	225
c) Other	25	45
5. Solid-state devices	See note f	
6. Other components and materials:		
a) Fiber used as electrical insulation or cord bushings	65	117
b) Varnished cloth insulation	60	108
c) Thermoplastic materials	Rise based on temperature limits of the material	
d) Phenolic composition used as electrical insulation or as parts where failure results in risk of fire or electric shock[g]	125	225
e) Wood or other combustibles	65	117
f) Sealing compound	15°C (27°F) less than the melting point	
g) Fuses	65	117
C. CONDUCTORS		
1. Appliance wiring material[h]	25°C (45°F) less than the temperature limit of the wire	
2. Flexible cord (for example, SJO, SJT)	35	63
3. Conductors of field-wired circuits to be permanently connected to the product	35	63
D. GENERAL		
1. All surfaces of the product and surfaces adjacent to or upon which the product may be mounted	65	117
2. Surfaces intended to be contacted by the user in operating the unit (control knobs, push buttons, levers, and similar parts):		
a) Metal	35	63
b) Nonmetallic	60	108

Table 26.1 Continued on Next Page

Table 26.1 Continued

Materials and components	°C	°F
3. Surfaces subjected to casual contact by the user (enclosure, customer access panels, and similar surfaces):		
a) Metal	45	81
b) Nonmetallic	65	117

[a] The motor diameter is to be measured in the plane of the laminations of the circle circumscribing the stator frame, excluding lugs, boxes, and similar parts, used solely for motor cooling, mounting, assembly, or connection.

[b] See 26.4.

[c] For an electrolytic capacitor which is physically integral with or attached to a motor, the temperature rise on insulating material integral with the capacitor enclosure shall not be more than 65°C (117°F).

[d] A capacitor that operates at a temperature higher than a 65°C (117°F) rise shall be evaluated on the basis of its marked temperature rating.

[e] The temperature rise of a resistor may exceed the values shown when the power dissipation is 50 percent or less of the manufacturer's rating.

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

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

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

3) 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 operational tests.

[g] The limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to compounds which have been investigated and determined to be acceptable for temperatures higher than those specified in this table.

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

26.4 For a thermocouple-measured temperature of a coil of an alternating-current motor having a diameter of 7 inches (178 mm) or less, the thermocouple is to be mounted on the integrally-applied insulation on the conductor. At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature rise measured by a thermocouple is permitted to exceed the indicated maximum by the following amounts if the temperature rise of the coil, as measured by the change-in-resistance method, is not more than that specified in Table 26.1:

a) On coil windings of alternating-current motors having a diameter of 7 inches (178 mm) or less, open type.

1) 5°C (9°F) for Class A insulation.

2) 10°C (18°F) for Class B insulation.

b) On coil windings of alternating-current motors having a diameter of more than 7 inches, open type.

1) 15°C (27°F) for Class A insulation.

2) 20°C (36°F) for Class B insulation.

c) 15°C (27°F) for item (B)(3)(a) in Table 26.1.

26.5 A thermocouple junction and adjacent thermocouple lead wire are to be held in secure thermal contact with the surface of the material whose temperature is being measured. In most cases, acceptable thermal contact results from securely taping or cementing the thermocouple in place. If a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

26.6 The formula for obtaining the temperature of copper by the change-in-resistance method is as follows:

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

in which:

T is the calculated temperature in degrees C;

R is the resistance in ohms at temperature T (while hot);

r is the resistance in ohms at temperature t; and

t is the reference (room temperature) in degrees C.

26.7 A temperature is determined 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-minute intervals), indicate no change. The thermocouples and related instruments are to be accurate and calibrated in accordance with current laboratory practice. The thermocouple wire is to conform with the requirements specified in the Initial Calibration Tolerances for Thermocouples table in the Standard for Temperature Measurement Thermocouples, ANSI/ISA MC96.1.

26.8 For vault-ventilating ports that are not intended for continuous operation, the Temperature Test, Section 26, is to be conducted so that the intermittent or short-time operation of the unit is taken into consideration.

27 Voltage Variation Test

27.1 The unit shall function as intended at 85 – 110 percent of rated voltage without readjustment. Tests are to be conducted at maximum, minimum, and intermediate input voltages.

28 Temperature Variation Test

28.1 A unit for indoor use shall function as intended while operated at rated voltage and with its related equipment when subjected to any temperature between 0 – 49°C (32 – 120°F).

28.2 The length of exposure to any of the temperatures referred to in 28.1 is to be 4 hours or more.

29 Humidity Test

29.1 A unit shall function as intended during and after exposure for 24 hours to air having a relative humidity of 85 percent at a temperature of 32 ±2°C (90 ±3.6°F).

30 Electric Shock Current Test

30.1 When the open circuit potential between any part that is exposed only during operator servicing and either earth ground or any other exposed accessible part exceeds 42.4 volts peak, the part shall comply with the requirements of 30.2 – 30.4, as applicable.

30.2 The continuous current flow through a 500-ohm resistor shall not exceed the values specified in Table 30.1 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 30.1
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 shall be used to determine the maximum current corresponding to frequencies not shown. The table applies to repetitive nonsinusoidal or sinusoidal waveforms.

30.3 The transient current flowing through a 500-ohm resistor connected as described in 30.2 shall not exceed 809 milliamperes, regardless of duration. If the transient current exceeds 809 milliamperes, the duration of the current shall not exceed the value determined by the following equation:

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

in which:

I is the peak current in milliamperes and

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. The interval between occurrences shall be at least 60 seconds when the current is repetitive. Typical calculated values of maximum allowable transient current duration are shown in Table 30.2.

30.4 With reference to the requirements in 30.2 and 30.3, the current is to be measured while the resistor is connected between ground and each accessible part individually, and all accessible parts collectively when 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, when the parts are simultaneously accessible.

30.5 With reference to the requirement in 30.4, parts are determined to be simultaneously accessible when they are capable of being contacted by one or both hands of a person at the same time. For the purpose of these requirements, one hand is determined to be able to contact parts simultaneously when the parts are within a 4 by 8 inch (102 by 203 mm) rectangle; and two hands of a person are determined to be able to contact parts simultaneously when the parts are not more than 6 feet (1.83 m) apart.

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