UL 1034

STANDARD FOR SAFETY

Burglary-Resistant Electric Locking Mechanisms

UL Standard for Safety for Burglary-Resistant Electric Locking Mechanisms, UL 1034

Sixth Edition, Dated May 18, 2011

Summary of Topics

This revision of ANSI/UL 1034 dated June 23, 2020 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 7, 2020.

No Text on This Page

MAY 18, 2011
(Title Page Reprinted: June 23, 2020)

ANSI/UL 1034-2015 (R2020)

UL 1034

Standard for Burglary-Resistant Electric Locking Mechanisms

First Edition – July, 1974
Second Edition – September, 1980
Third Edition – September, 1987
Fourth Edition – July, 1994
Fifth Edition – February, 2000

Sixth Edition

May 18, 2011

This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through June 23, 2020.

The most recent designation of ANSI/UL 1034 as a Reaffirmed American National Standard (ANS) occurred on June 3, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

The Department of Defense (DoD) has adopted UL 1034 on July 1, 1992. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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 apply to the construction, performance, and operation of burglary-resistant electric locking mechanisms and their related devices, such as control units, control switches, and power supplies, and the like used to secure and release doors.

1.2 A burglary-resistant electric locking mechanism shall be rated according to the three elements used to determine its maximum effectiveness:

a) Static strength rating of 500 pounds-force (2224 N), 1000 pounds-force (4448 N), or 1500 pounds-force (6673 N). See 55.2.1.

b) Dynamic strength rating of 33 foot-pounds-force (45 J), 50 foot-pounds-force (68 J), or 70 foot-pounds-force (95 J). See 55.3.1.

c) Endurance rating of 100,000 or 250,000 cycles. See 38.2.1.

A burglary-resistant electric locking mechanism shall be rated with its maximum static strength, dynamic strength, and endurance.

1.3 A burglary-resistant electric locking mechanism is intended to be used in conjunction with an access control system or a manual-release mechanism. A burglary-resistant electric locking mechanism shall be constructed so that it either does not interfere with egress through the door or other opening cover that it is used to control, or its locking action shall be capable of being released as required by the authority having jurisdiction if an emergency egress is required.

1.4 These requirements do not pertain to the fire-retardant classification of a door and releasing-device assembly.

1.5 The term "product" as used in this standard refers to all types of burglary-resistant electric locking mechanisms.

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 or of electric shock or injury to persons shall be evaluated using appropriate additional component and end-product requirements to maintain the level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard does not comply with this standard. Revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

2 Components

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

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

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

b) Is superseded by a requirement in this standard.

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

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

3 Units of Measurement

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

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

4 Undated References

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

5 Glossary

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

5.2 CIRCUITS, ELECTRICAL –

a) High-Voltage (Class 1) – A circuit involving a potential of not more than 600 volts and having circuit characteristics in excess of those of a low-voltage, power-limited circuit.

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

c) Power-Limited – A circuit whose output is limited as specified in Power-Limited Circuits, Section 30.

d) Class 2 – A circuit in which the voltage and power limitations are in accordance with the requirements of Table 30.1 for AC circuits and Table 30.2 for DC circuits.

e) Class 3 – A circuit in which the voltage and power limitations are in accordance with the requirements of Table 30.1 for AC circuits and Table 30.2 for DC circuits.

5.3 CORD-CONNECTED PRODUCT – A product intended for connection to the power source by means of a supply cord. By the nature of its design, such a product is intended to be moved for interchange or realignment of the component of a system.

5.4 ELECTRIC LOCKING MECHANISM – An electrically-operated door strike, dead-bolt, or the like.

5.5 ELECTROMAGNETIC LOCK – An electrically-powered lock using an electromagnet magnetically coupled to an armature to provide locking power.

5.6 LINE-VOLTAGE – The voltage at any field connected source of supply, nominally 50-60 hertz (Hz); 115, 208, or 230 volts.

5.7 PRIMARY BATTERY – Any battery which, by construction, is not intended to be recharged.

5.8 SECONDARY BATTERY – Any battery which, by construction, is intended to be recharged.

5.9 STANDBY CONDITION – The ready-to-operate condition which exists prior to being operated to unlock.

CONSTRUCTION

ASSEMBLY

6 General

6.1 Product assembly

6.1.1 The product shall be factory-built as a complete assembly and shall include all the essential components necessary for its intended function when installed (used) as intended. The product may be shipped from the factory as two or more major subassemblies. See the subassembly requirement in 6.1.2.

6.1.2 If the product is not assembled by the manufacturer as a complete unit, it shall be arranged in major subassemblies. Each subassembly shall be capable of being incorporated into a final assembly without requiring alteration, cutting, drilling, threading, welding, or similar tasks by the installer. Two or more subassemblies, which must bear a definite relationship to each other for the correct installation or operation of the product, shall be arranged and constructed to permit them to be incorporated into the complete assembly only in the intended relationship with each other without need for alteration or alignment, or such subassemblies shall be assembled, tested, and shipped from the factory as one element. However, this requirement does not apply to the alteration, cutting, drilling, threading, welding, or similar tasks by the installer on the door, door jamb, or the like to install and mount the product to perform its intended function.

6.2 Electrical protection

6.2.1 Louvers and other openings in an enclosure shall be constructed and located to reduce the risk of unintentional contact with uninsulated high-voltage live parts. In determining compliance with this requirement, parts such as covers, panels, and grilles used as part of the enclosure are to be removed unless tools are required for their removal or an interlock is provided.

6.2.2 Uninsulated high-voltage live parts shall be located, covered, or enclosed as indicated in 6.2.3 – 6.2.5.

6.2.3 Openings directly over uninsulated high-voltage live parts shall not exceed 0.187 inch (4.75 mm) in any dimension unless the configuration prevents direct entry to uninsulated high-voltage live parts and complies with the requirements of 6.2.4 or 6.2.5. See Figure 8.2 for examples of top cover constructions that may be considered to prevent direct entry.

6.2.4 An opening in an electrical enclosure that does not permit entrance of a 1-inch (25.4-mm) diameter rod shall be sized and arranged so that a probe, as illustrated in Figure 6.1, cannot be made to contact any uninsulated live electrical part (other than low-voltage) when inserted through the opening in a straight or articulated position.

6.2.5 An opening that permits entrance of a 1-inch (25.4-mm) diameter rod may be used under the condition described in Figure 6.2.

Figure 6.1

Probe

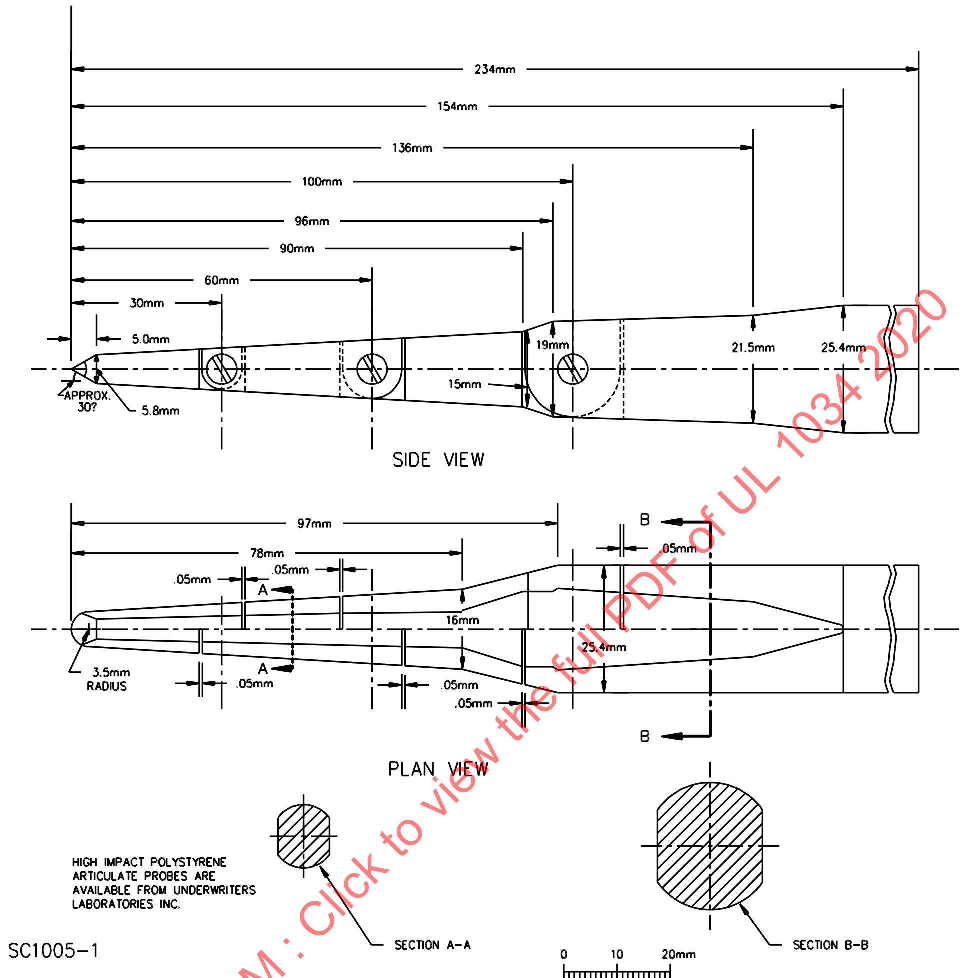
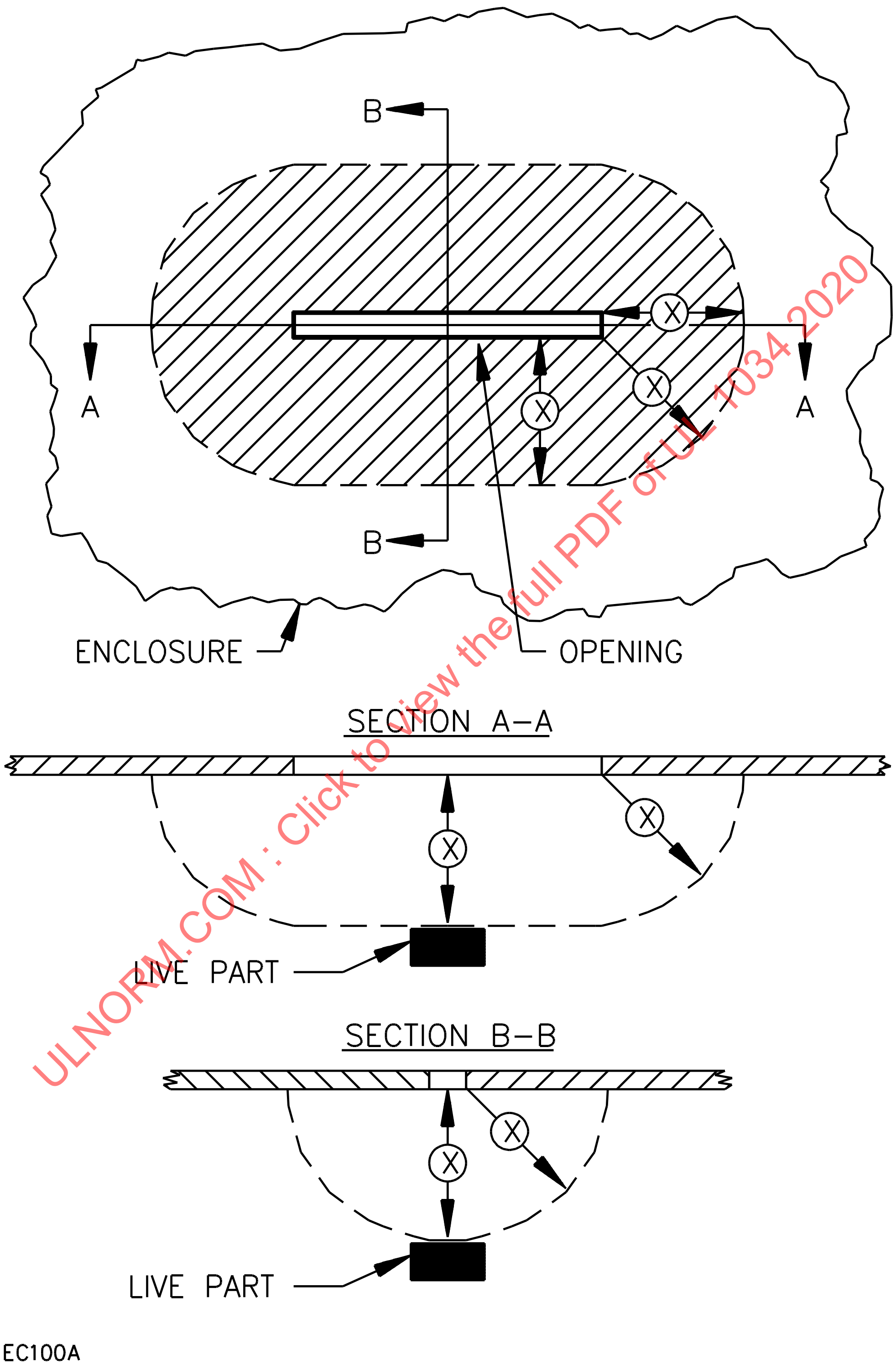


Figure 6.2

Openings in enclosure



The opening is not prohibited from being used when, within the enclosure, there is no uninsulated live metal part or film-coated wire less then X inches (mm) from the perimeter of the opening, as well as within the volume generated by projecting the perimeter X inches normal to its plane. X equals five times the diameter of the largest diameter rod that is capable of being inserted through the opening, and not less than 6-1/16 inches (154 mm).

7 Protection of Service Personnel

7.1 An uninsulated live part of a high-voltage circuit within an enclosure shall be located, covered, or enclosed so as to reduce the risk of unintentional contact by persons performing service functions which may be performed while the equipment is energized.

7.2 During the examination of a product in connection with the requirements specified in 7.1, a part of the outer enclosure which may be removed without the use of tools, or part of the outer enclosure which may be removed by the user to allow access for making intended operating adjustments, is to be disregarded; that is, it will not be assumed that the part in question reduces the risk of electric shock.

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

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

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

b) Terminals and splices with insulation rated for the potential encountered; and

c) Insulated wire.

8 Enclosures

8.1 General

8.1.1 The frame and enclosure of a product shall have the strength and rigidity to resist total or partial collapse and the attendant reduction of spacings, loosening or displacement of parts, or other defects. See Mechanical Strength Tests for Enclosures, Section 49.

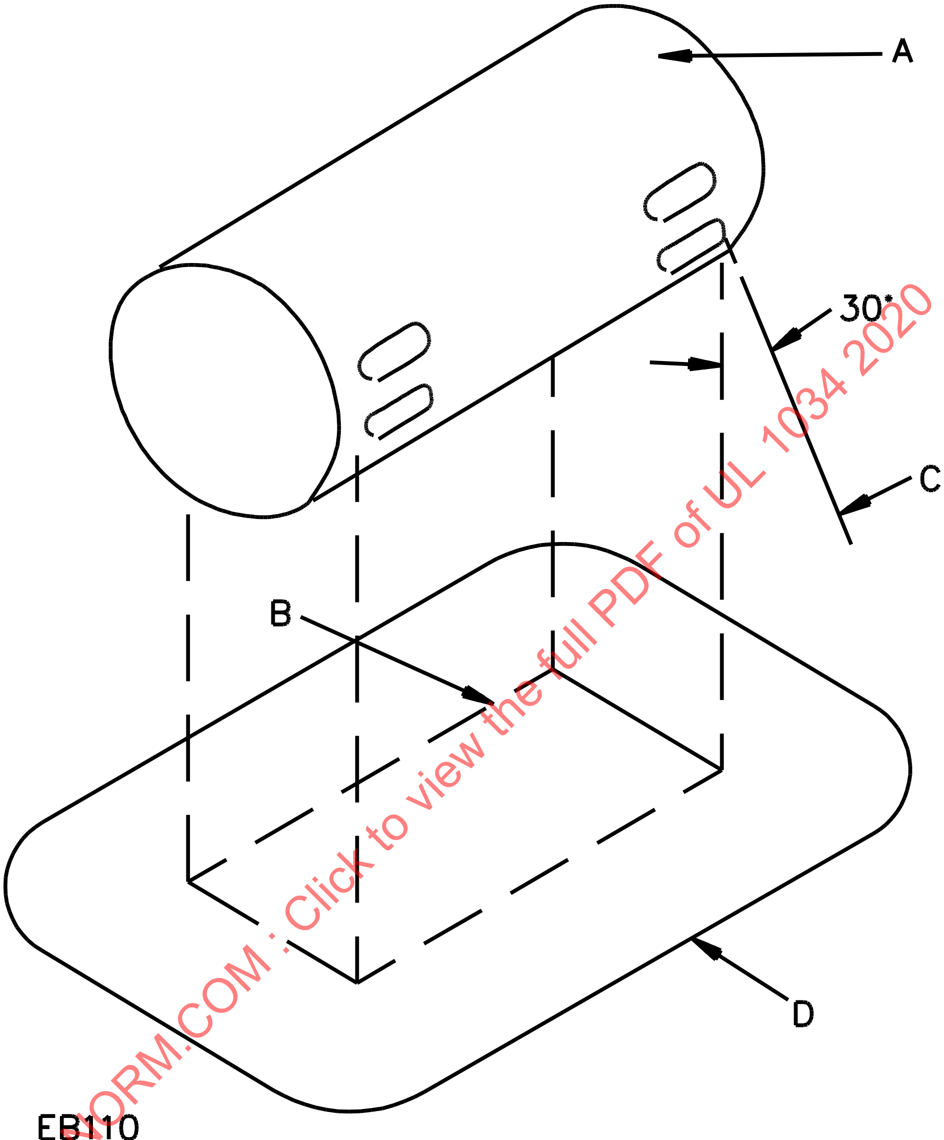
8.1.2 Operating parts, such as gear mechanisms, light-duty relays, and similar devices, shall be enclosed to protect against malfunction from dust or from other material which may impair their intended operation.

8.1.3 An enclosure containing other than power limited circuits shall be constructed to reduce the risk of emission of flame, molten metal, flaming or glowing particles, or flaming drops. See Ignition Through Bottom-Panel Openings, Section 48.

8.1.4 The requirement specified in 8.1.3 necessitates either a nonflammable bottom as specified in 8.4.2, or a barrier as described in Figure 8.1 under all areas containing combustible materials. However, see 8.4.3 for further specifications.

Figure 8.1

Barrier outline



a) The entire component under which a barrier (flat or dish with or without a lip or other raised edge) of noncombustible material is to be provided. The sketch above is of a metal enclosed component with ventilating openings to show that the barrier is required only for those openings from which flaming parts might come. If the component or assembly does not have its own noncombustible enclosure, the area to be protected would be the entire area occupied by the component or assembly.

b) Projection of the outline of the area of (A) which needs a bottom barrier vertically downward onto the horizontal plane of the lowest point on the outer edge (D) of the barrier.

c) Inclined line that traces out an area (D) on the horizontal plane of the barrier. Moving around the perimeter of the area (B) which needs a bottom barrier, this line projects at a 30-degree angle from the line extending vertically at every point around the perimeter of (A) and oriented to trace out the largest area, except that the angle may be less than 30 degrees if the barrier or portion of the bottom cover contacts a vertical barrier or side panel of noncombustible material, or if the horizontal extension of the barrier (B) to (D) would exceed 6 inches (152 mm).

d) Minimum outline of the barrier, except that the extension (B) – (D) need not exceed 6 inches (flat or dished with or without lip or other raised edge). The bottom of the barrier may be flat or formed in any manner if every point of area (D) is at or below the lowest point on the outer edge of the barrier.

8.1.5 A construction using individual barriers under components, groups of components or assemblies, as specified in Figure 8.1, is to be considered as complying with the requirement specified in 8.1.3.

8.2 Product enclosure mounting

8.2.1 An enclosure shall have means for mounting that shall be accessible without disassembly of any operating part of the product. Removal of a completely assembled panel to mount the enclosure may be performed.

8.3 Doors and covers

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

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

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

8.3.2 Fasteners requiring the use of a tool or key shall be used for all enclosures if access is not required for operation of the product.

8.4 Enclosure openings

8.4.1 Openings in the enclosure shall be constructed and of such size so that direct entry of foreign objects is prevented. See also 6.2.3. See Figure 8.2 for examples of top cover constructions that are considered to prevent direct entry. See also Figure 8.3 for examples of side openings.

Figure 8.2

Cross sections of top cover designs

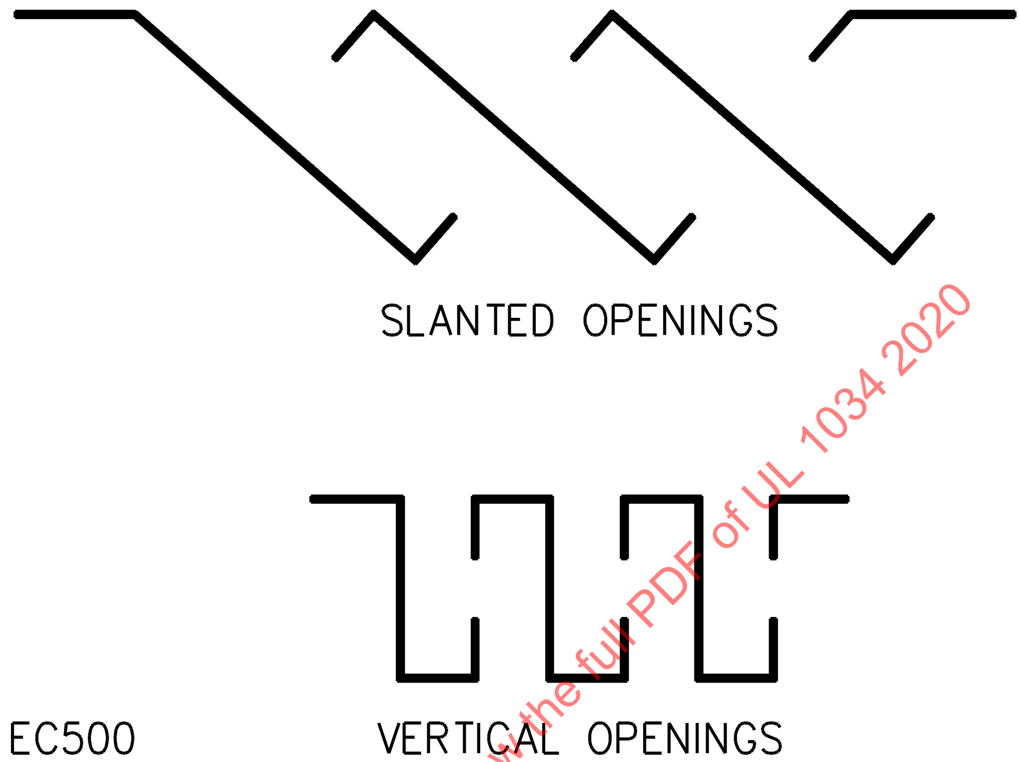
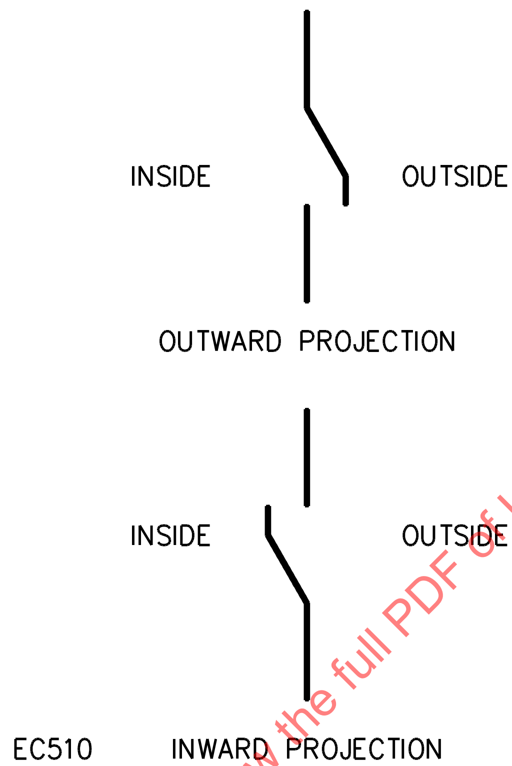


Figure 8.3

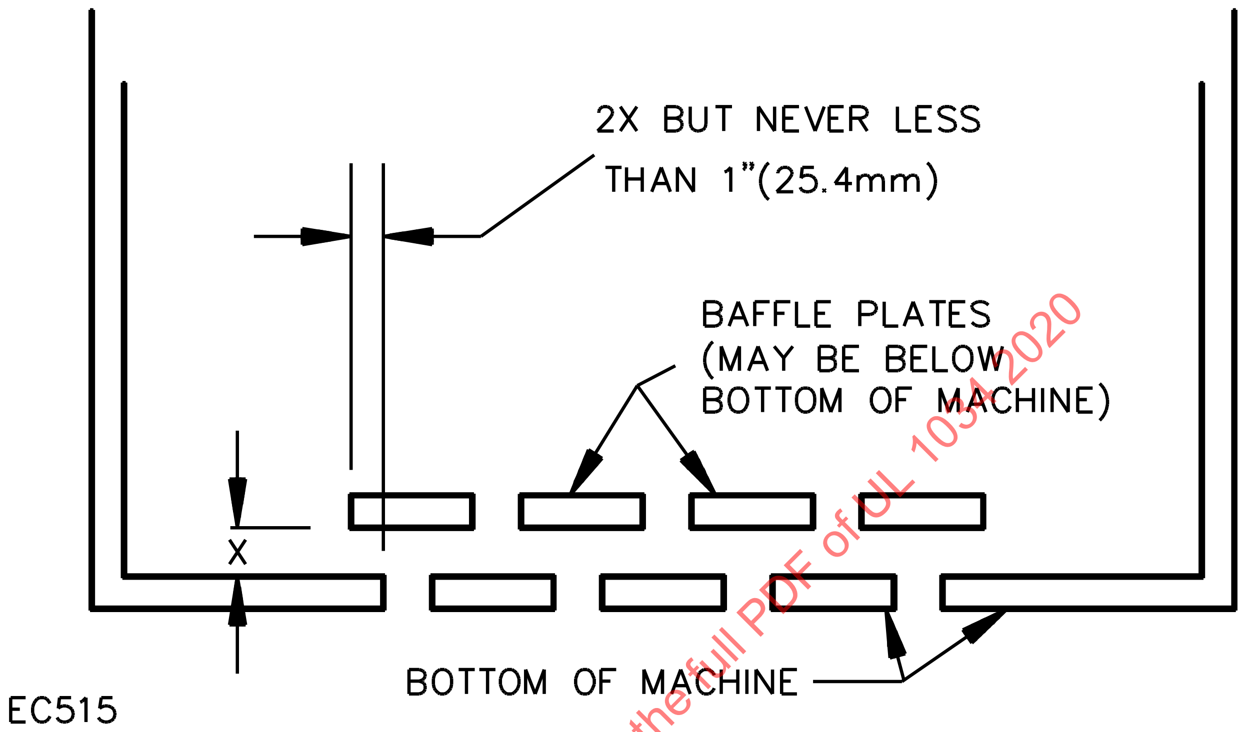
Louvers



8.4.2 Openings may be provided in the bottom panels or in pans under areas containing materials not classified as 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, if constructed so that materials are prevented from falling directly from the interior of the product onto the supporting surface of any other location under the product. Figure 8.4 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) sheet-steel bottom panel in which 5/64-inch (2.0-mm) maximum diameter round holes are spaced not closer together than 1/8 inch (3.2 mm) center-to-center. Other constructions may be used if they comply with Ignition Through Bottom-Panel Openings, Section 48.

Figure 8.4

Baffle



8.4.3 The bottom of the enclosure under areas containing only materials classified as V-1 or less flammable, may have openings not larger than 1/16 square inch (40.3 mm^2).

8.4.4 Openings may be used, without limitation on size or number, in areas containing:

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

b) Plugs and receptacles; and

c) Underneath impedance-protected or thermally-protected motors.

8.4.5 Openings in the enclosure shall not give access to any relays, terminals, controls, or related components that might be subject to tampering by hand or with tools.

8.5 Screens and expanded metal

8.5.1 Screens and expanded metal used as a barrier, enclosure or part of an enclosure, shall comply with the requirements specified in 8.5.2 and 8.5.3 and with the Mechanical Strength Tests for Enclosures, Section 49.

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

Exception: If the indentation of a barrier or the enclosure will not alter the clearance between uninsulated live parts and grounded metal so as to impair performance or reduce spacings below the minimum required values, see General (Spacings), Section 24, 0.020 inch (0.53 mm) expanded steel mesh or perforated sheet steel [0.023 inch (0.58 mm) if zinc coated] may be used if:

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

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

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

8.6 Cast metal

8.6.1 The thickness of cast metal for an enclosure shall be as specified in Table 8.1.

Exception: Cast metal of lesser thickness may be used if consideration has been given to the shape, size, and function of the enclosure, and it provides equivalent mechanical strength. See Mechanical Strength Tests for Enclosures, Section 49.

Table 8.1
Cast-metal electrical enclosures

Use, or dimensions of area involved[a]	Minimum thickness, inch (mm)			
	Die-cast metal		Cast metal of other than the die-cast type	
Area of 24 square inches (115 cm^2) or less and having no dimension greater than 6 inches (152 mm)	1/16	(1.6)	1/8	(3.2)
Area greater than 24 square inches or having any dimension greater than 6 inches	3/32	(2.4)	1/8	(3.2)
At a threaded conduit hole	1/4	(6.4)	1/4	(6.4)
At an unthreaded conduit hole	1/8	(3.2)	1/8	(3.2)

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

8.7 Sheet metal

8.7.1 The thickness of sheet metal for an enclosure shall not be less than specified in Table 8.2 or Table 8.3, whichever applies.

Exception: Sheet metal of lesser thickness may be used if consideration has been given to the shape, size, and function of the enclosure, and it provides equivalent mechanical strength. See Mechanical Strength Tests for Enclosures, Section 49.

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

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

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

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

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

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

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

1) A single sheet with single formed flanges (formed edges),

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

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

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

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

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

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

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

1) A single sheet with single formed flanges (formed edges),

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

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

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

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

8.8 Polymeric materials

8.8.1 Among the factors taken into consideration when determining compliance of a nonmetallic enclosure are:

a) The mechanical strength;

b) Resistance to impact;

c) Moisture-absorptive properties;

d) Flammability and resistance to ignition from electrical sources;

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

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

All these factors are considered with regard to aging in accordance with the Polymeric Materials Test, Section 45, and Mechanical Strength Tests for Enclosures, Section 49.

9 Electric Shock

9.1 Any part that is exposed only during operator servicing shall not present the risk of electric shock. See Electric Shock Current Test, Section 37.

10 Corrosion Protection

10.1 Iron and steel parts, other than bearings, and the like where such protection is impracticable, shall be protected against corrosion by enameling, galvanizing, sherardizing, plating, or other equivalent means. Bearing surfaces shall be constructed of materials that resist binding due to corrosion.

10.2 The requirement specified in 10.1 applies to all enclosures of sheet steel or cast iron, and to all springs and other parts upon which intended mechanical operation may depend.

Exception No. 1: This requirement does not apply to parts, such as washers, screws, bolts, and the like, if corrosion of such unprotected parts would not be likely to result in a risk of fire, electric shock, or unintentional contact with moving parts that can cause injury to persons, or to impair the operation of the unit.

Exception No. 2: Parts made of stainless steel, polished or treated, if necessary, do not require additional protection against corrosion.

10.3 Metal used in cabinets and enclosures shall be galvanically compatible.

Exception: If galvanic action does not result in impaired operation of the product, risk of fire, electric shock, or unintentional contact with moving parts that can cause injury to persons, this requirement does not apply.

10.4 Hinges and other attachments shall be resistant to corrosion.

FIELD-WIRING CONNECTIONS

11 General

11.1 Wiring terminals or leads shall be provided for connection of conductors of at least the size required by the National Electrical Code, ANSI/NFPA 70.

12 Cord-Connected Products

12.1 A portable product that is intended to be connected to high-voltage or line voltage shall be provided with not less than 6 feet (1.8 m) of flexible cord and a two- or three-prong attachment-plug intended and rated for connection to the supply circuit.

Exception: The cord may be less than 6 feet in length if it is evident that use of the longer cord:

a) May result in damage to the cord or product;

b) May result in a risk of fire, electric shock, or injury to persons; or

c) Is not required for the intended operation of the product.

12.2 A flexible cord may be used with a stationary product.

12.3 The flexible cord shall be Type SJ, SJT, or equivalent; minimum 18 AWG (0.82 mm^2); and rated for use at the voltage and ampacity rating of the product.

12.4 The power-supply cord shall be provided with strain relief means so that a stress on the cord will not be transmitted to terminals, splices, or internal wiring. See Strain Relief Test, Section 47.

12.5 If a knot in a flexible cord serves as strain relief, a 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 which may cause abrasion of the insulation on the conductors.

12.6 Clamps of any material (metal or otherwise) may be used on cords and supply leads without varnished-cloth insulating tubing or the equivalent under the clamp, unless the tubing or its equivalent is necessary to prevent the clamp from damaging the cord or supply leads.

12.7 The supply cord or supply leads shall be prevented from being pushed into the product through the cord-entry hole if such displacement is likely to:

a) Subject the cord or supply leads to mechanical damage or to exposure to a temperature higher than that for which the cord or supply leads are rated;

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

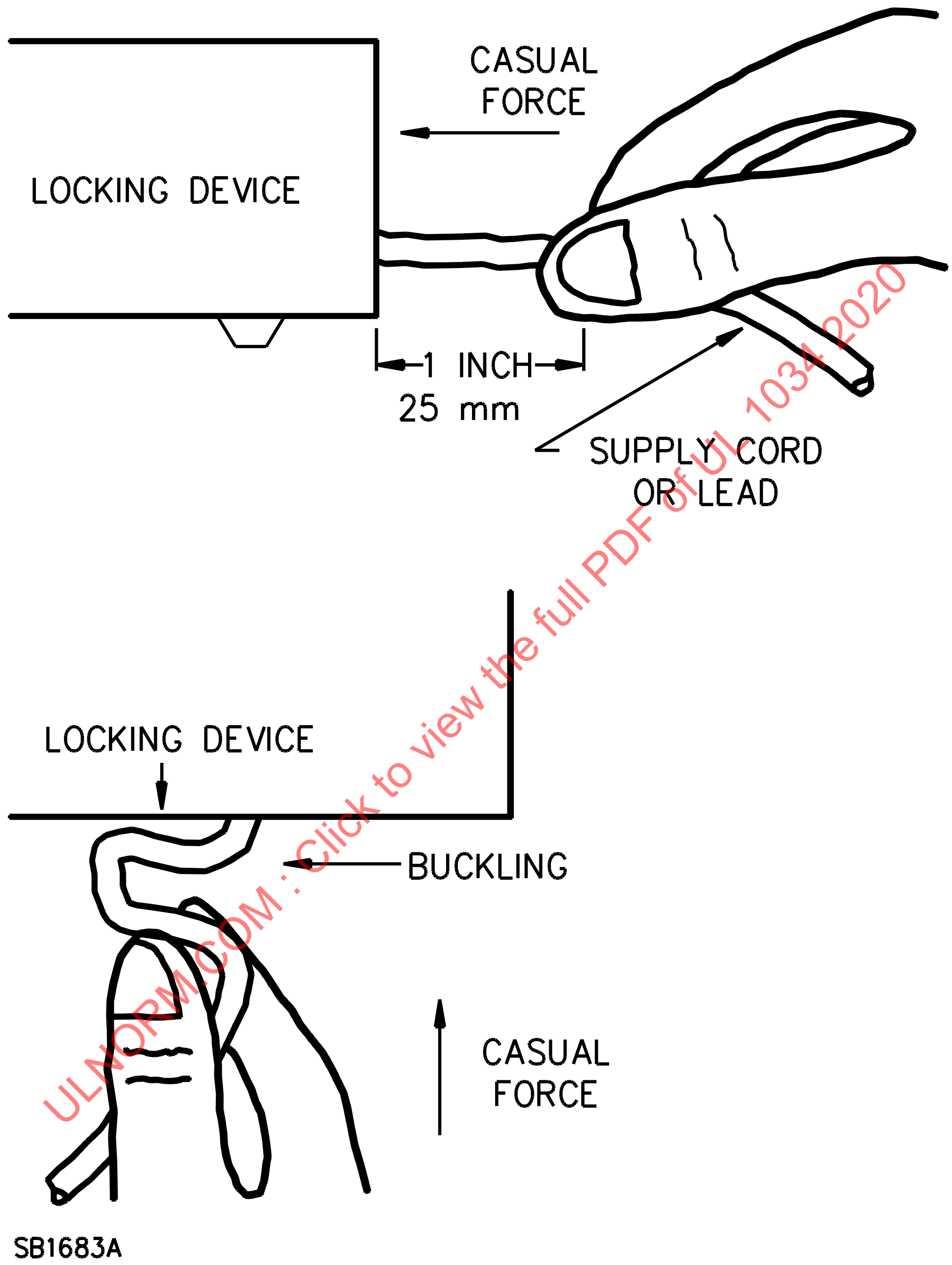
c) Damage internal connections or components.

12.8 To determine compliance with 12.7, a product shall be tested in accordance with 12.9 without occurrence of any of the conditions specified in 12.7.

12.9 The supply cord or supply leads are to be held 1 inch (25.4 mm) from the point where the cord emerges from the product and is then to be pushed back with casual force as shown in Figure 12.1. The force is to be applied until the cord is buckled but in no case shall the force exceed 6 pounds-force (26.7 N).

Figure 12.1

Supply cord or supply leads push-back/strain relief evaluation



13 Permanently-Connected Products

13.1 General

13.1.1 A fixed product shall have provision for connection of one of the wiring systems in accordance with the National Electrical Code, ANSI/NFPA 70.

13.1.2 A knockout provided for connection of a field-wiring system to a field-wiring compartment shall accommodate conduit of the trade size indicated in Table 13.1.

Table 13.1
Trade size of conduit in inches (mm OD)

Wire size, AWG	(mm^2)	Number of wires[a] 2		3		4		5		6	
14	(2.1)	1/2	(21.3)	1/2	(21.3)	1/2	(21.3)	1/2	(21.3)	1/2	(21.3)
12	(3.3)	1/2	(21.3)	1/2	(21.3)	1/2	(21.3)	3/4	(26.7)	3/4	(26.7)
10	(5.3)	1/2	(21.3)	1/2	(21.3)	1/2	(21.3)	3/4	(26.7)	3/4	(26.7)
8	(8.4)	3/4	(26.7)	3/4	(26.7)	1	(33.4)	1	(33.4)	1-1/4	(42.3)
6	(13.3)	3/4	(26.7)	1	(33.4)	1	(33.4)	1-1/4	(42.3)	1-1/4	(42.3)

NOTES

1 Trade size as in Specifications for Zinc Coated Rigid Steel Conduit, ANSI C80.1.

2 When there are more than three conductors in a raceway or cable or when there is more than one conduit, tube, or raceway, see note 8 to Tables 310-16 – 310-19 of the National Electrical Code, ANSI/NFPA 70.

[a] This table is based on the assumption that all conductors are of the same size and there are no more than six conductors in the conduit. When more than six conductors are involved or when all of them are not of the same size, the internal cross-sectional area of the smallest conduit that is to be used is determined by multiplying by 2.5 the total cross-sectional area of the wires, based on the cross-sectional area of Type THW wire.

13.1.3 A terminal box or compartment in which power supply connections are to be made shall be located so that the connections are accessible without removing parts other than a service cover or panel and the cover of the outlet box or compartment in which the connections are made.

13.1.4 A terminal compartment intended for the connection of a supply raceway shall be secured in position and shall be prevented from turning.

13.1.5 The product shall be provided with field-wiring terminals or leads for the connection of conductors having an ampacity not less than that required by the product. It is assumed that branch circuit conductors rated 60°C (140°F) will be used.

13.2 Field-wiring terminals

13.2.1 General

13.2.1.1 As used in these requirements, field-wiring terminals are those terminals to which power supply (including equipment grounding) or control connections will be made in the field when the product is installed.

13.2.1.2 A field-wiring terminal shall comply with the requirements in the Standard for Wire Connectors, UL 486A-486B, or the Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E, or the field-wiring requirements (Code 2) in the Standard for Terminal Blocks, UL 1059, or the field-wiring requirements in the Standard for Electrical Quick-Connect Terminals, UL 310, or

13.2.2.1 – 13.2.2.5. The current-carrying parts shall be silver, copper, a copper alloy, or a similar nonferrous conductive material. Securing screws and the like may be plated steel.

Exception: Equipment provided with quick-connect terminals intended for field termination of electrical conductors to the equipment and complying with UL 310 shall be provided with strain relief. The installation instructions shall include instructions for effecting the strain relief and references to the specific connectors to be used.

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

a) Two screws or rivets;

b) Square shoulders or mortises;

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

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

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

13.2.2 General application

13.2.2.1 Nonferrous soldering lugs or solderless (pressure) wire connectors shall be used for 8 AWG (8.4 mm^2) and larger wires. If the connectors or lugs are secured to a plate, the plate thickness shall not be less than 0.050 inch (1.27 mm). Securing screws may be plated steel.

13.2.2.2 A wire binding screw intended for connection of the power supply (line voltage) source shall not be smaller than No. 10 (4.8 mm diameter).

Exception: A No. 8 (4.2 mm diameter) screw may be used for the connection of one 14 AWG (2.1 mm^2) or smaller conductor, and a No. 6 (3.5 mm diameter) screw may be used for the connection of a 16 AWG (1.3 mm^2) or smaller conductor. The screw may be of plated steel.

13.2.2.3 For connection of other than power supply (line voltage) circuits using 10 AWG (5.3 mm^2) and smaller wires, a wire binding screw shall not be smaller than No. 8 (4.2 mm diameter), except that a No. 6 (3.5 mm diameter) screw may be used for the connection of a 14 AWG (2.1 mm^2) or smaller conductor, and a No. 4 (2.8 mm diameter) screw may be used for 19 AWG (0.65 mm^2) or smaller conductor.

13.2.2.4 Terminal plates 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 wires in position. Other constructions may be used if they provide equivalent thread security of the wire binding screw.

b) Be of a nonferrous metal not less than 0.050 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) or smaller screw.

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

13.2.3 Qualified application

13.2.3.1 Any of the following terminal configurations may be used for connection of field wiring if all of the conditions specified in 13.2.3.2 are complied with.

a) Telephone Type Terminals – Nonferrous terminal plates employing a narrow, V-shaped slot for securing of a conductor in a special post construction. Requires special tool for wire connection.

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

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

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

e) Solder Terminals – Conventional nonferrous solder terminals.

f) Other Terminals – Other terminal connections may be used if found to be equivalent to (a) – (e) and limited to the same restrictions.

13.2.3.2 Any of the terminal configurations listed in 13.2.3.1 may be used for connection of field wiring if they comply with all of the following conditions:

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, along with information as to where the tool may be obtained.

b) The range of wire sizes shall be indicated on the installation wiring diagram. The minimum permissible wire size to be used shall not be less than 22 AWG (0.32 mm^2).

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

d) The terminal configuration shall comply with the requirements of the Special Terminal Assemblies Tests, Section 50.

Exception: Terminals complying with the requirements in any of the standards specified in 13.2.1.2 are not required to be subjected to the Special Terminal Assemblies Tests, Section 50.

13.3 Field-wiring leads

13.3.1 If leads are provided in lieu of wiring terminals, they shall not be less than 6 inches (152 mm) long, and shall not be smaller than 22 AWG (0.32 mm^2).

Exception No. 1: A lead may be less than 6 inches in length if it is evident that the use of a longer lead:

a) May result in damage to the lead insulation or product;

b) May result in a risk of fire, electric shock, or injury to persons; or

c) Is not required for the intended operation of the product.

Exception No. 2: Solid copper leads as small as 26 AWG (0.13 mm^2) may be used if:

a) The current does not exceed 1 ampere for lengths up to 2 feet (61 cm) and the current does not exceed 0.4 ampere for lengths up to 10 feet (3.05 m);

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

c) The assembled conductors comply with the requirement of 47.2.1 for strain relief; and

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

13.3.2 For connection of a line voltage source, the leads shall not be smaller than 18 AWG (0.82 mm^2).

13.3.3 Leads intended for field connection shall be provided with a strain relief if stress on the lead may be transmitted to terminals, splices or internal wiring. See Strain Relief Test, Section 47.

13.4 Polarity identification

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

13.4.2 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 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 distinguishable from the other leads.

14 Grounding

14.1 A grounding means shall be provided for all equipment containing parts which require grounding; see Bonding for Grounding, Section 18.

14.2 The following are considered to constitute means for grounding:

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

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

c) In a cord-connected product, an equipment grounding conductor in the cord.

14.3 On a permanently-connected product, a terminal intended solely for the connection of an equipment grounding conductor shall be capable of securing a conductor of the size intended for the particular application in accordance with the National Electrical Code, ANSI/NFPA 70.

14.4 A soldering lug, a push-in, a screwless connector, or a quick-connect or similar friction-fit connector shall not be used for the grounding terminal intended for the connection of field supply connections, or for the grounding wire in a supply cord.

14.5 On a permanently-connected product, 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 identified such as by being marked "G," "GR," "GROUND," or "GROUNDING," or the like, or by a marking on a wiring diagram provided on the product (see also 14.6). The wire binding screw or pressure wire connector shall be secured to the frame or enclosure of the product and shall be located so that it is unlikely to be removed during service operations, such as replacing fuses, resetting manual-reset devices, or the like.

14.6 If a pressure wire connector intended for grounding is located where it could be mistaken for a neutral conductor of a grounded supply, it shall be identified by the marking "EQUIPMENT GROUND", a green color identification, or both.

14.7 On a permanently-connected product, the surface of an insulated lead intended solely for the connection of an equipment grounding conductor shall be finished in a continuous green color or a continuous green color with one or more yellow stripes, and no other lead shall be so identified.

14.8 On a cord-connected product, the grounding conductor of the flexible cord shall be finished with a continuous green color or with a continuous green color with one or more yellow stripes, and no other conductor shall be so identified. The grounding conductor shall be secured to the frame or enclosure of the product by a positive means (see Bonding for Grounding, Section 18) that is not likely to be removed during any servicing operation not involving the power-supply cord. The grounding conductor shall be connected to the grounding blade of the attachment plug.

INTERNAL WIRING

15 General

15.1 Internal wiring shall have thermoplastic or rubber insulation not less than 1/64 inch (0.4 mm) thick for 0 – 300 volt applications if:

a) Power is less than 375 volt-amperes (VA);

b) Current is less than 5 amperes; and

c) The wiring is not subject to flexing or mechanical abuse.

Otherwise, thermoplastic or rubber insulation not less than 1/32 inch (0.8 mm) thick and rated 600 volts shall be used. Other insulating material of lesser thickness may be used if it is equivalent.

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

15.3 Insulation, such as coated fabric and extruded tubing, shall not be damaged by the temperature or other environmental conditions to which it may be subjected in intended use.

15.4 Wireways shall be smooth and entirely free from sharp edges, burrs, fins, moving parts, and the like which may cause abrasion of the conductor insulation. Holes in sheet metal walls through which insulated wires pass shall be provided with a bushing if the wall is 0.042 inch (1.07 mm) or less thick. Holes in walls thicker than 0.042 inch shall have smooth, rounded edges.

16 Wiring Methods

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

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

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

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

16.5 A printed wiring assembly using insulating coatings or encapsulation shall be tested for dielectric voltage-withstand before and after being treated. If it is impractical to use untreated samples, finished samples shall be subjected to the Dielectric Voltage-Withstand Test, Section 41, after they are subjected to the Humidity Test, Section 35; Temperature Test, Section 42; and other applicable tests specified in this standard.

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

16.7 If the cord hole is in phenolic composition or other nonconducting material, or in metal not less than 0.042 inch (1.07 mm) thick, a smooth, rounded surface is considered to be the equivalent of a bushing.

16.8 Ceramic materials and some molded compositions may be used for insulating bushings.

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

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

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

17 Separation of Circuits

17.1 Internal wiring of circuits which operate at different potentials shall be separated by barriers, clamps, routing, or other means determined to be equivalent, unless all conductors are provided with insulation which is rated for the highest potential involved. See 17.3.

17.2 If a barrier is used to provide separation between the wiring of different circuits, it shall be of metal or of insulating material. A barrier of insulating material shall not be less than 0.028 inch (0.71 mm) thick. Any clearance between the edge of a barrier and a compartment wall shall not be more than 1/16 inch (1.6 mm).

17.3 When Class 2, Class 3, and power-limited fire protection circuit conductors are to occupy the same enclosure as electric light, power, Class 1, or nonpower-limited fire protection circuit conductors, both of the following conditions shall be met:

a) The enclosure shall provide a minimum of two conductor entry openings so that the Class 2, Class 3, and power-limited fire protection circuit conductors are segregated from electric light, power, Class 1 and nonpower-limited fire protection circuit conductors. The installation document shall completely detail the entry routing of all conductors into the enclosure.

b) The enclosure shall be constructed so that, with all field-installed wiring connected to the product, a minimum of 1/4 inch (6.4 mm) spacing is provided between all Class 2, Class 3, and power-limited fire protection circuit conductors and all electric light, power, Class 1 and nonpower-limited fire protection circuit conductors. Compliance with this requirement is achieved by specific wire routing configurations that are detailed in the installation document. When a wire routing scheme does not maintain a separation of 1/4 inch (6.4 mm), barriers shall be used to provide separation.

Exception: The requirements in 17.3 (a) and (b) do not apply when all circuit conductors operate at 150 volts or less to ground and:

a) The Class 2, Class 3, and power-limited fire protection circuits are installed using CL3, CL3R, or CL3P, or substitute cable permitted by the National Electrical Code, NFPA 70, and the Class 2, Class 3, and power-limited fire protection circuit conductors extending beyond the cable jacket are separated by a minimum of 1/4 inch or by nonconductive tubing or by a nonconductive barrier from all other conductors, or

b) The Class 2, Class 3, and power-limited fire protection circuit conductors are installed as a Class 1 or higher circuit.

18 Bonding for Grounding

18.1 In a high-voltage product, provision shall be made for the grounding of all exposed or accessible noncurrent-carrying metal parts which are likely to become energized and which may be contacted by a user, operator, or by service personnel during service operations likely to be performed while the product is energized.

18.2 Uninsulated metal parts, such as cabinets, electrical enclosures, capacitors and other electrical components are to be bonded for grounding if they may be contacted by the operator or serviceman, except as specified in 18.3.

18.3 The following metal parts need not be grounded:

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

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

c) Cabinets, panels, and covers that do not enclose uninsulated live parts if wiring is separated from the cabinet, panel, or cover so that it is not likely to become energized.

d) Panels and covers that are insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar materials not less than 0.028 inch (0.71 mm) thick, and secured in place. If material having a lesser thickness is used, consideration is to be given to such factors as its electrical, mechanical, and flammability properties when compared with materials in thicknesses specified above.

18.4 The metal enclosure of a product having a slide-out chassis is considered to be grounded if the resistance between the point of connection of the equipment grounding means and enclosure does not exceed 0.1 ohm. Unless a separate grounding conductor is used, this will require that all nonconductive coatings between the enclosure and equipment grounding means be penetrated when the chassis is inserted in the enclosure. In such cases, metal-to-metal contact shall be maintained at any point of insertion or withdrawal of the chassis.

18.5 Metal-to-metal hinge bearing members for a door or cover are considered to be a means for bonding a door or cover for grounding if a minimum of two pin-type hinges, each with a minimum of three knuckles, are used.

18.6 A separate component bonding conductor shall be of copper, a copper alloy, or other material intended for use as an electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by metallic or nonmetallic coatings, such as enameling, galvanizing, or plating. A separate bonding conductor or strap shall not be subject to mechanical damage or shall be located within the confines of the outer enclosure or frame, and not be secured by a removable fastener used for any purpose other than bonding for grounding, unless the bonding conductor is unlikely to be omitted after removal and replacement of the fastener.

18.7 The bonding shall be by a clamped, riveted, bolted, or screwed connection; welding, soldering, and brazing materials having a softening or melting point greater than 445°C (833°F). The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. Except as mentioned in 18.10, bonding around a resilient mount shall not depend on the clamping action of rubber or other nonmetallic material.

18.8 With reference to 18.7, a bolted or screwed connection that incorporates a star washer under the screwhead or a serrated screwhead may be used for penetrating nonconductive coatings. If the bonding means depends upon screw threads, two or more screws or two full threads of a single screw shall engage the metal.

18.9 An internal connection for bonding internal parts to the enclosure for grounding, but not for a field-installed grounding conductor or for the grounding wire in a supply cord, may use a quick-connect terminal of the specified dimensions if the connector is not likely to be displaced and the component is limited to use on a circuit having a branch circuit protective device, rated as specified in Table 18.1.

Table 18.1
Internal terminal connections for bonding

Terminal dimensions,		Rating of protective device,
inches	(mm)	amperes
0.020 by 0.187 by 0.250	(0.51 by 4.75 by 6.35)	20 or less
0.032 by 0.187 by 0.250	(0.81 by 4.75 by 6.35)	20 or less
0.032 by 0.205 by 0.250	(0.81 by 5.2 by 6.35)	20 or less
0.032 by 0.250 by 0.312	(0.81 by 6.35 by 7.92)	60 or less

18.10 A connection that depends upon the clamping action exerted by rubber or other nonmetallic material may be used if it complies with the requirements specified in 18.13 under any intended degree of compression permitted by a variable clamping device, and if the results are still in compliance with 18.13 after exposure to the effects of oil, grease, moisture, and thermal degradation which may occur in service.

Also, the effect of assembling and disassembling such a clamping device for maintenance is to be considered, with particular emphasis on the likelihood of the clamping device being reassembled in its intended fashion.

18.11 Except as mentioned in 18.14 and 18.16 on a cord-connected product, a bonding conductor or strap shall have a cross-sectional area not less than that of the grounding conductor of the supply cord.

18.12 On a permanently-connected product, the size of a conductor used to bond an electrical enclosure shall be based on the rating of the branch circuit overcurrent device to which the equipment will be connected. The size of the conductor or strap shall be as specified in Table 18.2.

Table 18.2
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.

18.13 A conductor, such as a clamp or strap, used in place of a separate wire conductor as specified in 18.12, may be considered for use if the minimum cross-sectional conducting area is equivalent to the wire sizes specified in Table 18.2.

18.14 A bonding conductor to an electrical component need not be larger than the size of the conductors supplying the component.

18.15 Splices shall not be used in wire conductors used to bond electrical enclosures or other electrical components.

18.16 If more than one size branch circuit overcurrent protection device is involved, the size of the bonding conductor is to be based on the rating of the overcurrent device intended to provide ground-fault protection for the component bonded by the conductor. For example, if a component is individually protected by a branch circuit overcurrent device smaller than other overcurrent devices used with the equipment, a bonding conductor for that component is sized on the basis of the overcurrent device intended for ground-fault protection of the component.

18.17 The continuity of the grounding system of the product shall not rely on the dimensional integrity of nonmetallic material.

COMPONENTS, ELECTRICAL

19 General

19.1 Mounting of components

19.1.1 A switch, lampholder, attachment-plug, connector base, or similar electrical component shall be secured in position and, except as specified in 19.1.2 – 19.1.7, shall be prevented from turning.

19.1.2 In the mounting or supporting of small, fragile, insulating parts, screws or other fastenings shall not be tight enough to cause cracking or breaking of these parts with expansion and contraction.

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

a) The switch is 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 rotate the switch during intended operation of the switch.

b) The means for mounting the switch makes it unlikely that the operation of the switch will loosen it.

c) Spacings are not reduced below the minimum required values if the switch rotates.

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

19.1.4 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 non-removable jewel, need not be prevented from turning if rotation will not reduce spacings below the minimum required values.

19.1.5 Uninsulated live parts shall be secured to the base or mounting surface so that they will be prevented from turning or shifting in position, if such motion may result in a reduction of spacings below the intended values. (The securing of contact assemblies shall provide for the continued alignment of contacts.)

19.1.6 The means for preventing turning shall consist of more than friction between surfaces.

19.1.7 A lock washer that provides both spring take-up and an interference lock may be used as the means for preventing a small stem-mounted switch or other device having a single-hole mounting means from turning.

19.1.8 A flush plate for outlet-box mounting shall be of:

a) Minimum 0.030 inch (0.76 mm) ferrous metal,

b) Minimum 0.040 inch (1.02 mm) nonferrous metal, or

c) Minimum 0.100 inch (2.54 mm) nonconductive material.

19.1.9 A yoke or strap or the mounting ears of a part intended to be mounted on a standard outlet box or similar back box shall be of 0.040 inch (1.02 mm) or thicker steel. If a nonferrous metal is used, it shall be of thickness sufficient to provide mechanical strength and rigidity not less than that of 0.040 inch thick steel.

19.2 Insulating materials

19.2.1 Insulating materials used for a base for the support of live parts shall be porcelain, phenolic or cold-molded composition, or the equivalent.

19.2.2 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 that such parts and the ends of replaceable terminal screws do not come in contact with the supporting surface.

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

19.2.4 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 intended 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).

19.2.5 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 that specified in Table 19.1.

Table 19.1
Thickness of flat sheets of insulating material

Maximum dimensions				Minimum thickness,[a]	
Length or width,		Area,			
inch	(cm)	$inch^2$	(cm^2)	inch	(mm)
24	(60.9)	360	(2323)	3/8	(9.5)
48	(122.0)	1152	(7423)	1/2	(12.7)
48	(122.0)	1728	(11,148)	5/8	(15.9)
over 48	(over 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) in thickness may be employed for a panel if the panel is adequately supported or reinforced to provide rigidity not less than that of a 3/8 inch sheet. Material less than 3/16 inch (4.8 mm) may be employed for subassemblies, such as supports for terminals for internal wiring, resistors, and other components.

19.3 Fuseholders

19.3.1 A fuseholder shall be installed or arranged so that adjacent uninsulated high-voltage live parts, other than the screw shell of a plug fuseholder, cartridge fuse clips, or wiring terminals to the fuseholder, will not be exposed to contact by persons removing or replacing fuses. A separation of less than 4 inches (102 mm) is considered to be adjacent.

19.4 Current-carrying parts

19.4.1 All current-carrying parts shall be of silver, copper, a copper alloy, or other material intended for use as an electrical conductor.

Exception: Multimetallic thermal elements and heater elements of a thermal protector need not comply with this requirement.

19.4.2 Bearings, hinges, and the like are not to be used as current-carrying parts.

20 Overcurrent Protection

20.1 If a primary circuit breaker or fuse is provided, its rating shall be in accordance with the maximum input to the product.

21 Semiconductors

21.1 Semiconductors shall be rated for the intended application under all environmental conditions to which they may be exposed in service. See Performance Tests, Sections 27 – 50.

22 Switches

22.1 A switch provided as part of the product shall have a current and voltage rating not less than that of the circuit that it controls when the product is operated under any condition of intended service. If the circuit controlled has a power factor less than 75 percent, the switch shall have a horsepower rating (judged on the basis of the ampere equivalent) or a rating of not less than 200 percent of the maximum load current.

23 Transformers and Coils

23.1 A transformer shall be of the two-coil or insulated type.

Exception: An autotransformer may be used, if the terminal or lead common to both input and output circuits is identified, and the output circuits are located only within the enclosure containing the autotransformer. See 13.4.1 for polarity identification specifications.

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

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

SPACINGS

24 General

24.1 Except as mentioned in 25.1, spacings between uninsulated live parts and between uninsulated live parts and dead metal parts shall not be less than those indicated in 24.2 – 24.6.

24.2 The spacings between an uninsulated live part and:

a) A wall or cover of a metal enclosure;

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

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

shall not be less than those specified in Table 24.1.

24.3 The spacings between an uninsulated live part and:

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 which is isolated (insulated),

shall not be less than those specified in Table 24.1. See 25.1 for component spacing specifications.

Table 24.1
Minimum spacings

Point of application	Voltage range (AC)	Minimum spacings[a,b] Through air, inch	(mm)	Over surface, inch	(mm)
To walls of enclosure:					
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 (general application):					
with barriers	0 – 30	1/8	(3.2)	3/16	(4.8)
	31 – 150	1/8	(3.2)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)
without barriers	0 – 30	3/16	(4.8)	3/16	(4.8)
	31 – 150	1/4	(6.4)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)
Rigidly clamped assemblies[c]:					
100 volt-amperes maximum[d]	0 – 30	1/32	(0.8)	1/32	(0.8)
over 100 volt-amperes	0 – 30	3/64	(1.2)	3/64	(1.2)
	31 – 150	1/16	(1.6)	1/16	(1.6)
	151 – 300	3/32	(2.4)	3/32	(2.4)
Other parts	0 – 30	1/16	(1.6)	1/8	(3.2)
	31 – 150	1/8	(3.2)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)

[a] 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; except that 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. The liner shall be located so that it will not be affected adversely by arcing. Insulating material having a thickness less than that specified may be used if it is suitable for the particular application.

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

[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).

24.4 If a short circuit between uninsulated live parts of the same polarity would impair the intended operation of the product, the spacings between such parts shall not be less than those indicated for other parts in Table 24.1.

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

24.6 The "To walls of enclosure" spacings are not to be applied to an individual enclosure of a compartment part within an outer enclosure.

25 Components

25.1 Minimum values of spacings are not specified for a semiconductor or relay socket, a semiconductor, a relay, a potentiometer, and similar components used in electronic circuits. Spacings in such components shall be such that the circuit complies with the Dielectric Voltage-Withstand Test, Section 41.

PERFORMANCE

ALL UNITS

26 General

26.1 Test units and data

26.1.1 Burglary-resistant electric locking mechanisms and accessories that are fully representative of production units are to be used for each of the tests specified in Sections 27 – 50, unless otherwise specified.

26.1.2 The devices used for testing are to be those specified by the wiring diagram of the product, except that substitute devices may be used if they produce functions and load conditions equivalent to those obtained with the devices intended to be used with the product in service.

26.2 Test samples and miscellaneous data

26.2.1 The following samples are to be provided for testing:

a) Two or more complete samples of each product to be tested.

b) One or more samples of each encapsulated or sealed assembly, in the unencapsulated or unsealed condition.

c) Installation and operating instructions (see 68.1 and 68.2).

26.3 Test voltages

26.3.1 Unless otherwise specified, the test voltage at rated frequency for each test of a product shall be as specified in Table 26.1.

Table 26.1
Test voltages

Nameplate voltage rating	Test voltage
110 to 120	120
220 to 240	240
Other	marked nameplate rating

26.4 Test fixture

26.4.1 A burglary-resistant electric locking mechanism intended to be used in an ordinary door is to be mounted in the test fixture described in 26.4.2 for the Normal Operation Test, Section 27; Undervoltage Operation Test, Section 32; Overload Test, Section 38; Endurance Test, Section 39; Forcing Tests, Section 55; Tool Manipulation Attack Test, Section 56; and Residual Magnetism Test, Section 57.

26.4.2 The door used to test a locking mechanism intended for use in an ordinary door shall be solid wood, 1-1/2 to 1-3/4 inches (38 to 44 mm) thick by 36 inches (0.91 m) wide and 72 to 84 inches (1.8 to 2.1 m) high. The door is to be mounted in a sheet steel frame, which is mounted into a masonry wall or in a ridged steel frame secured to the floor and braced on the side that would be the inside of the door. The door is to be hung on three heavy-duty, five-knuckle, ball-bearing hinges.

Exception: A locking mechanism intended for use on a door or opening cover that differs from the test door described in 26.4.2 is to be tested on the door or opening cover that it is constructed for or on a test fixture most representative of the door or opening cover.

27 Normal Operation Test

27.1 A unit shall perform its intended function when installed as specified in 27.2.

27.2 The unit is to be mounted as intended in the test fixture described in 26.4.2 and its terminals connected to circuits of related equipment as indicated by the installation-wiring diagram.

27.3 If equipment must be mounted in a definite position in order to function as intended, it shall be tested in that position.

27.4 Power-input supply terminals are to be connected to supply circuits of rated voltage and frequency.

28 Input Test

28.1 The input of a product shall not exceed the marked current, power, or volt-ampere rating by more than 10 percent when the product is operated under all conditions of use while connected to a source of supply in accordance with 28.2.

28.2 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. If 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.

29 Output Measurement Test

29.1 The measured voltage of all output circuits shall be within 85 and 110 percent of their marked rating under the following conditions:

a) With primary power connected and varied from 85 percent to 110 percent of rated voltage. When a standby battery is used, a fully charged battery shall be connected.

b) With primary power connected and varied from 85 percent to 110 percent of rated voltage. When a standby battery is used, it shall be disconnected.

c) When a standby battery is used, the product shall be tested with the primary power disconnected. The standby battery shall be replaced with a variable voltage filtered DC power supply and the voltage varied from 85 percent to 110 percent of rated battery voltage.

29.2 Measurements shall be made with no load or with the minimum load that is specified by the manufacturer. When more than one output circuit is provided, all circuits shall have no load connected or the minimum load that is specified by the manufacturer connected to each circuit.

29.3 Upon completion of 29.2, measurements shall then be made with the maximum load connected to the output circuit. When more than one output circuit is provided, all circuits shall have the maximum load connected. When connecting the maximum load to each output circuit will exceed the total output capacity of the product, the output circuit to be measured shall be loaded to its maximum rating and the other output circuits shall have their load adjusted so that the maximum output capacity of the product is reached. This shall be repeated for each output circuit.

29.4 Rated load is that value of resistive load which causes the rated current to flow when the load is connected to the output circuit and the input voltage to the product is adjusted to its rated voltage.

29.5 The output circuits of a burglary-resistant electric locking unit shall be power-limited. See Power-Limited Circuits, Section 30.

Exception: This requirement does not apply to an output circuit using a connection device or other method rated for high-voltage wiring, such as a 125-volt, 15-ampere, parallel-blade receptacle.

30 Power-Limited Circuits

30.1 General

30.1.1 All field-wiring circuits shall be classified as a power-limited or nonpower-limited circuit. A circuit shall be considered nonpower-limited unless otherwise identified in the installation documentation and marking on the product.

30.1.2 The power source (or sources) supplying a power-limited circuit shall be either:

a) Inherently limited requiring no overcurrent protection or

b) Limited by a combination of a power source and overcurrent protection devices such that a power-limited circuit has electrical characteristics as described in Table 30.1 for AC circuits or Table 30.2 for DC circuits.

Table 30.1
Power source limitations for alternating current Class 2 and Class 3 circuits

	Circuit voltage V_{max}[a] (volts)	Power source maximum nameplate ratings		Current limitations I_{max}[b] (amps)	Power limitations VA_{max}[c] (volt-amps)	Maximum overcurrent protection (amps)
		VA (volt-amps)	Current (amps)			
Inherently limited power source (overcurrent protection not required)						
Class 2	0 to 20	$5.0 \times V_{max}$	5.0	8.0	–	–
	over 20 to 30	100	$100/V_{max}$	8.0	–	–
	over 30 to 150	$0.005 \times V_{max}$	0.005	0.005	–	–
Class 3	over 30 to 100	100	$100/V_{max}$	$150/V_{max}$	–	–
Not inherently limited power source (overcurrent protection required)						
Class 2	0 to 20	$5.0 \times V_{max}$	5.0	$1000/V_{max}$	250[d]	5.0
Class 3	over 20 to 30	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$
	over 30 to 100	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$
	over 100 to 150	100	$100/V_{max}$	1.0	NA	1.0

Table 30.1 Continued on Next Page

Table 30.1 Continued

	Circuit voltage V_{max}[a] (volts)	Power source maximum nameplate ratings VA (volt-amps)	Power source maximum nameplate ratings Current (amps)	Current limitations I_{max}[b] (amps)	Power limitations VA_{max}[c] (volt-amps)	Maximum overcurrent protection (amps)

NOTES

1 Adapted from the National Electrical Code, ANSI/NFPA 70, copyright National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

2 For nonsinusoidal AC, V_{max} shall not be greater than 42.4 volts peak. Where wet contact immersion not included) is likely to occur, Class 3 wiring methods shall be used, or V_{max} shall not be greater than 15 volts for sinusoidal AC and 21.2 volts peak for nonsinusoidal AC.

[a] V_{max}: Maximum output voltage regardless of load with rated input applied.

[b] I_{max}: Maximum output current under any noncapacitive load, including short circuit, and with overcurrent protection bypassed, when used. When a transformer limits the output current, I_{max} limits apply after 1 minute of operation. Where a current limiting impedance is used in combination with a nonpower-limited transformer or a stored energy source, such as a storage battery, in order to limit the output current, I_{max} limits apply after 5 seconds.

[c] $(VA)_{max}$: Maximum volt-ampere output after 1 minute of operation regardless of load, and with overcurrent protection bypassed, when used.

[d] When the power source is a transformer, $(VA)_{max}$ is 350 volt-amperes or less where V_{max} is 15 volts or less.

Table 30.2
Power source limitations for direct current Class 2 and Class 3 circuits

	Circuit voltage V_{max}[a] (volts)	Power source maximum nameplate ratings VA (volt-amps)	Power source maximum nameplate ratings Current (amps)	Current limitations I_{max}[b] (amps)	Power limitations VA_{max}[c] (volt-amps)	Maximum overcurrent protection (amps)
Inherently limited power source (overcurrent protection not required)						
Class 2	0 to 20	5.0× V_{max}	5.0	8.0	–	–
	over 20 to 30	100	$100/V_{max}$	8.0	–	–
	over 30 to 60	100	$100/V_{max}$	$150/V_{max}$	–	–
	over 60 to 150	0.005 × V_{max}	0.005	0.005	–	–
Class 3	over 60 to 100	100	$100/V_{max}$	$150/V_{max}$	–	–
Not inherently limited power source (overcurrent protection required)						
Class 2	0 to 20	5.0 × V_{max}	5.0	$1000/V_{max}$	250[d]	5.0
Class 3	over 20 to 60	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$
	over 60 to 100	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$
	over 100 to 150	100	$100/V_{max}$	1.0	N/A	1.0

NOTES

1 Adapted from the National Electrical Code, ANSI/NFPA 70, copyright National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

2 A dry cell battery shall be considered an inherently limited power source, when the voltage is 30 volts or less and the capacity is equal to or less than that available from series connected No. 6 carbon zinc cells.

3 For DC interrupted at a rate of 10 to 200 hertz, V_{max} shall not be greater than 24.8 volts. Where wet contact (immersion not included) is likely to occur, Class 3 wiring methods shall be used, or V_{max} shall not be greater than 30 volts for continuous DC and 12.4 volts for DC that is interrupted at a rate of 10 to 200 hertz.

[a] V_{max}: Maximum output voltage regardless of load with rated input applied.

Table 30.2 Continued on Next Page

Table 30.2 Continued

	Circuit voltage V_{max}[a] (volts)	Power source maximum nameplate ratings		Current limitations I_{max}[b] (amps)	Power limitations VA_{max}[c] (volt-amps)	Maximum overcurrent protection (amps)
		VA (volt-amps)	Current (amps)			

[b] I_{max}: Maximum output current under any noncapacitive load, including short circuit, and with overcurrent protection bypassed, when used. When a transformer limits the output current, I_{max} limits apply after 1 minute of operation. Where a current limiting impedance is used in combination with a nonpower-limited transformer or a stored energy source, such as a storage battery, in order to limit the output current, I_{max} limits apply after 5 seconds.

[c] $(VA)_{max}$: Maximum volt-ampere output after 1 minute of operation regardless of load, and with overcurrent protection bypassed, when used.

[d] When the power source is a transformer, $(VA)_{max}$ is 350 volt-amperes or less where V_{max} is 15 volts or less.

30.1.3 With regard to 30.1.2, acceptable means for current limiting include:

a) Transformer winding impedance;

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

c) Circuit components (resistors, regulators, transistors, and similar components) that comply with the Temperature Test, Section 42, under I_{max} condition; and

d) Current limiting impedances determined to be suitable for the application (positive temperature coefficient varistor or similar component).

Circuit component burnout, permanent (by soldered means or similar method) or replaceable fuses, opening of conductors on printed-wiring boards, or opening of internal wiring conductors shall not be used as a means of current limiting.

30.1.4 The overcurrent protection device specified in 30.1.2 shall be of the noninterchangeable type such that it cannot be renewed in the field with an overcurrent device having a higher current rating.

30.1.5 When the product contains a float battery charger, the V_{max}, I_{max}, and VA_{max} shall be measured with both the AC power source and the battery connected to the product. When the circuit contains a battery transfer relay or a trickle charge battery circuit, the V_{max}, I_{max}, and VA_{max} are to be measured first with the product energized only from the AC power source and then measured a second time with the product energized solely from the battery. The battery used during these measurements shall have the largest capacity specified in the manufacturer's installation document and shall be fully charged.

30.1.6 When measuring the I_{max} and VA_{max}, all overcurrent protection devices of the control unit shall be short-circuited. However, current limiting devices shall not be bypassed and shall remain functional.

30.2 Maximum voltage

30.2.1 With the circuit 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 under these two conditions shall be considered V_{max}. When the product incorporates a secondary source of supply, the test is to be repeated with the primary power source disconnected and with the circuit energized solely from the secondary power source. The V_{max} value obtained from each power source shall be considered separately when applying the requirements in Table 30.1 or Table 30.2.

30.3 Maximum current

30.3.1 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 shall be adjusted from open circuit to short circuit as quickly as possible and the highest current noted. The load resistor is then to be readjusted to produce the highest current obtained and the current through the load resistor is to be measured after 1 minute or after 5 seconds as determined by Table 30.1 or Table 30.2.

30.3.2 When 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 effect, 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 30.1 or Table 30.2. The results are in compliance when the I_{max} value stated in Table 30.1 or Table 30.2 cannot be maintained for more than 5 seconds.

30.3.3 When a transformer limits the value of I_{max}, and when I_{max} is unable to 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 when the extrapolated value of I_{max} at 1 minute does not exceed the I_{max} limitations as indicated in Table 30.1 or Table 30.2.

30.4 VA_{max} (Not inherently limited circuits only)

30.4.1 The circuit is to be energized from a rated source of supply and then the circuit under test is to be 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 shall then 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 maximum volt-ampere, VA_{max}, 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, VA_{max}; calculated; and then connected to the circuit. After 1 minute, the voltage and current are again to be measured. The results of this test are in compliance when the calculated volt-ampere, VA, output of the circuit does not exceed the values specified in Table 30.1 or Table 30.2, after 1 minute.

31 Standby Power

31.1 The use of a standby power supply is optional. If a standby power supply, such as a battery, is provided, it shall be of sufficient capacity to supply power to the system for 4 hours while operating the locking mechanism once every 5 minutes. See 31.2 for further standby power specifications.

31.2 If the battery capacity is such that it cannot provide operation for 4 hours, the product shall be prominently marked as specified in 62.12.

31.3 Instructions for the replacement of batteries shall be on the product, and the polarity shall be indicated. See 62.1(h) for additional battery maintenance specifications.

32 Undervoltage Operation Test

32.1 A product shall operate as intended while installed in the test fixture described in 26.4.2 and energized at 85 percent of its rated voltage. See 55.2.2 and 55.3.2 for static and dynamic strength tests.

32.2 If a standby battery is used, the reduced voltage value is to be computed on the basis of the rated nominal battery voltage.

33 Overvoltage Operation Test

33.1 A product, other than an electrical coil used in a burglary-resistant electric locking mechanism to operate the locking mechanism or to provide the locking action, shall withstand 110 percent of its rated supply voltage continuously for 24 hours without damage and shall operate as intended at the increased voltage at the conclusion of the test. The product is to be in the operating condition (locked or unlocked) that causes the most power to be used by the product.

33.2 An electrical coil used in a burglary-resistant electric locking mechanism to operate the locking mechanism or to provide the locking action, shall withstand 125 percent of its rated supply voltage continuously for 24 hours without damage and shall operate as intended at the increased voltage at the conclusion of the test.

34 Variable Ambient Test

34.1 A product other than the locking mechanism shall function as intended at the test voltage with its related equipment at ambient temperatures of 0 and 49° C (32 and 120° F). See 34.2 for locking mechanism ambient temperature specifications.

34.2 A locking mechanism or any other product intended for outdoor use shall function as intended at the test voltage with its related equipment at ambient temperatures of minus 35 and plus 66°C (minus 31 and plus 151°F).

34.3 The exposure to any of the temperatures specified in 34.1 and 34.2 shall be 4 hours or more.

35 Humidity Test

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

35.2 Cord-connected products powered from a high-voltage source shall comply with the requirements of the Leakage Current Test, Section 36, following exposure to high humidity.

36 Leakage Current Tests for Cord-Connected Products

36.1 The leakage current of a cord-connected product intended to be located in an area accessible to contact by persons, or one which is interconnected to a product that is accessible to contact by persons, shall not exceed the values specified in Table 36.1 when tested as specified in 36.7 and 36.8 after exposure to the Humidity Test, Section 35.

Table 36.1
Maximum leakage current

Type of product[a]	Maximum leakage current, (mA)
Two-wire cord-connected product	0.50
Three-wire (including grounding conductor) cord-connected, portable product	0.50
Three-wire (including grounding conductor) cord-connected stationary or fixed product	0.75

[a] Products which incorporate a loss-of-ground detector which dependably opens the live conductors are exempted from the requirements of this table.

36.2 For this test, the product is to be de-energized, removed from the humidity environment, placed on a dry insulating surface, and immediately re-energized from a rated source of supply in accordance with 26.3.1. Leakage current measurements are to be made with the product in the standby and operating conditions.

36.3 For the purposes of this test, "leakage current" refers to all currents, including capacitively coupled currents, which may be conveyed between exposed conductive surfaces and ground or other exposed conductive surfaces.

36.4 All exposed conductive surfaces are to be tested for leakage currents. Where simultaneously accessible, leakage currents from these surfaces are to be measured to the grounded supply conductor individually, as well as collectively, and from one surface to another. Parts are considered to be exposed surfaces unless covered by an enclosure that reduces the risk of electric shock. Surfaces are considered to be simultaneously accessible when they can be readily contacted by one or both hands of a person at the same time.

36.5 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 metal foil with an area of 10 by 20 centimeters (3.9 by 7.8 inches) in contact with the surface. If the surface is less than 10 by 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the product.

36.6 The measurement circuit for leakage current is to be as illustrated in Figure 36.1. The measurement instrument is defined in (a) – (c). The meter which is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument and need not have all of the attributes of the defined instrument.

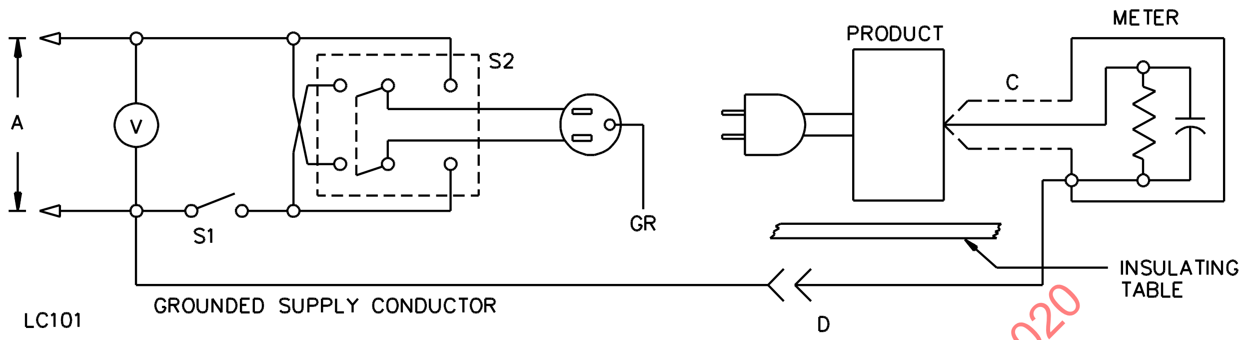
a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.

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.

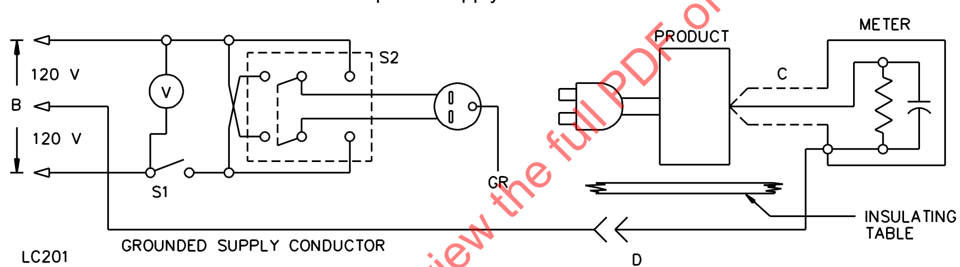
c) Over a frequency range of 0 – 100 kilohertz, the measurement circuitry is to have a frequency response (ratio of indicated to actual value of current) that is equal to the ratio of the impedance of a 1500 ohm resistor shunted by a 0.15 microfarad capacitor to 1500 ohms. At indications of 0.5 and 0.75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

Figure 36.1

Leakage current measurement circuits



a) Product intended for connection to a 120 or 208 volt power supply.



b) 240 or 208 volt product intended for connection to a 3-wire, grounded neutral power supply, as illustrated above.

c) Probe with shielded lead – Under some circumstances where higher frequency components are present, shielding of measuring instrument and its leads may be necessary.

d) Separated and used as clip when measuring currents from one part of a product to another.

36.7 A sample of the product is to be prepared and conditioned for leakage current measurement as follows:

a) The sample is to be representative of the wiring methods, routing, components, component location and installation, and the like of the product.

b) The grounding conductor is to be open at the attachment-plug and the test product isolated from ground.

c) The sample is to be conditioned as described in 35.1.

36.8 With the supply voltage adjusted to the test voltage, as specified in 26.3.1, leakage current is to be measured as soon as possible after completion of the Humidity Test, Section 35. The leakage current test sequence, with reference to the measuring circuit specified in Figure 36.1, is to be as follows:

a) With switch S1 open, the product is to be connected to the measurement circuit. Leakage current is to be measured using both positions of switch S2. All manual switching devices then are to be operated in their normal manner, and leakage currents are to be measured using both positions of switch S2.

b) With the product switching devices in their intended operating positions, switch S1 shall then be closed, energizing the product and within a period of 5 seconds, the leakage current is to be measured using both positions of switch S2. All manual switching devices then are to be operated in their intended manner, and leakage currents are to be measured using both positions of switch S2.

c) The product switching devices then are to be returned to their intended operating positions and the product allowed to operate until thermal equilibrium is obtained. Leakage current is to be monitored continuously. For this test, "thermal equilibrium" is defined as that condition where leakage current is found to be constant or decreasing in value. Both positions of switch S2 are to be used in determining this measurement.

d) Immediately after the test, any single-pole switch on the product is to be opened, and the leakage current monitored until constant or decreasing values are recorded. Readings are to be taken in both positions of switch S2.

37 Electric Shock Current Test

37.1 If the open circuit potential between any part that is exposed only during operator servicing and either earth ground, or any other exposed accessible part, exceeds 42.4 volts peak, the part shall comply with the requirements of 37.2 – 37.4, as applicable.

37.2 The continuous current flow through a 500-ohm resistor shall not exceed the values specified in Table 37.1 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 37.1
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.

37.3 The duration of a transient current flowing through a 500-ohm resistor connected as described in 37.2 shall not exceed:

a) The value determined by the following equation:

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

in which:

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

I is the peak current in milliamperes, and

b) 809 milliamperes, regardless of duration.

The interval between occurrences shall be equal to or greater than 60 seconds if the current is repetitive. Typical calculated values of maximum transient current duration are shown in Table 37.2.

Table 37.2
Maximum transient current duration

Maximum peak current (I) through 500-ohm resistor, milliamperes	Maximum duration (T) of waveform containing excursions greater than 7.1 milliamperes peak
7.1	7.26 seconds
8.5	5.58
10.0	4.42
12.5	3.21
15.0	2.48
17.5	1.99
20.0	1.64
22.5	1.39
25.0	1.19
30.0	919 milliseconds
40.0	609
50.0	443
60.0	341
70.0	274
80.0	226
90.0	191
100.0	164
150.0	92
200.0	61
250.0	44
300.0	34
350.0	27
400.0	23
450.0	19
500.0	16
600.0	12
700.0	10
809.0	8.3

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

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

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

in which:

C is the maximum capacitance of the capacitor in microfarads and

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

E is to be measured 5 seconds after the capacitor terminals are made accessible, such as by the removal or opening of an interlocked cover, or the like. Typical calculated values of maximum capacitance are shown in Table 37.3.

Table 37.3
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	26.6
100	36.5
90	43.8
80	53.8
70	68.0
60	89.4
50	124.00
45	150.00
42.4	169.00

37.5 With reference to the requirements of 37.2 and 37.3, 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.

37.6 With reference to the requirements of 37.5, 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.

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

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

37.9 Current measurements are to be made:

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

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

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

38 Overload Test

38.1 General

38.1.1 A burglary-resistant electric locking mechanism shall operate as intended during and after 50 cycles of operation at a rate of not more than 17 cycles per minute while connected to a source of supply adjusted to 115 percent of the rated test voltage. The locking mechanism is to be mounted as intended in the test fixture described in 26.4.2. The sequence of each cycle for a locking mechanism is to consist of:

a) Releasing the locking mechanism;

b) Opening the door;

c) Closing the door; and

d) Engaging the locking mechanism.

The door is to be opened by a pneumatic or hydraulic ram, or other mechanical means, and is to be equipped with a size 3 or heavier duty hydraulic door closer or with other closing means. The sequence of each cycle for an accessory is to consist of cycling it through its intended mode of operation.

38.1.2 Rated test loads are to be connected to the output circuits of the product. The test loads are to be electric locking mechanisms, remote indicators, relays, or the equivalent intended for connection to the product. If an equivalent load is used for an intended inductive load, a power factor of 60 percent is to be used. The rated loads are to be established with the product initially connected to a source of supply as specified in 26.3.1, after which the voltage is to be increased to 115 percent of the initial value.

38.1.3 For DC circuits, an equivalent inductive test load is to have the required DC resistance for the test current and the inductance (calibrated) necessary to obtain a power factor of 60 percent while the load is connected to a 60 Hz, AC voltage equal to the rated DC test voltage. The resultant AC current is to be equal to 0.6 times the DC current when the load is connected first to an AC voltage and then to a DC voltage equal to the rms value of the AC source.

38.2 Separately energized circuits

38.2.1 Separately energized circuits, such as dry contacts, that do not receive energy from the burglary-resistant electric locking mechanism or accessory, shall operate as intended during and after 50 cycles of operation at a rate of not more than 17 cycles per minute while connected to a voltage source as specified in 26.3.1, and with 150 percent rated current loads at 60 percent power factor applied to the output circuits.

39 Endurance Test

39.1 General

39.1.1 A burglary-resistant electric locking mechanism shall operate as intended at rated voltage and current without electrical or mechanical malfunction at a rate of not more than 17 cycles per minute for 100,000 cycles or 250,000 cycles. Scheduled maintenance is to be performed during the number of cycles used, if recommended by the manufacturer.

39.1.2 A burglary-resistant electric locking mechanism intended for use on an ordinary door is to be mounted on the test fixture described in 26.4.2 for the endurance test. One cycle is to consist of:

a) Releasing the locking mechanism;

b) Opening the door;

c) Closing the door; and

d) Engaging the locking mechanism.

The door is to be opened by a pneumatic or hydraulic ram, or other mechanical means, and is to be equipped with a size 3 or heavier duty hydraulic door closer or with other closing means.

39.2 Separately energized circuits

39.2.1 A switch, relay, or the like intended to operate a burglary-resistant electric locking mechanism shall operate as intended at rated voltage and current without electrical or mechanical malfunction at a rate of not more than 17 cycles per minute for 100,000 cycles or 250,000 cycles.

39.2.2 The switch, relay, or the like is to be connected to a source of supply in accordance with 26.4.1 and with rated load at 0.6 power factor applied to it. Scheduled maintenance is to be performed during the number of cycles used, if recommended by the manufacturer.

Exception: If the switch, relay, or the like is intended to be used with a specific electric locking mechanism, that mechanism may be used for the load.

40 Jarring Test

40.1 A burglary-resistant electric locking mechanism, or an accessory, shall withstand jarring resulting from impact and vibration anticipated in the intended application without causing release of the lock or unintended operation of a part, and without impairing its subsequent intended operation.

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

a) Swung through a pendulum arc from a height (h) of 30.5 inches (775 mm) or

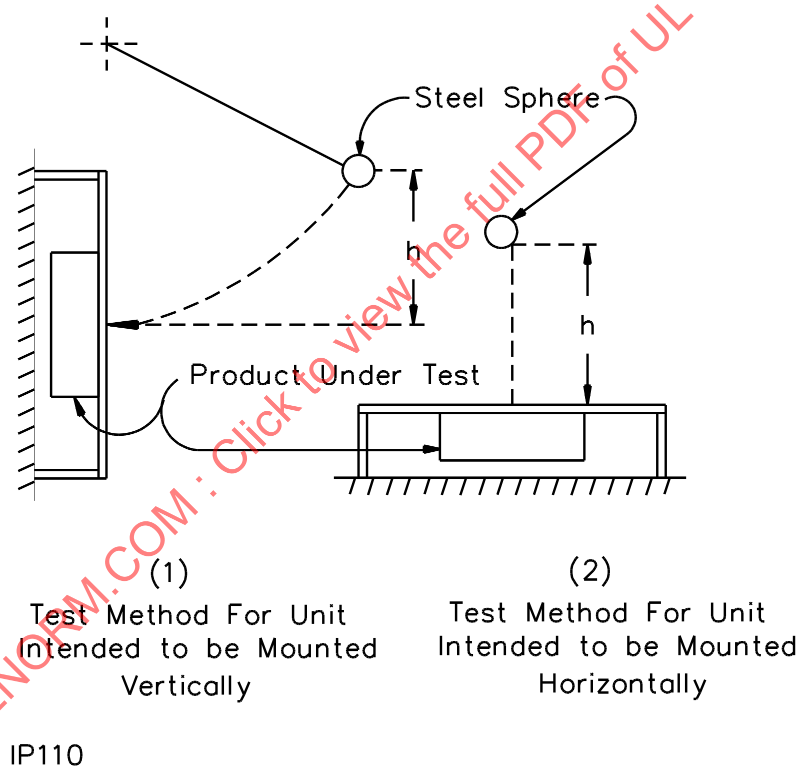
b) Dropped from a height of 30.5 inches, depending upon the mounting of the equipment.

See Figure 40.1 for the test diagram.

40.3 During this test, the unit is to be operated in the standby condition and connected to a rated source of supply as specified in 26.3.1.

Figure 40.1

Jarring test



41 Dielectric Voltage-Withstand Test

41.1 A product shall withstand for 1 minute, without breakdown, the application of an essentially sinusoidal AC potential of a frequency within the range of 40 – 70 Hz, or a DC potential, between live parts and the enclosure, live parts and exposed dead metal parts, and live parts of circuits operating at different potentials or frequencies. The test potential is to be (also, see 41.2):

a) For a product rated 30 volts AC rms (42.4 volts DC or AC peak) or less – 500 volts (707 volts, if a DC potential is used).

b) For a product rated between 31 and 250 volts AC rms – 1000 volts (1414 volts, if a DC potential is used).

c) For a product rated more than 250 volts AC rms – 1000 volts plus twice the rated voltage (1414 volts plus 2.828 times the rated AC rms voltage, if a DC potential is used).

41.2 For the application of a potential in accordance with 41.1, the voltage is to be the applicable value specified in (a), (b), or (c) of 41.1, based on the highest voltage of the circuits under test instead of the rated voltage of the product. Electrical connections between the circuits are to be disconnected before the test potential is applied.

41.3 Exposed dead metal parts referred to in 41.1 are noncurrent-carrying metal parts which are likely to become energized and accessible from outside of the enclosure of a product during intended operation with the door of the enclosure closed.

41.4 If an autotransformer is in the circuit, the primary of the transformer is to be disconnected and an AC test potential in accordance with 41.1 is to be applied directly to all wiring involving more than 250 volts.

41.5 If the charging current through a capacitor or capacitor type filter connected across the line, or from line to earth ground, is sufficient to prevent maintenance of the specified AC test potential, the capacitor or filter is to be tested using a DC test potential in accordance with 41.1.

41.6 The test potential may be obtained from any convenient source having sufficient capacity to maintain the specified voltage. The output voltage of the test apparatus is to be monitored. Starting at zero, the potential is to be increased at a rate of approximately 200 volts per minute until the required test value is reached and is to be held at that value for 1 minute.

41.7 A printed wiring assembly or other electronic circuit component that would be damaged by the application of, or would short-circuit, the test potential, is to be removed, disconnected, or otherwise rendered inoperative before the test. A representative subassembly may be tested instead of an entire product. Rectifier diodes in the power supply may be individually shunted before the test to avoid destroying them in the case of a malfunction elsewhere in the secondary circuits.

42 Temperature Test

42.1 The materials used in the construction of a product shall not attain temperature rises greater than those specified in Table 42.1.

42.2 The values for temperature specified in Table 42.1 are based on an assumed ambient temperature of 25 ±15°C (77 ±27°F), and tests are to be conducted at an ambient temperature within that range. A temperature is considered to be constant when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but at not less than 5 minute intervals, indicate no change.

Table 42.1
Maximum temperature rises

Materials and components	°C	°F
A. COMPONENTS		
1. Capacitors:[a,b]		
a) Electrolytic types	40	72
b) Other types	65	117
2. Rectifiers – at any point		

Table 42.1 Continued on Next Page

Table 42.1 Continued

Materials and components	°C	°F
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:		
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:[c]		
a) Carbon	50	90
b) Wire wound	125	225
c) Other	50	90
5. Solid state devices	See note (d)	
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 whose malfunction or deterioration will result in a risk of fire or electric shock[e]	125	225
e) Wood or other combustibles	65	117
f) Sealing compound	15°C or 59°F less than the melting point	
g) Fuses	65	117
B. CONDUCTORS		
1. Appliance wiring material[f]	25°C or 77°F less than the temperature limit of the wire	

Table 42.1 Continued on Next Page

Table 42.1 Continued

Materials and components	°C	°F
2. Flexible cord (for example, SJO, SJT)	35	63
3. Conductors of field-wired circuits to be permanently-connected to the product	35	63
C. GENERAL		
1. All surfaces of the product and surfaces adjacent to or upon which the product may be mounted	65	117
2. Surfaces normally contacted by the user in operating the unit (control knobs, push buttons, levers, or the like):		
a) Metal	35	63
b) Nonmetallic	60	108
3. Surfaces subjected to casual contact by the user (enclosure, grille, or the like):		
a) Metal	45	81
b) Nonmetallic	65	117

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

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

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

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

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

2) A quality control program is established by the manufacturer consisting of 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 that results in the maximum temperatures, for 24 hours while connected to a source of rated voltage and frequency in an ambient of at least 49°C (120°F).

[e] The limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to compounds that have been investigated and determined to have special heat-resistant properties.

[f] 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 or 77°F less than the temperature limit of the wire in question.

42.3 Temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2) or by the resistance method, except that the thermocouple method is not to be used for a temperature measurement at any point where supplementary thermal insulation is used.

42.4 Thermocouples consisting of 30 AWG (0.06 mm^2) iron and constantan wires and a potentiometer-type indicating instrument shall be used whenever referee temperature measurements by thermocouples are necessary.

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

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

in which:

Δt is the temperature rise in degrees C,

R is the resistance in ohms at end of test,

r is the resistance in ohms at start of test,

k is 234.5 for copper or 225.0 for electrical conductor grade aluminum,

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

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

42.6 To determine compliance with 42.1, the product is to be connected to a supply circuit of rated voltage and frequency as specified in 26.3.1, and operated continuously under representative service conditions that are likely to produce the highest temperature.

42.7 If a current-regulating resistor or reactor is provided as a part of the product, it is to be adjusted for the maximum resistance or reactance at normal current.

42.8 For a locking device intended to have power applied in the locked condition or the unlock the device, the test is to be continued until constant temperatures are attained during the normal standby condition or until one hour has elapsed.

43 Abnormal Operation Test

43.1 A product operating in any condition of intended operation shall not increase the risk of fire or electric shock when abnormal fault conditions are introduced.

43.2 To determine compliance with 43.1, the product is to be connected to a source of supply specified in 26.3.1 and operated under the most severe circuit fault conditions likely to be encountered in service. There shall be no emission of flame or molten metal, or any other manifestation of a risk of fire (see 43.4), or dielectric breakdown when tested as specified in the Dielectric Voltage-Withstand Test, Section 41.

43.3 The fault condition is to be maintained continuously until constant temperatures are attained or until burnout occurs, if the fault does not result in the operation of an overload protective device. Shorting of a secondary of the power supply transformer and shorting of an electrolytic capacitor would represent typical fault conditions.

43.4 After being wrapped in a single layer of bleached cheesecloth having an area of 14 – 15 square yards to the pound (25.8 – 27.7 m^2/kg), and a count of 32 by 28, the product is to be energized. There shall be no molten metal or flame emitted from the unit as a result of this test as evidenced by ignition or charring of the cheesecloth.

44 Electrical Transient Tests

44.1 General

44.1.1 While energized from a source of supply in accordance with 26.3.1 the product shall:

a) Experience no electrical or mechanical failure of any components of the product;

b) Operate as intended following the test;

c) As applicable, retain required stored memory (such as date, time, and location) within the unit when subjected to the tests described in 44.2 – 44.4.

Exception No. 1: Annunciation of a trouble signal that, either automatically restores or is manually resettable through the operator interface is acceptable during the internally induced and field-wiring transient tests.

Exception No. 2: Supplemental information stored within the product is not required to be retained during any of the transient tests.

44.2 Supply line transients

44.2.1 A high-voltage, AC-operated unit shall be subject to supply line transients induced directly between the power supply circuit conductors of the unit under test.

44.2.2 For this test, the product is to be connected to a transient generator capable of producing the Location Category A, 100 kHz Ring Wave transient as defined in Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits, ANSI/IEEE C62.41.

44.2.3 *Deleted.*

44.2.4 The unit is to be subjected to 500 oscillatory transient pulses induced at a rate of six transients per minute. Each transient pulse is to be induced 90 degrees into the positive half of the 60-Hz cycle. A total of 250 pulses are to be applied so that the polarity of the transients is positive with reference to earth ground, and the remaining 250 pulses are to be negative with regard to earth ground.

44.3 Internally induced transients

44.3.1 The product is to be energized in the intended standby condition while connected to a source of supply in accordance with 26.3.1. The supply source is to be alternately de-energized for approximately 1 second, then energized for approximately 9 seconds for a total of 500 times. Each interruption shall be at a rate of not more than 6 interruptions per minute. Standby power, if used, is to be connected during this test.

44.4 Input/output circuit transients

44.4.1 The unit is to be energized in the normal standby condition while connected to a source of supply in accordance with 26.3.1. All input/output, low-voltage (field-wiring) circuits are to be tested as specified in 44.4.2 and 44.4.3, and as a result of the test, shall comply with 44.1.1.

Exception: This test is not required when manufacturer's installation instructions indicate that it is not permitted to connect with input/output circuit cables greater than 98.5 ft (30 m) long.

44.4.2 For this test, each input/output circuit is to be subjected to the transient waveforms specified in Table 44.1 as delivered into a 200-ohm load. The transient pulses are to be coupled directly onto the input/output circuit conductors of the equipment under test.

Table 44.1
Input/output circuit transients

Peak voltage level, V	Minimum energy level, J	Minimum pulse duration, μs	Figure No.
2400	1.0	80	Figure 44.1
1000[a]	0.31	150	Figure 44.2

Table 44.1 Continued on Next Page

Table 44.1 Continued

Peak voltage level, V	Minimum energy level, J	Minimum pulse duration, µs	Figure No.
500[a]	0.10	250	Figure 44.3
100	0.011	1120	Figure 44.4

[a] Other applied transients having peak voltages representative of the entire range of 100 – 2400 volts shall be used in lieu of these values when the output circuit is only designed specifically to protect against these predetermined values. The transients shall meet or exceed the specified minimum pulse duration (Figure 44.5) and minimum energy level (Figure 44.6) parameters, and shall have an equal or faster minimum transient pulse rise time than that specified in Figure 44.7.

Figure 44.1

Input/output circuit transients – 2400V curve

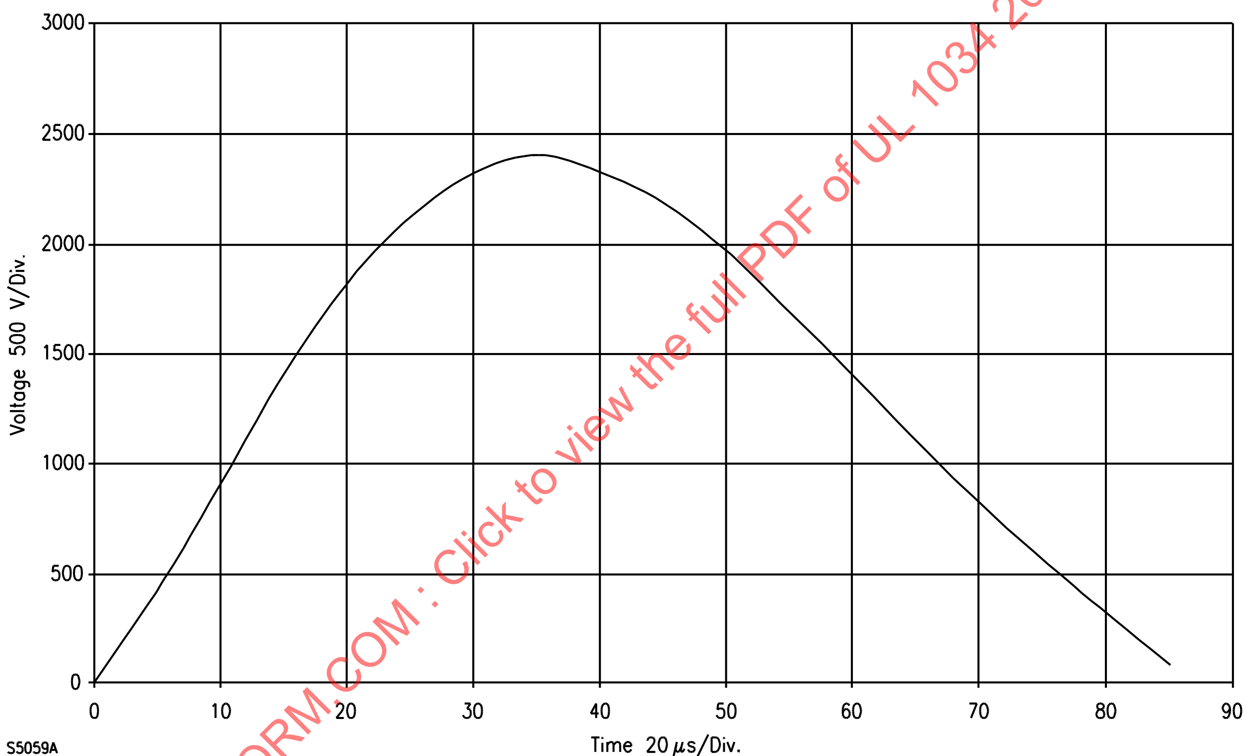


Figure 44.2

Input/Output circuit transients – 1000V curve

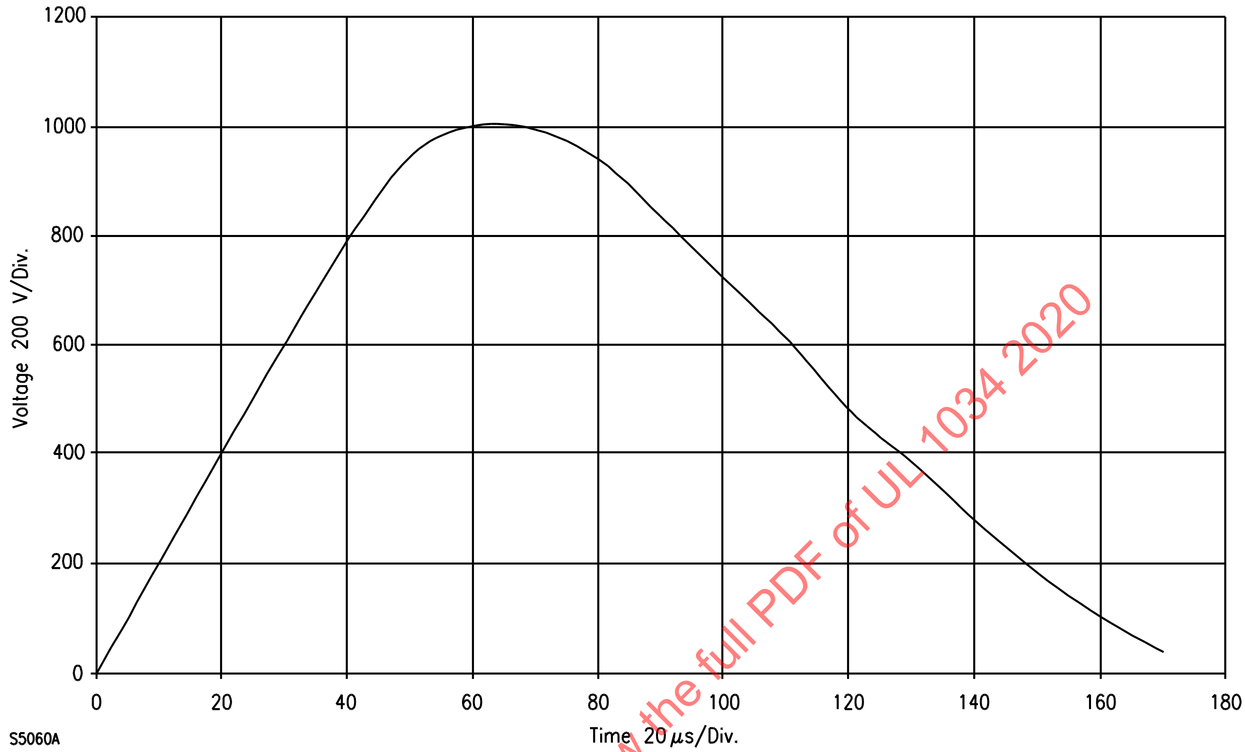


Figure 44.3

Input/output circuit transients – 500V curve

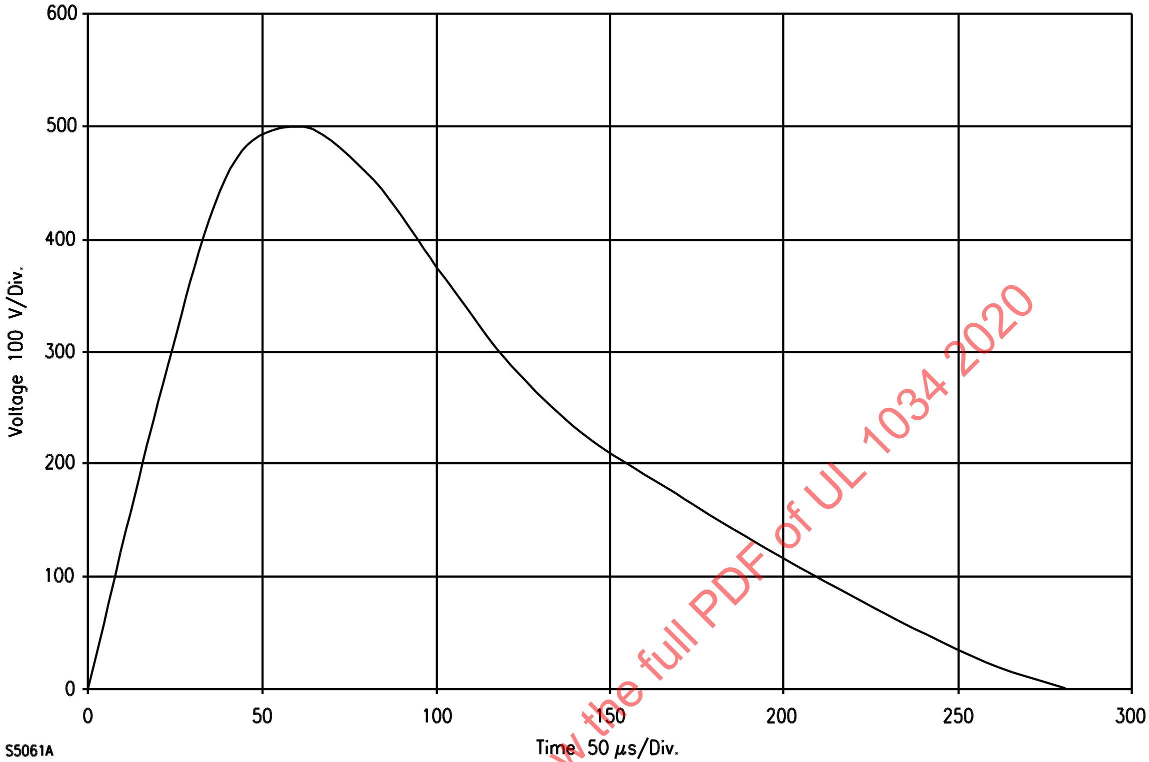


Figure 44.4

Input/output circuit transients – 100V curve

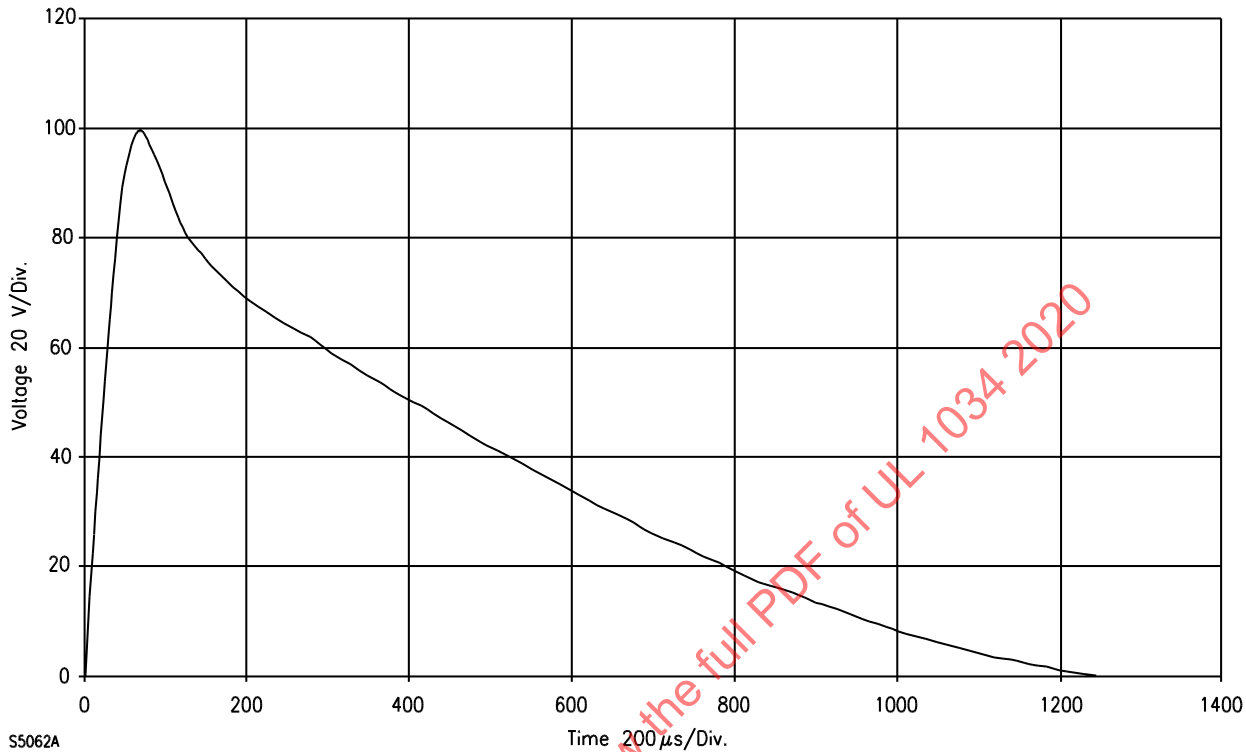


Figure 44.5

Minimum transient pulse duration vs. transient peak voltage

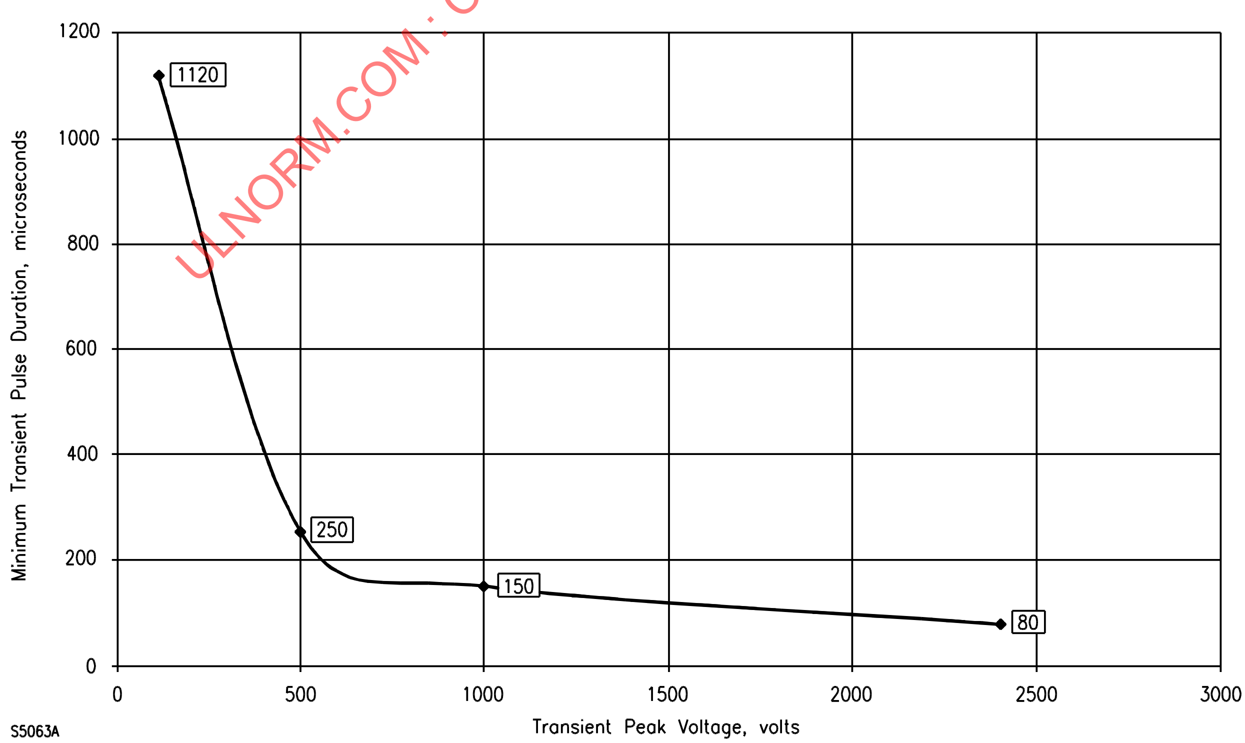


Figure 44.6

Minimum transient energy level vs. transient peak voltage

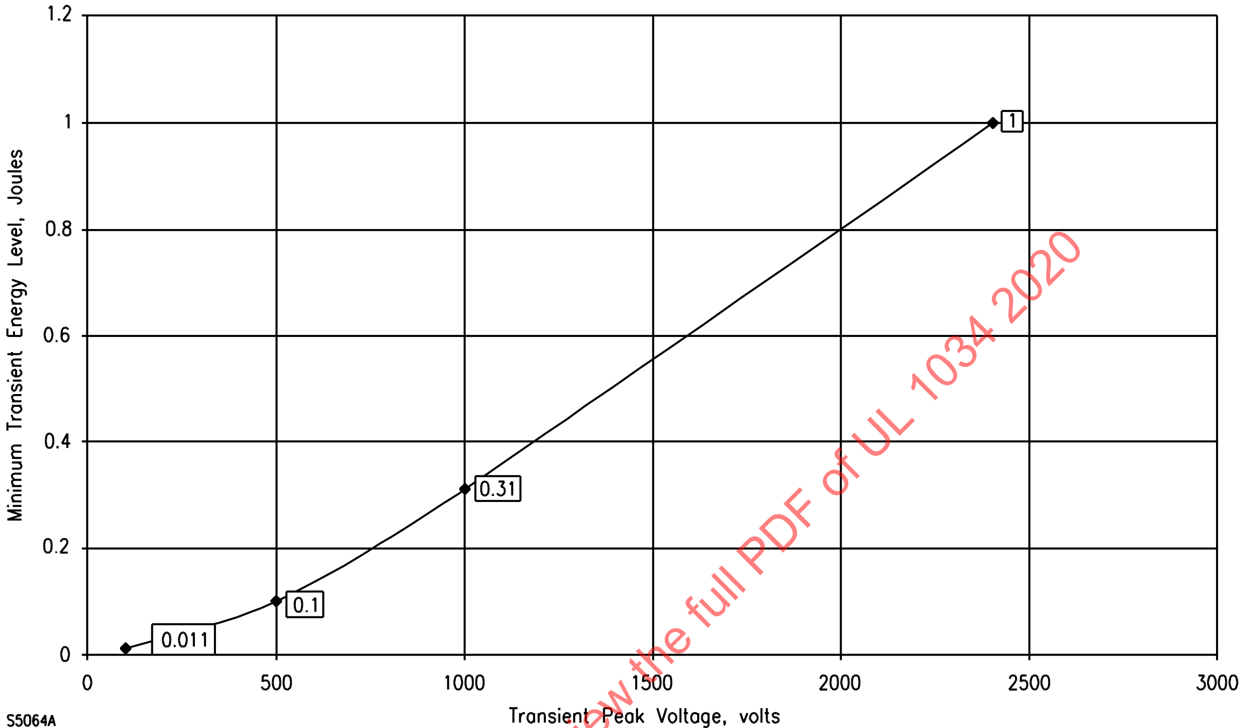
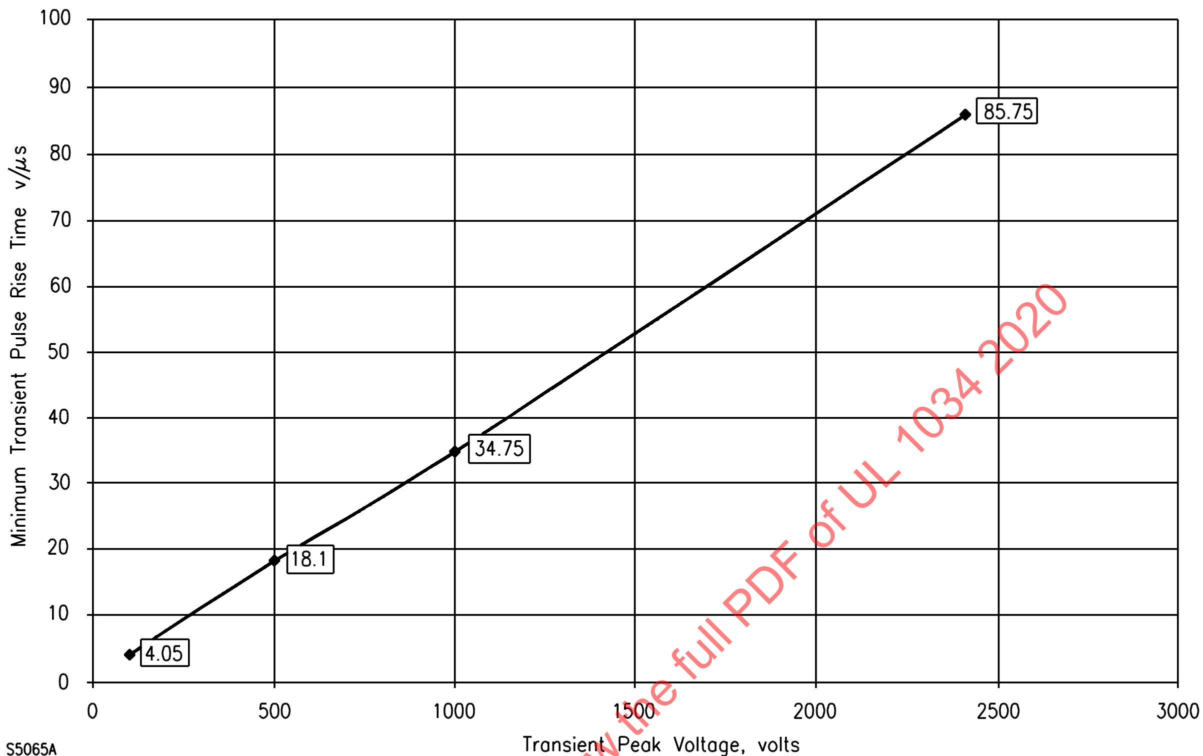


Figure 44.7

Minimum transient pulse rise time vs. transient peak voltage



44.4.3 Each input/output circuit is to be subjected to transient pulses induced at the rate of six pulses per minute as follows:

a) Twenty pulses (four at the 2400 peak voltage level and two at each of the other transient voltage levels specified in 44.4.2) between each lead or terminal and earth ground, consisting of ten pulses of one polarity, and ten of the opposite polarity (total of 40 pulses), and

b) Twenty pulses (four at the 2400 peak voltage level and two at each of the other transient voltage levels specified in 44.4.2) between any two circuit leads or terminals, consisting of ten pulses of one polarity, and ten of the opposite polarity (total of 20 pulses).

44.4.4 As an alternate to 44.4.1 – 44.4.3, the product shall be subjected to the Standard for Surge Tests per Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test, IEC 61000-4-5, and in accordance with the following:

Open Circuit Test Voltage,[a, b] Line to Ground	0.5kV and 1kV
Polarity	+ and –
Minimum number of surges at each polarity, voltage, coupling mode and signal line at a maximum rate of 1 per 5 second	5
Impedance in series with the transient generator	40 Ohm
Combination Wave Generator	1.2/50 us

[a] This test is not required when manufacturer's installation instructions indicate that it is not permitted to connect cables greater than 98.5 ft (30 m) long.

[b] The test pulses are coupled into the leads to be tested by means of appropriate coupling networks that maintain the test pulses within IEC 61000-4-5 specification.

44.4.5 The product under test is to be connected in accordance with the manufacturer's installation instruction, with the intended ancillary equipment and interconnecting cables insulated from ground reference for this test. Normal operation of the product shall be confirmed prior to the test.

44.4.6 Input/output circuits shall be subjected to transients injected by line-to-ground coupling mode only, using a 40 ohm series resistor.

44.4.7 If the product has a large number of identical inputs/outputs circuits, then representative samples of each type of input/output circuit may be subjected to this test and considered representative of other identical circuits.

44.4.8 The length of the unshielded input/output circuit conductors between the product and the coupling/decoupling network (s) shall be less than or equal to 6.5 feet (2 m). If it is specified in the manufacturer's installation instructions that input/output circuit shall only be connected with shielded cables, then in these cases, the transients shall be applied directly (i.e. without the 40 ohm series resistor) to the shield of a 65.5 ft (20 m) length of shielded cable. Current compensated chokes may be used to decouple input/output circuits carrying high frequency signals, to reduce attenuation problems.

44.4.9 A minimum of 5 pulses of each polarity shall be applied at each of the 0.5 kV and 1 kV, voltage levels. The maximum pulse rate of 1 per 5 s is used. If it is necessary to ensure that any failures are not due to applying the pulses too frequently then the devices shall be replaced and the test repeated with pulses at a rate of less than 1/min.

44.4.10 As a result of this test, the unit shall comply with the requirements of 44.1.1.

45 Polymeric Materials Test

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

46 Battery Replacement Test

46.1 The battery connections shall withstand 50 cycles of removal and replacement from the battery terminals without any reduction in contact integrity.

46.2 For this test, a product is to be installed as intended in service and the battery connections removed and replaced as recommended by the manufacturer. The product then shall comply with the requirements of the Normal Operation Test, Section 27.

47 Strain Relief Test

47.1 General

47.1.1 When tested as specified in 47.1.2, the strain relief means provided on a flexible cord shall withstand, for 1 minute without displacement, a pull of 35 pounds-force (156 N) applied to the cord with the connections within the product disconnected.

47.1.2 To apply this force, a 35 pound (15.88 kg) weight is to be secured to the cord and the cord is to be supported by the product so that the strain relief means will be stressed from any angle which the construction of the product permits. There shall not be movement of the cord sufficient to indicate that stress would have been transmitted to the internal connections.

47.2 Field-wiring leads

47.2.1 Each lead used for field connections shall withstand for 1 minute, a pull of 10 pounds-force (44.5 N) without evidence of damage or of transmittal of stress to the internal connections.

48 Ignition Through Bottom-Panel Openings

48.1 General

48.1.1 Both of the bottom-panel constructions described in 8.3.2 may be used without test. Other constructions may be used if they comply with the requirements of the tests specified in 48.2.1 – 48.2.4.

48.1.2 These tests do not apply to low-voltage power limited products or to products in which an internal fault does not produce flame, molten metal, flaming or glowing particles, or flaming drops.

48.2 Hot, flaming oil

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

48.2.2 A sample of the complete, finished bottom panel is to be securely supported horizontally several inches above a horizontal surface under a hood or other area that is well ventilated but free from drafts. Bleached cheesecloth that has an area of 14 – 15 square yards to the pound (26 – 28 m^2/kg) and a count of 32 by 28 per inch square (per 25.4 mm^2), and that is of sufficient size and shape, is to completely cover the pattern of openings in the panel, but is not to be large enough to catch any of the oil that runs over the edge of the panel or otherwise does not pass through the openings. The pan is to be centered under the center of the pattern of openings in the panel. The center of the cheesecloth is to be 2 inches (50.8 mm) below the openings. Use of a metal screen or wired-glass enclosure surrounding the test area is recommended to reduce the risk of injury to persons or damage due to splattering of the oil.

48.2.3 A small metal ladle [preferably not more than 2-1/2 inches (63.5 mm) in diameter] with a pouring lip, and a long handle whose longitudinal axis remains horizontal during pouring, is to be partially filled with 10 milliliters of No. 2 furnace oil, which is a medium-volatile distillate having:

a) An API gravity of 32 – 36 degrees;

b) A flash point of 110 – 190°F (43 – 88°C); and

c) An average calorific value of 136,900 Btu per gallon (39.7 MJ/L) (see Specification for Fuel Oil, ASTM D396-92).

The ladle containing the oil is to be heated and the oil ignited. After burning for 1 minute, all of the hot, flaming oil is to be poured from a position 4 inches (102 mm) above the openings and at the rate of approximately, but not less than, 1 milliliter per second in a steady stream onto the center of the pattern of openings.

48.2.4 Five minutes after completion of the pouring of the oil, the cheesecloth is to be replaced with a clean piece and a second 10 mL of hot, flaming oil is to be poured from the ladle onto the openings. Five minutes later, the cheesecloth is to be replaced again, and a third identical pouring is to be made. The openings may not be used if the cheesecloth is ignited in any of the three pourings.