

UL 294

Access Control System Units

UL Standard for Safety for Access Control System Units, UL 294

Fifth Edition, Dated January 29, 1999

SUMMARY OF TOPICS

These revision pages are being issued to add new definitions and to revise the scope of the standard and the Attack Test.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated September 5, 2008 and May 8, 2009.

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1

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January 29, 1999

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The most recent designation of ANSI/UL 294 as an American National Standard (ANSI) occurred on August 14, 2009. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or effective date information.

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CONTENTS

INTRODUCTION

1 Scope	7
2 General	7
2.1 Components	7
2.2 Units of measurement	8
2.3 Undated references	8
2.4 Terminology	8
3 Glossary	8
4 Installation and Operating Instructions	10A

CONSTRUCTION

ASSEMBLY

5 General	10A
5.1 Product assembly	10A
5.2 Electrical protection	11
6 Protection of Service Personnel	13
7 Enclosure	14
7.1 General	14
7.2 Doors and covers	14
7.3 Enclosure openings	14
7.4 Alarm enclosure	17
7.5 Screens and expanded metal	17
7.6 Cast metal	19
7.7 Sheet metal	19
7.8 Product enclosure mounting	20
7.9 Polymeric materials	20
8 Electric Shock	23
9 Corrosion Protection	23

FIELD WIRING CONNECTIONS

10 General	24
11 Cord Connected Products	24
12 Permanently Connected Products	25
12.1 General	25
12.2 Field-wiring terminals	25
12.3 Qualified application	27
12.4 Field wiring leads	28
12.5 Polarity identification	28
13 Grounding	29

INTERNAL WIRING

14 General	30
15 Wiring Methods	30
16 Separation of Circuits	31
17 Bonding for Grounding	31

COMPONENTS, ELECTRICAL

18 Mounting of Components	34
19 Insulating Materials	35
20 Fuseholders and Current-Carrying Parts	36
21 Overcurrent Protection	36
22 Semiconductors	36
23 Switches	36
24 Transformers and Coils	36

SPACINGS

25 General	36
26 Components	38
27 Computer Accessory Equipment	39

PERFORMANCE – ALL UNITS

28 General	40
28.1 Test units and data	40
28.2 Test samples and miscellaneous data	40
28.3 Test voltages	40
28.4 FCC requirements	41
29 Normal Operation Test	41
30 Input Measurement Test	41
31 Output Measurement Test	41
32 Electrical Supervision Test	42
32.1 General	42
32.2 Power interruption	42
33 Standby Power	42
34 Undervoltage Operation Test	42
35 Overvoltage Operation Test	43
36 Variable Ambient Test	43
37 Humidity Test	43
38 Leakage Current Tests for Cord-Connected Products	43
39 Electric Shock Current Test	47
40 Overload Test	51
40.1 General	51
40.2 Separately energized circuits	51
41 Endurance Test	51
41.1 General	51
41.2 Separately energized circuits	51
42 Jarring Test	52
43 Dielectric Voltage-Withstand Test	53
44 Temperature Test	53
45 Abnormal Operation Test	57

46	Electrical Transient Tests	57
46.1	General	57
46.2	Supply line transients	58
46.3	Internally induced transients	58
46.4	Output circuit transients	58
47	AC Induction Test	60
48	Polymeric Materials Test	61
49	Battery Replacement Test	61
50	Drop Test	61
51	Strain Relief Test	62
51.1	General	62
51.2	Field-wiring leads	62
52	Tests for Ignition Through Bottom-Panel Openings	62
52.1	General	62
52.2	Hot, flaming oil	62
52.3	Molten PVC and copper	63
53	Mechanical Strength Tests for Enclosures	64
53.1	Constant-force test	64
53.2	Impact test	64
54	Special Terminal Assemblies Tests	64
54.1	General	64
54.2	Disconnection and reconnection	65
54.3	Mechanical secureness	65
54.4	Flexing test	65
54.5	Millivolt drop test	65
54.6	Temperature test	65
55	Attack Tests	66
55.1	Destructive attack, access control systems	66
55.2	Nondestructive attack	66A
56	Tests for Alarm Sounding Devices	66A
57	Alarm Housing Test	67

MANUFACTURING AND PRODUCTION LINE TESTS

58	Production Line Dielectric Voltage-Withstand Test for High-Voltage Products	67
59	Production Line Grounding Continuity Test	68

MARKINGS

60	Details	69
61	Marking Permanency Tests	71

OUTDOOR USE EQUIPMENT

ASSEMBLY

62	General	71
63	Construction	71
63.1	General	71
63.2	Corrosion protection	72
64	Field-Wiring Connections	73
65	Internal Wiring	73
66	Components, Electrical Insulating Material	74

PERFORMANCE

67 Rain Test	74
68 Dust Test	78
69 Variable Ambient Test	78
70 Metallic Coating Thickness Test	78
71 Corrosion Tests	80
71.1 General	80
71.2 Salt spray (fog)	81
71.3 Moist hydrogen sulfide (H ₂) – air mixture	81
71.4 Moist carbon dioxide (CO ₂) – sulfur dioxide (SO ₂) – air mixture	81
72 Ultraviolet Light and Water Exposure Test	82
73 Accelerated Aging Tests for Gaskets, Sealing Compounds, and Adhesives	82

MARKINGS

74 Details	84
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ACCESSORY EQUIPMENT

75 General	84
76 Construction	84
77 Performance (Installation) Test	85
78 Markings	85

APPENDIX A

Standards for Components.....	A1
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INTRODUCTION

1 Scope

1.1 These requirements apply to the construction, performance, and operation of systems intended to regulate or control:

- a) Entry into a protected area or a restricted area or
- b) Access to or the use of a device(s) by electrical, electronic or mechanical means.

1.1 revised August 14, 2009

1.2 These requirements apply to computer equipment that, when used in conjunction with the main control, is necessary for proper operation of the access control system. This Standard does not apply to supplementary computer equipment that is not necessary for operation of the access control system if single opens, earth ground faults or wire-to-wire shorts on the circuit connection from the computer to the access control system does not inhibit intended operation.

1.3 Deleted October 29, 2001

2 General

2.1 Components

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

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

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

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

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

2.2 Units of measurement

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

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

2.3 Undated references

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

2.4 Terminology

2.4.1 The term "product" as used in this standard refers to all types of access control system units.

3 Glossary

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

3.1.1 ACCESS CONTROL – The monitoring or control of traffic through portals of a protected area by identifying the requestor and approving entrance or exit.

3.1.1 added August 14, 2009

3.1.2 ACCESS CONTROL SYSTEM, CLASS I – A system of access control intended for, but not limited to, a controlled area that is not required to meet the destructive Attack Test.

3.1.2 added August 14, 2009

3.1.3 ACCESS CONTROL SYSTEM, CLASS II – A system of access control intended for, but not limited to, a protected area that can withstand the destructive Attack Test for 2 minutes.

3.1.3 added August 14, 2009

3.1.4 ACCESS CONTROL SYSTEM, CLASS III – A system of access control intended for, but not limited to, a restricted area that can withstand the destructive Attack Test for 5 minutes, or 2 minutes if an alarm is activated during the test.

3.1.4 added August 14, 2009

3.2 CIRCUITS, ELECTRICAL:

a) High-Voltage – 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 alternating current (AC), 42.4 volts direct current (DC) or AC peak.

c) Power Limited – A circuit whose output is limited as described in Tables 3.1 and 3.2. The power limitation is provided by the construction of the transformer, a fixed impedance, a noninterchangeable fuse, a nonadjustable manual reset circuit protective device, or a regulating network.

3.3 COMPUTER ACCESSORY EQUIPMENT – Equipment connected to the access control system either on or off premise that is relied upon by the system for normal operation.

3.3.1 CONTROLLED AREA – A room, office, building, facility, premises, or grounds to which access is monitored, limited, or controlled.

3.3.1 added August 14, 2009

3.4 CORD-CONNECTED UNIT – A unit intended for connection to the power source by means of a supply cord. Such a unit is intended to be moved for reasons of interchange or realignment of the units of a system.

3.5 FAIL SECURE – A condition under which the system or part of the system ceases to operate in such a way as to not allow unauthorized access.

3.6 HVAC SYSTEM – Heating, Ventilating, and Air-Conditioning system.

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

3.8 NORMAL STANDBY CONDITION – The ready-to-operate condition that exists prior to being operated.

3.9 PRIMARY BATTERY – Any battery which by design or construction is not intended to be recharged.

3.9.1 PROTECTED AREA – A room, office, building, facility, premise or grounds to which access is monitored, and limited and/or controlled, whereby the authorized person of the Access Control System may grant access to non-authorized persons.

3.9.1 added August 14, 2009

3.10 RADIO FREQUENCY – Electromagnetic radiation, normally higher than 20 Khz.

3.10.1 RESTRICTED AREA – A room, office, building, facility, premises, or grounds to which access is monitored, limited and strictly controlled, whereby only the administrator of the Access Control System will issue credentials that will lead to access.

3.10.1 added August 14, 2009

3.11 SAFETY CIRCUIT – Any circuit that is intended to reduce the risk of fire, electric shock, or contact by persons with moving parts that may cause injury (an interlock circuit, for example).

Table 3.1
Power limitations for inherently limited power source (overcurrent protection not required)

Circuit voltage V_{max}^a AC-DC, volts	Maximum nameplate ratings		Current limitation I_{max}^b , amperes
	VA, volt-amperes	Current, amperes	
0 to 20	$5.0 \times V_{max}^a$	5.0	8.0
over 20 to 30	100	$100/V_{max}^a$	8.0
over 30 to 100	100	$100/V_{max}^a$	$150/V_{max}^a$
over 100 to 250 DC only	$0.030 \times V_{max}^a$	0.030	0.030

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^a V_{max} : Maximum output voltage regardless of load with rated input applied. 0 – 20 V-rms, 0 – 28.3 DC or AC peak; 20 – 30 V-rms, 28.3 – 42.4 V DC or AC peak.

^b I_{max} : Maximum output current after 1 minute of operation under any noncapacitive load, including short circuit.

Table 3.2
Power limitations for power sources not inherently limited (overcurrent protection required)

Circuit voltage V_{max}^a AC-DC, volts	Maximum nameplate ratings		Current limitation I_{max}^b , amperes	Power limitation $(VA)_{max}^c$, volt-amperes	Maximum overcurrent protection, amperes
	VA, volt-amperes	Current, (amperes)			
0 to 20	$5.0 \times V_{max}^a$	5.0	$1000/V_{max}^a$	250 ^d	5.0
over 20 to 100	100	$100/V_{max}^a$	$1000/V_{max}^a$	250 ^d	$100/V_{max}^a$
over 100 to 150	100	$100/V_{max}^a$	1.0	NA	1.0

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^a V_{max} : Maximum output voltage regardless of load with rated input applied. See footnote a to Table 3.1.

^b I_{max} : Maximum output after 1 minute of operation under any noncapacitive load, including short circuit, and with overcurrent protection bypassed.

^c $(VA)_{max}$: Maximum volt-ampere output regardless of load with overcurrent protection bypassed.

^d If the power source is a transformer $(VA)_{max}$ is 350 or less when V_{max} is 15 or less.

3.12 SECONDARY BATTERY – Any battery that is intended to be recharged.

3.13 SOFTWARE – Instructions that are temporarily or permanently stored in the computer's memory and used to provide function and control of the computer's components.

3.14 SYSTEM DATABASE – Information entered into the computer by authorized personnel including items such as names, security information for system users, emergency phone numbers, and graphics.

4 Installation and Operating Instructions

4.1 A copy of the installation and operating instructions intended to accompany the product and related schematic wiring diagrams and installation drawings are to be furnished with the sample submitted for investigation. The instructions, drawings, and diagrams are to be used as guides in the examination and test of the product, and for this purpose need not be in final printed form.

4.2 The instructions and drawings shall include at least the following:

- a) Typical installation drawing layouts and complete representative installation wiring diagram(s) for the product indicating recommended locations and wiring methods that shall be in accordance with the National Electrical Code, ANSI/NFPA 70;
- b) A concise description of the operation, testing, and maintenance procedures for the product, and recommended testing frequency;
- c) Replacement parts, such as lamps or batteries, which shall be identified in the instructions by a part number, manufacturer's model number, or the equivalent;
- d) A description of the conditions which might be expected to result in impaired operation of the product(s); and
- e) A description of any features provided to reduce the risk of a fire or electric shock, and a warning against bypassing such features.

4.3 The instructions shall be provided on the product, on a separate sheet, or as part of a manual. If instructions are not provided directly on the product, the instructions or manual shall be referenced in the marking information on the product. See Marking, General, Section 59.

CONSTRUCTION

ASSEMBLY

5 General

5.1 Product assembly

5.1.1 An access control system or unit shall not impair the intended operation of panic hardware used in conjunction with it.

5.1.2 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.

5.1.3 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 shall be arranged and constructed to permit them to be incorporated into the complete assembly only in the intended relationship with each other, where this is necessary, without need for alteration or alignment. Otherwise, such subassemblies shall be assembled, tested, and shipped from the factory as one element.

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5.2 Electrical protection

5.2.1 Louvers and other openings in the enclosure shall be constructed and located to reduce the risk of contact by persons 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.

5.2.2 Uninsulated high-voltage live parts shall be located, guarded, or enclosed as indicated in 5.2.3 and 5.2.4.

5.2.3 Openings directly over uninsulated high-voltage live parts shall not exceed 0.187 inch (4.75 mm) in any dimension unless the configuration is arranged to reduce the risk of unintentional contact by persons with uninsulated high-voltage live parts. See Figure 7.2 for examples of top cover constructions which may be used.

5.2.4 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 5.1, cannot be made to contact any uninsulated live high-voltage electrical part when inserted through the opening in a straight or articulated position.

5.2.5 An opening that permits entrance of a 1-inch (25.4-mm) diameter rod may be used under the conditions described in Figure 5.2.

Figure 5.1
Articulate probe

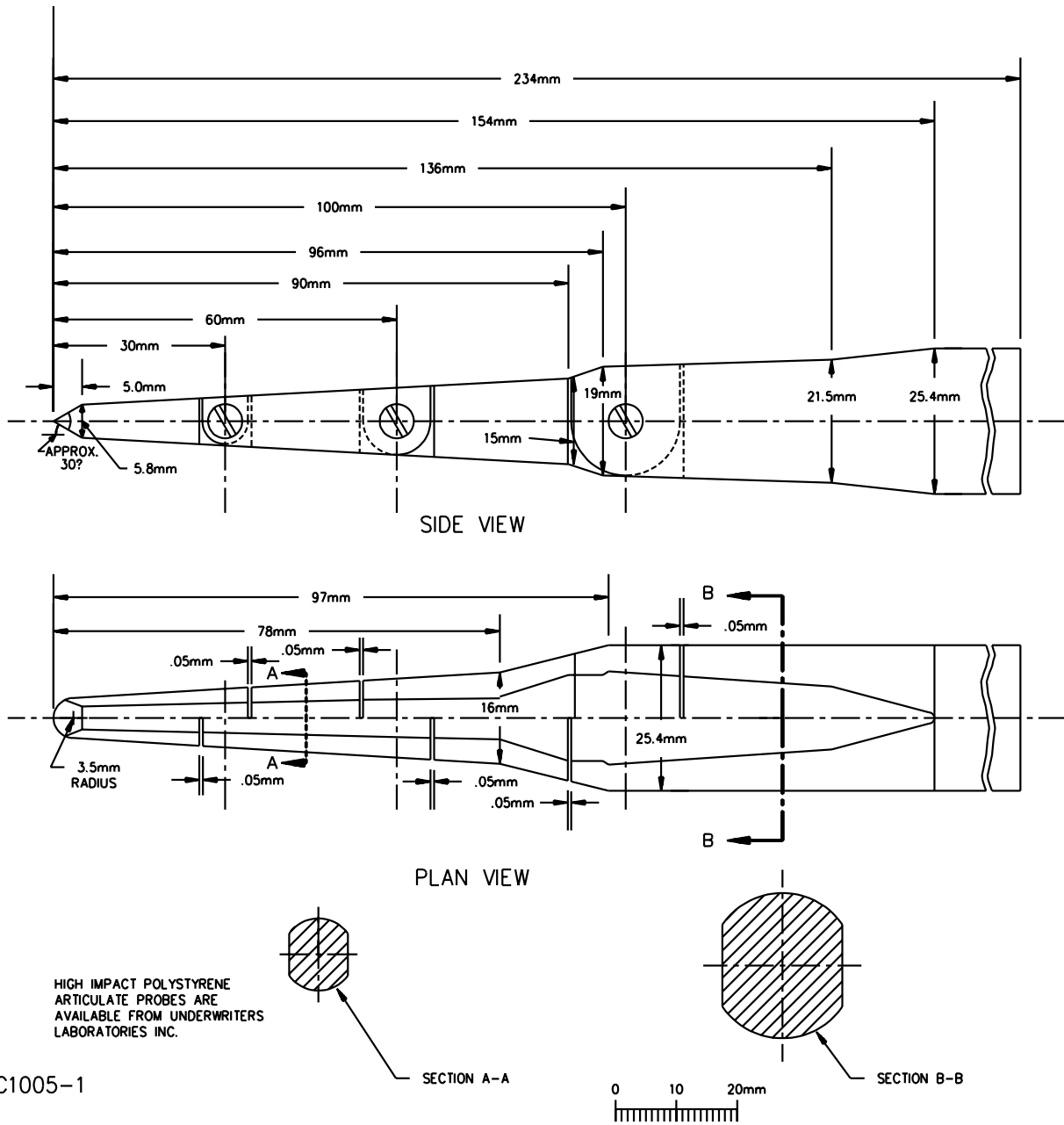
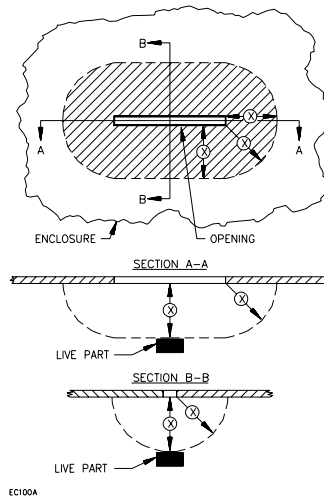


Figure 5.2
Opening in enclosure



NOTE – The opening may be used if, within the enclosure, there is no uninsulated live part or film-insulated wire less than X inches (mm) from the perimeter of the opening, as well as within the volume generated by projecting the perimeter X inches (mm) normal to its plane. X equals five times the diameter of the largest diameter rod that can be inserted through the opening, but not less than 6-1/4 inches (154 mm).

6 Protection of Service Personnel

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

6.2 The requirements specified in 6.1 are not satisfied by a part of the enclosure that may be removed:

- a) To allow access by a user making intended operating adjustments or
- b) Without the use of tools.

6.3 An electrical component that may require examination, replacement, adjustment, servicing, or maintenance while the product is energized shall be located and mounted with respect to other components and with regard 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.

6.4 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.

7 Enclosure

7.1 General

7.1.1 The enclosure of a product shall have the strength and rigidity to resist total or partial collapse and attendant reduction of spacings, loosening or displacement of parts, or other defects. See the Mechanical Strength Tests for Enclosures, Section 52.

7.1.2 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 that may impair their intended operation.

7.1.3 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 the Tests for Ignition Through Bottom-Panel Openings, Section 51.

7.1.4 The requirement specified in 7.1.3 requires either a nonflammable bottom in accordance with 7.3.2, or a protective barrier as illustrated in Figure 7.1 under all areas containing combustible materials. However, openings in the bottom of an enclosure that comply with the requirements of 7.3.3 may be used.

7.1.5 A construction using an individual barrier under a component, group of components, or an assembly, as specified in Figure 7.1, shall comply with the requirement specified in 7.1.3.

7.2 Doors and covers

7.2.1 An enclosure cover shall be hinged, sliding, or similarly attached to secure it against removal if:

- a) Displacing the cover gives access to fuses or any other overcurrent protective device, the intended functioning of which requires renewal; or
- b) Opening the cover is required as part of the intended operation of the unit.

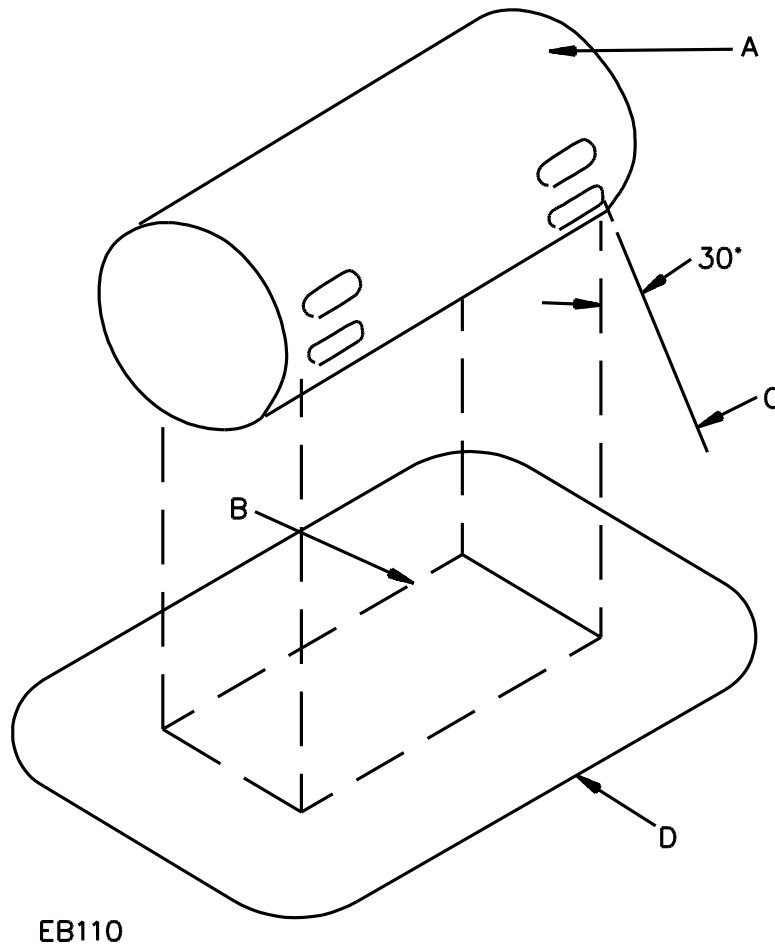
Exception: If its position is supervised by a contact intended to disable the system or activate an audible or visual warning, an enclosure cover need not comply with the requirements of this paragraph. See also 32.1.4.

7.2.2 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.

7.3 Enclosure openings

7.3.1 Openings in the enclosure shall be constructed and sized to reduce the risk of direct entry of foreign objects. See also 5.2.2. See Figure 7.2 for examples of top cover constructions which may be used. See also Figure 7.3 for examples of side openings which may be used.

Figure 7.1
Location and extent of protective barrier



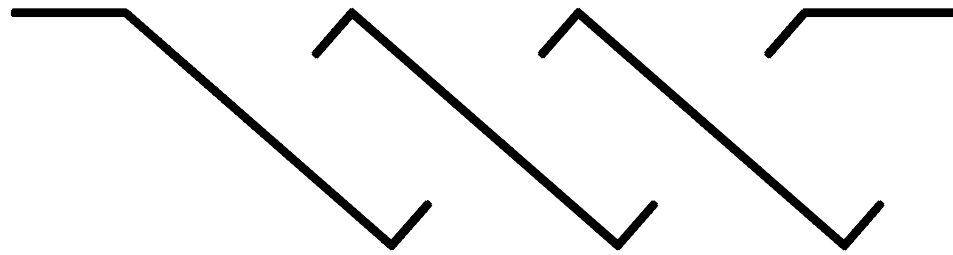
A – The entire component under which a barrier (flat or dished, with or without a lip or other raised edge) of nonflammable material is to be provided. The sketch above is of a metal enclosed component with ventilating openings to show that the protective barrier is required only for those openings from which flaming parts might come. If the component or assembly does not have its own nonflammable 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.

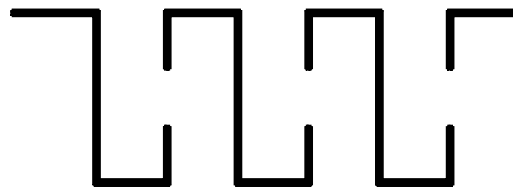
C – Inclined line that traces out an area (D) on the horizontal plane of the barrier. Moving around the perimeter of the area (B) which needs a bottom barrier, this line projects at a 30-degree angle from the line extending vertically at every point around the perimeter of (A) and oriented to trace out 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 nonflammable 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 a 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.

Figure 7.2
Top cover designs



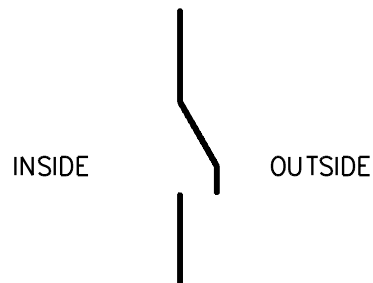
SLANTED OPENINGS



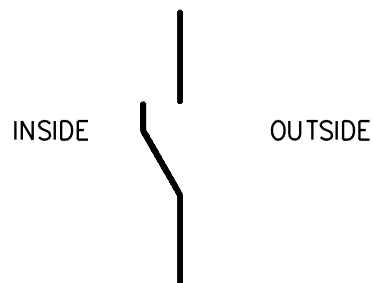
EC500

VERTICAL OPENINGS

Figure 7.3
Louver designs



OUTWARD PROJECTION



EC510

INWARD PROJECTION

7.3.2 An opening in a bottom panel or protective pan may be used if both the following conditions are met:

- a) The interior above the panel or pan contains no material classified as V-1 in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.
- b) The panel or pan by its construction prevents materials from falling from the interior of the product directly onto the supporting surface or anything else under the product.

7.3.3 Figure 7.4 illustrates a type of baffle that complies with the requirement in 7.3.2(b). A second construction that meets this requirement is a 0.040-inch (1.02-mm) sheet-steel bottom panel in which 5/64-inch (2.0-mm) maximum-sized, round holes are spaced not closer together than 1/8 inch (3.2 mm) center-to-center. Constructions other than these two may be used if they comply with the Tests for Ignition Through Bottom-Panel Openings, Section 51.

7.3.4 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 mm²).

7.3.5 Openings may be used, without limitation of the size or number of openings, in areas:

- a) Containing only PVC, TFE, CTFE, FEP, and neoprene insulated wire or cable;
- b) Containing plugs and receptacles; and
- c) Underneath impedance protected or thermally protected motors.

7.3.6 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.

7.4 Alarm enclosure

7.4.1 The alarm housing shall be protected against disassembly and removal from its mounting surface by a pry-off tamper and tamper contacts on at least one-half of the outer cover securing devices, and by a construction at least equivalent in strength to a complete 0.067-inch (1.70-mm) steel outer housing and an electrical inner lining of 0.053-inch (1.35-mm) steel that cover all sides except the back.

7.4.2 Either the outer and inner housings shall be connected in a closed protection circuit, or fully insulated electric linings shall be used so that an alarm will result if the housing is penetrated by drills, pry bars, or similar tools.

7.4.3 Connection of linings, housings, and housing contacts shall be supervised by the closed protection circuit entering and leaving at different points.

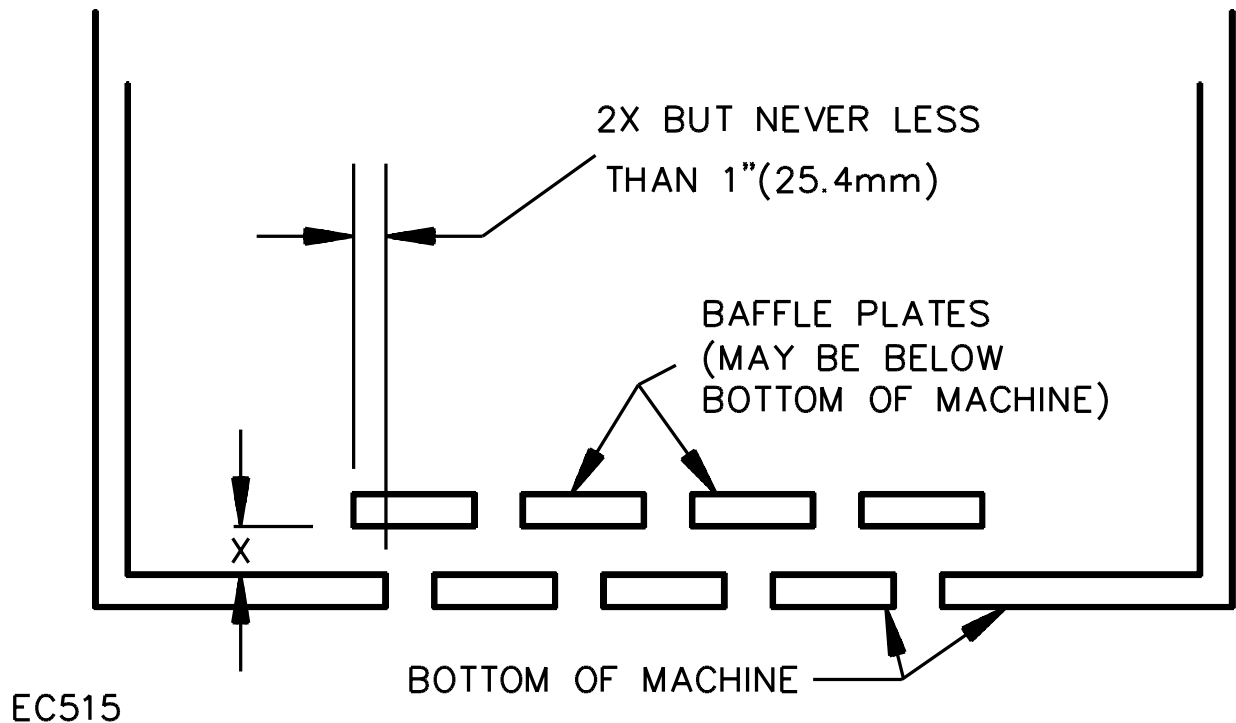
7.4.4 The specifications as to thickness of metal and baffles refer to conventional arrangements. Other constructions may be used if equivalent protection against attack is provided.

7.4.5 For the performance requirement of an alarm enclosure, see the Alarm Housing Test, Section 56.

7.5 Screens and expanded metal

7.5.1 A screen or mesh of expanded metal used as a guard, enclosure or part of an enclosure shall comply with the requirements of 7.5.2 – 7.5.4 and with the Mechanical Strength Tests for Enclosures, Section 52.

Figure 7.4
Baffle



7.5.2 Perforated sheet steel or sheet steel used for expanded metal mesh shall not be less than 0.042 inch (1.07 mm) in thickness [0.045 inch (1.17 mm) if zinc coated] if the mesh openings or perforations are 1/2 square inch (323 mm²) or less in area. For larger openings, the steel shall not be less than 0.080 inch (2.03 mm) in thickness [0.084 inch (2.13 mm) if zinc coated]. The largest dimension shall not exceed 4 inches (102 mm).

7.5.3 With reference to the requirements in 7.5.2, expanded steel mesh or perforated sheet steel that is 0.020 inch (0.53 mm) thick [0.023 inch (0.58 mm) thick if zinc coated] may be used if the indentation of a guard or the enclosure will not alter the clearance between uninsulated live parts and grounded metal so as to impair performance or reduce spacings below the minimum required values (see Spacings, General, Section 25). If this is the case, then either:

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

7.5.4 The wires of a screen shall not be less than No. 16 AWG (1.29 mm diameter) steel if the screen openings are 1/2 square inch (323 mm²) or less in area and shall not be less than No. 12 AWG (2.05 mm diameter) steel for larger screen openings.

7.6 Cast metal

7.6.1 The thickness of cast metal for an enclosure shall be as specified in Table 7.1. However, cast metal of lesser thickness may be used if, consideration being given to the shape, size, and function of the enclosure, the cast metal has been determined to provide the same level of mechanical strength. See the Drop Test, Section 49, and the Mechanical Strength Tests for Enclosures, Section 52.

Table 7.1
Cast-metal enclosures

Use, or dimensions of area involved ^a	Minimum thickness			
	Die-cast metal		Cast metal of other type than the die-cast type	
	inch	(mm)	inch	(mm)
Area of 24 square inches (155 mm 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.				

7.6.2 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, there shall not be less than 3-1/2 nor more than 5 threads in the metal, and the construction shall allow a standard conduit bushing to be attached as intended.

7.6.3 If threads for the connection of conduit are tapped only part of the way through a hole in an enclosure wall, there shall not be less than 3-1/2 threads in the metal, and there shall be a smooth, rounded inlet hole for the conductors that has been determined to provide the same level of protection to the conductors as that of a standard conduit bushing.

7.7 Sheet metal

7.7.1 The thickness of sheet metal for an enclosure shall not be less than that specified in Table 7.2 or 7.3, whichever applies.

Exception: Sheet metal of lesser thickness may be used if, consideration being given to the shape, size, and function of the enclosure, the sheet metal has been determined to provide the same level of mechanical strength. See the Drop Test, Section 49, and the Mechanical Strength Tests for Enclosures, Section 52.

7.7.2 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, or

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

7.7.3 A plate or plug closure for an unused conduit opening or other hole in the enclosure shall not be less than:

- a) 0.027 inch (0.69 mm) thick if of ferrous metal or
- b) 0.032 inch (0.81 mm) thick if of nonferrous metal,

for a hole having a maximum diameter of 1-3/8 inches (34.9 mm).

7.7.4 A closure for a hole larger than 1-3/8 inch (34.9 mm) diameter shall have a thickness equal to that required in 7.7.1 for the enclosure of the device. Otherwise, a standard knockout seal shall be used. Such plates or plugs shall be securely mounted.

7.7.5 A knockout in a sheet metal enclosure shall be removable without undue deformation of the enclosure.

7.7.6 A knockout shall be provided with a surrounding surface that can seat a conduit bushing as intended. The knockout shall be located so that installation of a bushing at any knockout likely to be used during installation will not result in spacings between uninsulated live parts and the bushing of less than those indicated in Spacings, General, Section 25.

7.8 Product enclosure mounting

7.8.1 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 is not considered to be disassembly of an operating part.

7.9 Polymeric materials

7.9.1 Among the factors taken into consideration when judging the acceptability of a nonmetallic enclosure are:

- a) The mechanical strength;
- b) Resistance to impact;
- c) Moisture-absorption 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 47, and the Mechanical Strength Tests for Enclosures, Section 52.

Table 7.2
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 inches	Maximum length, ^c (cm)	Maximum width, ^b inches	Maximum length, ^c (cm)	Uncoated [MSG]	Metal Coated [GSG]
4.0	10.2	Not limited	6.25	0.020 (0.51)	0.023 (0.58)
4.75	12.1	5.75	17.1	[24]	[24]
6.0	15.2	Not limited	9.5	0.026 (0.66)	0.029 (0.74)
7.0	17.8	11.5	22.2	[22]	[22]
8.0	20.3	Not limited	12.0	0.032 (0.81)	0.034 (0.86)
9.0	22.9	18.0	33.0	[20]	[20]
12.5	31.8	Not limited	19.5	0.042 (1.07)	0.045 (1.14)
14.0	35.6	18.0	53.3	[18]	[18]
18.0	45.7	Not limited	27.0	0.053 (1.35)	0.056 (1.42)
20.0	50.8	25.0	73.7	[16]	[16]
22.0	55.9	Not limited	33.0	0.060 (1.52)	0.063 (1.60)
25.0	63.5	31.0	88.9	[15]	[15]
25.0	63.5	Not limited	39.0	0.067 (1.70)	0.070 (1.78)
29.0	73.7	36.0	104.1	[14]	[14]
33.0	83.3	Not limited	51.0	0.080 (2.03)	0.084 (2.13)
38.0	96.5	47.0	137.2	[13]	[13]
42.0	106.7	Not limited	64.0	0.093 (2.36)	0.097 (2.46)
47.0	119.4	59.0	172.7	[12]	[12]
52.0	132.1	Not limited	80.0	0.108 (2.74)	0.111 (2.82)
60.0	152.4	74.0	231.4	[11]	[11]
63.0	160.0	Not limited	97.0	0.123 (3.12)	0.126 (3.20)
73.0	185.4	90.0	228.6	[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 7.3
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, inches (mm)
Maximum width, ^b inches (cm)	Maximum length, ^c inches (cm)	Maximum width, ^b inches (cm)	Maximum length, inches (cm)	
3.0 7.6	Not limited	7.0 17.8	Not limited	0.023 0.58
3.5 8.9	4.0 10.2	8.5 21.6	9.5 24.1	
4.0 10.2	Not limited	10.0 25.4	Not limited	0.029 0.74
5.0 12.7	6.0 15.2	10.5 26.7	12.5 34.3	
6.0 15.2	Not limited	14.0 35.6	Not limited	0.036 0.91
6.5 16.5	8.0 20.3	15.0 38.1	18.0 45.7	
8.0 20.3	Not limited	19.0 48.3	Not limited	0.045 1.14
9.5 24.1	11.5 29.2	21.0 53.3	25.0 63.5	
12.0 30.5	Not limited	28.0 71.1	Not limited	0.058 1.47
14.0 35.6	16.0 40.6	30.0 76.2	37.0 94.0	
18.0 45.7	Not limited	42.0 106.7	Not limited	0.075 1.91
20.0 50.8	25.0 63.5	45.0 114.3	55.0 139.7	
25.0 63.5	Not limited	60.0 152.4	Not limited	0.095 2.41
29.0 73.7	36.0 91.4	64.0 162.6	78.0 198.1	
37.0 94.0	Not limited	87.0 221.0	Not limited	0.122 3.10
42.0 106.7	53.0 134.6	93.0 236.2	114.0 289.6	
52.0 132.1	Not limited	123.0 312.4	Not limited	0.153 3.89
60.0 152.4	74.0 188.0	130.0 330.2	160.0 406.4	

^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.

8 Electric Shock

8.1 Any part that is exposed only during operator servicing shall not present the risk of electric shock. See the Electric Shock Current Test, Section 38.

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

Exception: The conductive connection need not be provided if:

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

8.3 The maximum value of 5.2 megohms mentioned in 8.2 is to include the maximum tolerance of the resistor value used; that is, a resistor rated 4.2 megohms with 20 percent tolerance or a resistor rated 4.7 megohms with a 10 percent tolerance may be used. A component comprised of a capacitor with a built-in shunt resistor that complies with the requirements for antenna isolating capacitors may be rated a minimum of 1/4 watt.

8.4 The insertion in any socket of any vacuum tube or its glass or metal equivalent of like designation used in the product shall not result in a risk of electric shock.

9 Corrosion Protection

9.1 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 means providing such protection. Bearing surfaces shall resist binding due to corrosion.

9.2 The requirement specified in 9.1 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 the unprotected parts would not impair the operation of the unit or create a risk of fire, electric shock, or unintentional contact with moving parts that can cause injury to persons.

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

9.3 Metal used in cabinets and enclosures shall be used in combinations that are galvanically compatible. However, this requirement does not apply 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.

9.4 Hinges and other attachments shall be resistant to corrosion.

FIELD WIRING CONNECTIONS

10 General

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

11 Cord Connected Products

11.1 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-prong attachment plug or three-prong grounding-type attachment plug rated for connection to the required supply circuit.

Exception: The cord may be less than 6 feet (1.8 m) in length if the 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;*
- c) May impair the intended operation of the product; or*
- d) Is not required for the intended operation of the product.*

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

11.3 The flexible cord shall be of Type SJ, SJT, or other types determined to be equivalent, minimum No. 18 AWG (0.82 mm²). It shall be rated for use at the voltage and current rating of the product.

11.4 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 the Strain Relief Test, Section 50.

11.5 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.

11.6 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 the equivalent is necessary to prevent the clamp from damaging the cord or supply leads.

11.7 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 exposure to a temperature higher than 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.