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Third Edition

Standard for Electric Vehicle Supply Equipment

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Standard for Safety for Electric Vehicle Supply Equipment

Third Edition, Dated December 15, 2022

Summary of Topics

This Third Edition of the Standard for Electric Vehicle Supply Equipment, dated December 15, 2022, includes the following revisions: a) Removal of requirement to fasten in place devices rated over 125 V; b) Increase voltage to 1000 V input; c) Revisions due to withdrawal of UL 2744; d) Location of interrupting device for personnel protection systems in EVSE in accordance with the NEC

Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as “CSA Group”), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or UL at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and UL. CSA Group and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and UL pages.

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This Standard is subject to review within five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup.org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the Third Edition. The most recent designation of ANSI/UL 2594 as an American National Standard (ANSI) occurred on December 15, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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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Preface

This is the harmonized ANCE, CSA Group, and UL Standard for Electric Vehicle Supply Equipment. It is the Third edition of NMX-J-677-ANCE, the Third edition of CSA C22.2 No. 280, and the Third edition of UL 2594. This edition of NMX-J-677-ANCE supersedes the previous edition published on December 21, 2016. This edition of CSA C22.2 No. 280 supersedes the previous edition published on December 21, 2016. This edition of UL 2594 supersedes the previous edition published on December 21, 2016.

This harmonized standard was prepared by the Association of Standardization and Certification (ANCE), CSA Group, and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Working Group for Electric Vehicle Supply Equipment are gratefully acknowledged.

This standard is considered suitable for use for conformity assessment within the stated scope of the Standard.

The present Mexican Standard was reviewed and approved by the Comité de Normalización de la Asociación de Normalización y Certificación, A.C., CONANCE.

This standard was reviewed by the CSA Subcommittee on Electric Vehicle – Supply Equipment, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This standard has been developed in compliance with the Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

Application of Standard

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity.

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

Level of harmonization

This standard uses the IEC format but is not based on, nor is considered equivalent to, an IEC standard.

This standard is published as an equivalent standard for ANCE, CSA Group, and UL.

An equivalent standard is a standard that is substantially the same in technical content, except as follows: Technical national differences are allowed for codes and governmental regulations as well as those recognized as being in accordance with NAFTA Article 905, for example, because of fundamental climatic, geographical, technological, or infrastructural factors, scientific justification, or the level of protection that the country considers appropriate. Presentation is word for word except for editorial changes.

Reasons for differences from IEC

This standard provides general requirements for electric vehicle supply equipment for use in accordance with the electrical installation codes of Canada, Mexico, and the United States. At present there is no IEC standard for these products for use in accordance with these codes. Therefore, this standard does not employ any IEC standard for base requirements.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

INTRODUCTION

1 Scope

1.1 This Standard applies to conductive electric vehicle (EV) supply equipment with a primary source voltage of 1000 V ac or less, with a frequency of 50 or 60 Hz, and intended to provide ac power to an electric vehicle with an on-board charging unit. This Standard covers electric vehicle supply equipment intended for use where ventilation is not required.

1.2 With reference to 1.1, the following list of examples of electric vehicle supply equipment are included in this Standard:

a) EV Cord Sets – Rated 125 Vac maximum, 16 A maximum, intended for indoor and outdoor use;

b) Fastened in place EV Charging Stations – Rated 250 Vac maximum, 40 A maximum, intended for indoor or outdoor use;

c) Fixed in place EV Charging Stations – Rated 1000 Vac maximum, intended for indoor or indoor/outdoor use; and

d) Fixed in place EV Power Outlet – Rated 1000 Vac maximum, intended for indoor or indoor/outdoor use.

For Mexico, use 127 Vac where 120 or 125 Vac is referenced in this Standard. In Canada and the United States, this does not apply.

1.3 The products covered by this Standard are intended for use in accordance with the Installation Codes in Annex A, Ref. No. 1.

1.4 This Standard does not cover cord sets or power supply cords for applications other than EV charging cord sets. For cord sets and power supply cords not covered by this Standard, refer to Annex A, Ref. No. 2 and No. 3.

1.5 With reference to 1.2, this Standard does not cover electric vehicle charging equipment. For EV charging equipment not covered by this Standard, refer to Annex A, Ref. No. 4.

1.6 This Standard does not cover electric vehicle connectors. For electric vehicle connectors not covered by this Standard, refer to Annex A, Ref. No. 5

1.7 This Standard does not cover regular-use power outlets. For regular-use power outlets not covered by this Standard, refer to Annex A, Ref. No. 6.

1.8 This Standard does not cover equipment intended for wireless power transfer, which may also be designated as wireless charging, inductive charging, magnetic resonance charging, or any other similar designation indicating the transfer of power from the EVSE to the vehicle through other than a conductive connection.

2 Units of Measurement

2.1 The values given in SI (metric) units shall be normative. Any other values given shall be for information purposes only.

3 Components

3.1 Except as indicated in 3.2, a component used as a part of a unit covered by this Standard shall comply with the requirements for that component.

3.2 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.

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

3.4 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.

4 Normative References

4.1 Where reference is made to any Standard, such reference shall be considered to refer to the latest editions and revisions thereto available at the time of printing, unless otherwise specified.

4.2 Products covered by this Standard shall comply with the reference installation codes and Standards noted in Annex A as appropriate for the country where the product is to be used. When the product is intended for use in more than one country, the product shall comply with the installation codes and Standards for all countries where it is intended to be used.

4.3 For products intended for use in Canada, general requirements are given in Annex A, Ref. No. 74. In Mexico and the United States, this does not apply.

5 Definitions

5.1 For the purposes of this Standard, the following definitions apply. In addition, in the text of this document, the term “device” refers to the product covered by this Standard. The term “EV” applies to electric vehicles, including hybrid electric vehicles, plug-in electric vehicles, battery electric vehicles, and similar vehicles.

In Canada, all terms for which a definition appears in C22.2 No. 0 shall be deemed to have the definition as provided in C22.2 No. 0. The only exception is the definition of "Accessible" which shall remain as given in C22.2 No. 280-16. In Mexico and the United States, this does not apply.

5.2 ACCESSIBLE – Able to be contacted by an accessibility probe.

5.3 BONDED (BONDING) – The permanent joining of metallic parts to form an electrically conductive path that provides electrical continuity and the capacity to conduct any current likely to be imposed without a risk of electric shock or fire.

Note: See Figure 14.1 for an illustration of the terms “grounding” and “bonding” with corresponding terms for Canada and Mexico.

5.4 CHARGING CIRCUIT INTERRUPTING DEVICE (CCID) – A device that continuously monitors the differential current among all of the current-carrying line conductors in a grounded system and rapidly interrupts the circuit under conditions where the differential current exceeds the ground-fault trip threshold

of the charging circuit interrupting device. The device is identified by the letters CCID followed by the differential trip current rating of either 5 or 20 mA.

5.5 CHARGING STATION, ELECTRIC VEHICLE (EV) – A device used to provide power to an on-board charger.

5.6 COMMERCIAL GARAGE – A facility, or portion of a facility, used for the repair of internal combustion engine vehicles, in which the area may be classified due to vapors of flammable liquids (gasoline) being present.

5.7 CONTROL CIRCUIT – A circuit that carries electric signals but not main power current.

5.8 DEGREE OF PROTECTION – The extent of protection provided by an enclosure against access to parts which result in a risk of injury, ingress to foreign solid objects, and/or ingress of water as verified by standardized test methods.

5.9 DIRECT PLUG-IN EQUIPMENT – Devices that are provided with the means to connect to the wall outlet built into the product. No power cord is provided.

5.10 ELECTRIC VEHICLE (EV) – An over-the-road automotive type vehicle for highway use, such as a passenger automobile, bus, truck, van, motorcycle, or similar vehicle, which receives primary or supplementary propulsion power from an electric motor that draws current from a rechargeable storage battery.

5.11 ELECTRIC VEHICLE (EV) CABLE – A cable intended to connect the electric vehicle charging equipment to the electric vehicle.

5.12 ELECTRIC VEHICLE (EV) CORD SET (PORTABLE EVSE) – An EVSE intended for indoor and outdoor use that can be carried from one charging location to another and is transported in the vehicle when not in use. This type of cord set is subject to changing environmental conditions.

5.13 ELECTRIC VEHICLE PLUG – A device intended to transfer power when inserted into an electric vehicle receptacle, which establishes connection between conductors of the attached EV cable and the conductors connected to the EV receptacle. See Annex A, Ref. No. 5.

5.14 ELECTRIC VEHICLE (EV) RECEPTACLE – A device that is intended to provide power to an inserted EV plug. This device would be installed at the output of electric vehicle supply equipment. See Annex A, Ref. No. 5.

5.15 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) – A complete assembly consisting of conductors, connectors, devices, apparatus, and fittings installed specifically for the purpose of power transfer and information exchange between the branch circuit and the electric vehicle.

5.16 ENCLOSURE – That portion of a device that reduces the accessibility of a part that involves a risk of fire, electric shock, injury to persons, or hazardous energy levels, or reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

5.17 ENERGIZED PART – A part at some potential with respect to another part or earth.

5.18 EXPOSED – Visible but not necessarily able to be contacted by an accessibility probe.

5.19 FASTENED IN PLACE – A mounting means for EVSE which is specifically designed to permit periodic removal of the EVSE for relocation, interchangeability, maintenance or repair without the use of a tool.

5.20 FIXED IN PLACE – A mounting means for EVSE that requires a tool to remove the EVSE from its mounted position.

5.21 GROUND – A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth or to some conducting body that serves in place of the earth.

Note: See Figure 14.1 for an illustration of the terms “grounding” and “bonding” with corresponding terms for Canada and Mexico.

5.22 GROUNDING MONITOR/INTERRUPTER – A device that monitors equipment grounding continuity in a charging system, and either prevents the circuitry from becoming energized under conditions where the grounding is not available or interrupts the circuit under conditions where the grounding is lost during operation.

5.23 INSULATION, BASIC – The insulation required for the proper functioning of a device, and for basic protection against the risk of electric shock.

5.24 INSULATION, DOUBLE – A system of two independent insulations, each of which is capable of acting as the sole insulation between live and accessible parts in the event of failure of the other insulation. The insulation system resulting from a combination of basic and supplementary insulation.

5.25 INSULATION, REINFORCED – A single insulation system with such mechanical and electrical qualities that it, in itself, provides the same degree of protection against the risk of electric shock as does double insulation. The term “single insulation system” does not require that the insulation must be in one homogeneous piece. The insulation system comprises two or more layers that are not to be tested as supplementary or basic insulation.

5.26 INSULATION, SUPPLEMENTARY – An independent insulation provided in addition to the basic insulation to protect against the risk of electric shock in the event the basic insulation fails.

5.27 ISOLATION MONITOR/INTERRUPTER – A device that monitors the insulation resistance of an isolated circuit to ground and prevents energization of the circuit or disconnects an energized circuit when the insulation resistance drops below a predetermined value.

5.28 ISOLATION MONITOR/INTERRUPTER WITH SELF CHECK – A device similar to that described in 5.27 except that it is also equipped with an automatic supervisory circuit that periodically checks the operation of the isolation monitor and does not permit energizing the circuitry, or during operation, disconnects the energizing circuitry connected to the load terminals of the isolated circuit under conditions where the isolation monitor does not function properly.

5.29 KNOCKOUT – A portion of a wall of a sheet metal enclosure so fashioned that it may be removed readily by a hammer, screwdriver, and pliers at the time of installation in order to provide a hole for the attachment auxiliary device or raceway, cable, or fitting.

5.30 LEAKAGE CURRENT – Electric current which flows through a person upon contact between accessible parts of a device and ground or between accessible parts of a device and other accessible parts of the device.

5.31 LIMITED ENERGY CIRCUIT – An ac or dc circuit having a voltage not exceeding 1000 V and the energy limited to 100 volt-amperes by a means provided as part of the design.

5.32 LIVE PART – A conductive part, such as metal, within the device that during intended use has a potential difference with respect to earth ground or any other conductive part.

5.33 LOW-VOLTAGE, LIMITED-ENERGY (LVLE) CIRCUIT – A circuit involving an alternating current voltage of not more than 30 volts, rms (42.4 volts peak) or a direct current voltage of not more than 60 volts and supplied by:

a) An inherently limited Class 2 transformer or power unit or a not inherently limited Class 2 transformer or power unit and a fuse or other circuit protective device that is:

1) Not of the automatic reclosing type;

2) Trip-free from the reclosing mechanism; and

3) Either not readily interchangeable with a device of a different rating or has a marking in accordance with 74.9; or

b) A combination of an isolated transformer secondary winding and one or more resistors or a regulating network complying with 25.1.12 that complies with all the performance requirements for an inherently limited Class 2 transformer or power source.

5.34 OUTPUT CABLE TO THE ELECTRIC VEHICLE – An assembly consisting of a length of flexible EV cable and an electric vehicle connector (supplying power to the electric vehicle)§

§ Reprinted with permission from NFPA 70®-2014, *National Electrical Code*®, Copyright © 2013, National Fire Protection Association, Quincy, MA. This is not the complete and official position of the NFPA on the referenced subject which is represented solely by the standard in its entirety.

5.35 OVERVOLTAGE CATEGORY – A grouping of products based on typical installed location with respect to overvoltage protection and available energy.

5.36 POLLUTION DEGREE – The level of pollution present at the location on or in a product where the clearance and creepage distance measurement is made, and can be controlled by design of the product. For example, enclosures can be used to achieve pollution degree 3, and encapsulation can be used to achieve pollution degree 1.

5.37 POWER OUTLET, ELECTRIC VEHICLE (EV) – A device that is permanently wired and intended to provide a receptacle where there was previously no accessible receptacle. This product may be designated for indoor use only or indoor/outdoor use. The output of the device is a suitable receptacle and is intended for use with an EV Cord Set to charge electric vehicles. The vehicle owner would use the EV Power Outlet by plugging their EV Cord Set into the receptacle provided as the output of the EV Power Outlet.

5.38 PRIMARY CIRCUIT – Wiring and components that are conductively connected to the branch circuit.

5.39 PRIMARY SOURCE – The branch circuit to which the ac input of the device is connected.

5.40 SAFETY CIRCUIT – Any circuit that is used to reduce the risk of fire, electric shock, or injury to persons. For example, in some applications, an interlock circuit would be considered a safety circuit.

5.41 THREADED CONDUIT ENTRY – A conduit entry that is threaded so as to secure a rigid conduit without the use of a bushing or locknut.

5.42 TOOL – A screwdriver, coin, key or any other object that is used to operate a screw, latch, or similar fastening means.

5.43 VEHICLE CONNECTOR (EV CONNECTOR) – A device, which by insertion into a vehicle inlet, establishes an electrical connection to the electric vehicle for the purpose of providing power and information exchange. The device is provided with means for attachment of an EV cable. This device is part of the Vehicle Coupler.

5.44 VEHICLE COUPLER – The means enabling the connection, at will, of an EV cable to the vehicle. It consists of a Vehicle Connector and a Vehicle Inlet.

5.45 VEHICLE INLET – The part incorporated in, fixed to the vehicle, or intended to be fixed to it, which receives power from the vehicle connector. This device is part of the Vehicle Coupler.

CONSTRUCTION

6 General

6.1 EV cord sets

6.1.1 EV cord sets shall consist of an attachment plug, flexible power cord, personnel protection system with enclosure (see 6.1.2), EV cable, and a vehicle connector. For direct plug-in EV cord sets, the flexible power cord is not provided.

6.1.2 An EV cord set shall be provided with one or more enclosures that house all hazardous live parts, and energy hazardous circuits, excluding the flexible power cord or the EV cable. The enclosure shall protect the various parts of the device against mechanical damage from forces external to the EV Cord Set and shall protect the user from contact with internal hazardous parts. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, and access to hazardous energy shall comply with the applicable enclosure requirements specified in this Standard. See 6.1.3.

6.1.3 EV Cord Sets shall be investigated based on the intended use of the device. Intended use is defined as portable, intended for indoor/outdoor use.

See 45.3 and Annex B for a list of applicable tests for each intended use classification. Construction requirements will specify which classification is required to comply with that specific requirement. Construction requirements with no specification apply to all classification types. All EV cord sets shall be evaluated based on an expected operating ambient of minus 30 °C to 40 °C (minus 22 °F to 104 °F).

6.1.4 The frame or chassis of the device shall not be used to carry current during intended operation.

6.2 EV charging stations

6.2.1 EV charging stations shall be provided with a suitable output connection consisting of either an EV receptacle or an Output Cable to the Electric Vehicle.

6.2.2 EV charging stations shall be provided with enclosures that house all hazardous live parts, and energy hazardous circuits, excluding the flexible power cord and the EV cable. The enclosure shall protect the various parts of the device against mechanical damage from forces external to the EV charging station. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, and access to hazardous energy shall comply with the applicable enclosure requirements specified in this Standard. See 6.2.3.

6.2.3 EV charging stations shall be investigated based on the intended use of the charging station. Intended use shall be classified as one of the following:

a) Indoor use only, fastened in place;

b) Indoor/outdoor use, fastened in place;

c) Indoor use only, fixed in place; or

d) Indoor/outdoor use, fixed in place.

See 45.3 and Annex B for a list of applicable tests for each intended use classification. Construction requirements will specify which classification is required to comply with that specific requirement. Construction requirements with no specification apply to all classification types. All EV charging stations shall be evaluated based on an expected operating ambient of minus 30 °C to 40°C (minus 22 °F to 104 °F).

6.2.4 The frame or chassis of the device shall not be used to carry current during intended operation.

6.2.5 In the United States, metering devices incorporated into EV charging stations shall comply with the applicable requirements in Annex A, Ref. No. 7 or in Annex A, Ref. No. 8. In Canada and Mexico, this does not apply – see 3.1.

6.3 EV power outlets

6.3.1 EV power outlets shall have a suitably rated grounding type, non-locking type receptacle in accordance with Annex A, Ref. No. 27 provided as its output connection to the electric vehicle.

6.3.2 EV power outlets shall be provided with enclosures that house all hazardous live parts, and all energy hazardous circuits. The enclosure shall protect the various parts of the device against mechanical damage from forces external to the enclosure, and shall protect the user from contact with internal hazardous parts. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, and access to hazardous energy shall comply with the applicable enclosure requirements specified in this Standard. See 6.3.3.

6.3.3 EV power outlets shall be investigated based on the intended use of the device. Intended use shall be classified as indoor-use only, fixed in place EV power outlets, or indoor/outdoor-use fixed in place EV power outlets. See 45.3 and Annex B for a list of applicable tests for each intended use classification. Construction requirements will specify which classification is required to comply with that specific requirement. Construction requirements with no specification apply to all classification types. All EV power outlets shall be evaluated based on an expected ambient of minus 30 °C to 40 °C (minus 22 °F to 104 °F).

6.3.4 The frame or chassis of the device shall not be used to carry current during intended operation.

6.3.5 In the United States, metering devices incorporated into EV power outlets shall comply with the applicable requirements in Annex A, Ref. No. 7 or Annex A, Ref. No. 8. In Canada and Mexico, this does not apply – see 3.1.

7 Frame and Enclosure

7.1 General

7.1.1 An enclosure shall be formed and assembled so that it has the strength and rigidity required to resist the abuses to which it may be subjected without resulting in a risk of fire or electrical shock due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other defects.

7.1.2 The enclosure shall prevent molten metal, burning insulation, flaming particles, or similar materials from falling on combustible materials outside the enclosure.

7.1.3 A part, such as a dial, display face, or nameplate, that serves as a functional part of the enclosure shall comply with the enclosure requirements in this Standard.

7.1.4 A product that is intended for use in a commercial garage and contains a component that produces arcing or sparking, such as a snap switch, a relay, or a receptacle, shall have that component inherently located a specified height above the floor as described below. For products where these components are not inherently located above this specified height, the requirements in 7.1.6 – 7.1.7 apply.

a) For Mexico and the United States, arcing and sparking parts shall be inherently located at least 457 mm (18 inches) above the floor.

b) For Canada, arcing and sparking parts shall be inherently located at least 50 mm (2 inches) above the floor.

7.1.5 Arcing and sparking components that have been evaluated and found to be suitable for use in a Class 1, Division 2 location using one of the following Standards, need not comply with 7.1.4:

a) Annex A, Ref. No. 9, or

b) Annex A, Ref. No. 10.

7.1.6 With reference to 7.1.4, products that are intended to be carried by hand and are capable of being placed on the floor and which would allow arcing and sparking components to be located less than 457 mm (18 inches) in the United States and Mexico, or 50 mm (2 inches) in Canada from the floor shall be marked in accordance with 74.10.

7.1.7 With reference to 7.1.4, products that are intended to be floor supported and contain arcing and sparking components inherently located above 457 mm (18 inches) in the United States and Mexico, or 50 mm (2 inches) in Canada shall be marked in accordance with 74.13.

7.1.8 All enclosures shall be rated for a specific degree of environmental protection as outlined in 7.7.

7.2 Access covers

7.2.1 An access cover shall be hinged where it gives access to a fuse or other overload protective device located in a hazardous live circuit, the functioning of which requires renewal or resetting by the user, or where it is required for the user to open the cover in connection with intended operation of the device. A means shall be provided to hold the cover positively closed.

7.2.2 A door or cover giving access to a fuse shall be tight fitting.

7.3 Metallic enclosures

7.3.1 General

7.3.1.1 A metallic enclosure shall comply with the requirements for mechanical strength in 7.6.

7.3.1.2 A metallic enclosure constructed of aluminum, steel, stainless steel, or similar metals is considered to comply with flammability requirements without test. Magnesium shall not be used as an enclosure material.

7.3.1.3 A metallic enclosure shall comply with the applicable environmental considerations for the intended use in accordance with 7.7.

7.3.2 Cast metal enclosures

7.3.2.1 Except as indicated in 7.3.2.2, the thickness of cast metal for an enclosure shall be as specified in Table 7.1.

7.3.2.2 Die cast metal and cast metal of a lesser thickness may be employed when upon investigation it is found to have equivalent mechanical strength as the metals described in Table 7.1 for the intended use.

Table 7.1
Thickness of Cast-Metal Enclosures

Use, or dimension of area involved	Minimum thickness, mm (inch)			
	Die-cast metal		Cast metal of other than the die-cast type	
Area of 154.8 cm^2 (24 square inches) or less and having no dimension greater than 152 mm (6 inches)	1.6[a]	(1/16)	3.2	(1/8)
Area greater than 154.8 cm^2 (24 square inches) or having any dimension greater than 152 mm (6 inches)	2.4	(3/32)	3.2	(1/8)
At a threaded conduit hole	6.4	(1/4)	6.4	(1/4)
At an unthreaded conduit hole	3.2	(1/8)	3.2	(1/8)

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

7.3.3 Sheet metal enclosures

7.3.3.1 Sheet metal enclosures shall comply with the requirements in Annex A, Ref. No. 11, or 7.3.3.2 – 7.3.3.5.

7.3.3.2 With reference to 7.3.3.1, the thickness of a sheet metal enclosure shall not be less than that specified in Table 7.2 and Table 7.3.

7.3.3.3 Table 7.2 and Table 7.3 are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

7.3.3.4 With reference to Table 7.2 and Table 7.3, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has the same outside dimensions as the enclosure surface and that has the torsional rigidity to resist the bending moments that are applied via the enclosure surface. A construction has equivalent reinforcement when it produces a structure that is as rigid as one built with a frame of angles or channels.

7.3.3.5 With reference to 7.3.3.4 and Table 7.2 and Table 7.3, a construction does not have a supporting frame when it is:

a) A single sheet with single formed flanges – formed edges;

b) A single sheet that is corrugated or ribbed;

c) An enclosure formed or fabricated from sheet metal; or

d) An enclosure surface loosely attached to a frame – for example, by spring clips.

Table 7.2
Thickness of Carbon Steel or Stainless Steel Enclosures

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness mm (inch)			
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,					
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	Uncoated		Metal coated	
10.2	(4.0)	Not limited		15.9	(6.25)	Not limited		0.51	(0.020)[d]	0.58	(0.023)[d]
12.1	(4.75)	14.6	(5.75)	17.1	(6.75)	21.0	(8.25)				
15.2	(6.0)	Not limited		24.1	(9.5)	Not limited		0.66	(0.026)[d]	0.74	(0.029)[d]
17.8	(7.0)	22.2	(8.75)	25.4	(10.0)	31.8	(12.5)				
20.3	(8.0)	Not limited		30.5	(12.0)	Not limited		0.81	(0.032)	0.86	(0.034)
22.9	(9.0)	29.2	(11.5)	33.0	(13.0)	40.6	(16.0)				
31.8	(12.5)	Not limited		49.5	(19.5)	Not limited		1.07	(0.042)	1.14	(0.045)
35.6	(14.0)	45.7	(18.0)	53.3	(21.0)	63.5	(25.0)				
45.7	(18.0)	Not limited		68.6	(27.0)	Not limited		1.35	(0.053)	1.42	(0.056)
50.8	(20.0)	63.5	(25.0)	73.7	(29.0)	91.4	(36.0)				
55.9	(22.0)	Not limited		83.8	(33.0)	Not limited		1.52	(0.060)	1.60	(0.063)
63.5	(25.0)	78.7	(31.0)	88.9	(35.0)	109.2	(43.0)				
63.5	(25.0)	Not limited		99.1	(39.0)	Not limited		1.70	(0.067)	1.78	(0.070)
73.7	(29.0)	91.4	(36.0)	104.1	(41.0)	129.5	(51.0)				
83.8	(33.0)	Not limited		129.5	(51.0)	Not limited		2.03	(0.080)	2.13	(0.084)
103.4	(38.0)	119.4	(47.0)	137.2	(54.0)	167.6	(66.0)				
106.7	(42.0)	Not limited		162.6	(64.0)	Not limited		2.36	(0.093)	2.46	(0.097)
119.4	(47.0)	149.9	(59.0)	172.7	(68.0)	213.4	(84.0)				
132.1	(52.0)	Not limited		203.2	(80.0)	Not limited		2.74	(0.108)	2.82	(0.111)
152.4	(60.0)	188.0	(74.0)	213.4	(84.0)	261.6	(103.0)				
160.0	(63.0)	Not limited		246.4	(97.0)	Not limited		3.12	(0.123)	3.20	(0.126)
185.4	(73.0)	228.6	(90.0)	261.6	(103.0)	322.6	(127.0)				

[a] See 7.3.3.4 and 7.3.3.5.

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

[c] "Not limited" applies only when the edge of the surface is flanged at least 12.7 mm (1/2 inch) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet steel for an enclosure intended for outdoor use shall not be less than 0.86 mm (0.034 inch) thick when metal coated and not less than 0.81 mm (0.032 inch) thick when uncoated.

Table 7.3
Thickness of Aluminum, Copper, or Brass Enclosures

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness mm (inches)
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	
7.6	(3.0)	Not limited		17.8	(7.0)	Not limited		0.58[d]
8.9	(3.5)	10.2	(4.0)	21.6	(8.5)	24.1	(9.5)	(0.023)
10.2	(4.0)	Not limited		25.4	(10.0)	Not limited		0.74
12.7	(5.0)	15.2	(6.0)	26.7	(10.5)	34.3	(13.5)	(0.029)
15.2	(6.0)	Not limited		35.6	(14.0)	Not limited		0.91
16.5	(6.5)	20.3	(8.0)	38.1	(15.0)	45.7	(18.0)	(0.036)
20.3	(8.0)	Not limited		48.3	(19.0)	Not limited		1.14
24.1	(9.5)	29.2	(11.5)	53.3	(21.0)	63.5	(25.0)	(0.045)
30.5	(12.0)	Not limited		71.1	(28.0)	Not limited		1.47
35.6	(14.0)	40.6	(16.0)	76.2	(30.0)	94.0	(37.0)	(0.058)
45.7	(18.0)	Not limited		106.7	(42.0)	Not limited		1.91
50.8	(20.0)	63.4	(25.0)	114.3	(45.0)	139.7	(55.0)	(0.075)
63.4	(25.0)	Not limited		152.4	(60.0)	Not limited		2.41
73.7	(29.0)	91.4	(36.0)	162.6	(64.0)	198.1	(78.0)	(0.095)
94.0	(37.0)	Not limited		221.0	(87.0)	Not limited		3.10
106.7	(42.0)	134.6	(53.0)	236.2	(93.0)	289.6	(114.0)	(0.122)
132.1	(52.0)	Not limited		312.4	(123.0)	Not limited		3.89
152.4	(60.0)	188.0	(74.0)	330.2	(130.0)	406.4	(160.0)	(0.153)

[a] See 7.3.3.4 and 7.3.3.5.

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

[c] "Not limited" applies only when the edge of the surface is flanged at least 12.7 mm (1/2 inch) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet copper, brass, or aluminum for an enclosure intended for outdoor use shall not be less than 0.74 mm (0.029 inch) thick.

7.4 Nonmetallic enclosures

7.4.1 General

7.4.1.1 A nonmetallic enclosure shall comply with the requirements for mechanical strength in 7.6.

7.4.1.2 Nonmetallic materials used in the construction of enclosures shall have a flammability rating in accordance with Flammability, Section 18.

7.4.1.3 A nonmetallic enclosure shall comply with the applicable environmental considerations for the intended use in accordance with 7.7.

7.4.1.4 Enclosures of molded or formed thermoplastic material shall be constructed so that any shrinkage or distortion of the material over time will not allow for the user to be exposed to hazardous live parts. Compliance is determined by the Mold Stress Test, Section 66.

7.4.1.5 The minimum thickness of a nonmetallic enclosure shall be such as to comply with the requirements of 7.4.1.1 – 7.4.1.4.

7.4.1.6 A polymeric material enclosure having in any single unbroken section, a projected surface area greater than 0.93 m^2 (10 square feet) or a single linear dimension greater than 1.83 m (6 feet) shall have a flame-spread rating of 200 or less when tested in accordance with:

a) Annex A, Ref. No. 12, or

b) Annex A, Ref. No. 13.

7.4.2 Electrical properties

7.4.2.1 A polymeric material used for enclosures of live parts shall comply with Table 7.4.

7.4.2.2 A polymeric material which encloses insulated live parts where the insulation thickness is greater than 0.071 mm (0.028 inch), need not comply with the HWI requirements listed in Table 7.4.

7.4.2.3 A polymeric material used in an enclosure that is separated through air by more than 0.8 mm (1/32 inch) from uninsulated live parts and more than 12.7 mm (1/2 inch) from arcing parts need not comply with the requirements in 7.4.2.1.

Table 7.4
Comparative Tracking Index (CTI) Hot Wire Ignition (HWI) and High-Current Arc Resistance to Ignition (HAI) Ratings of Insulating Materials

	CTI		HWI[b]		HAI[c,d]	
Flammability classification[a, d]	Voltage (V)	PLC	Mean ignition time (sec)	PLC	Mean no. of arcs	PLC
V-0, VTM-0	175 to 249	3	7 and up to 15	4	15 and up to 30	3
V-1, VTM-1	175 to 249	3	15 and up to 30	3	30 and up to 60	2

[a] Flammability Classification – described in Annex A, Ref. No. 15.

[b] Hot Wire Resistance to Ignition – described in Annex A, Ref. No. 14.

[c] High-Current Arc Resistance to Ignition – described in Annex A, Ref. No. 14.

[d] A material rated 5VA or 5VB which also carries a V-0 rating shall apply the values for a V-0 rating. A material rated 5VA or 5VB with no additional V-0 rating shall apply the values for a V-1 rating.

7.4.3 Thermal properties

7.4.3.1 Except as indicated in 7.4.3.2, a polymeric material used for the enclosure of live parts shall have a relative thermal index rating higher than the temperature observed on that polymeric part during the Temperature Test, Section 49, for the specific application of the insulating material.

7.4.3.2 This requirement does not apply to epoxy potting materials.

7.5 Openings in enclosures

7.5.1 General

7.5.1.1 The enclosure of a device shall be designed and constructed to reduce the risk of emission of flame, molten metal, flaming or glowing particles, or flaming drops.

7.5.1.2 Enclosures, regardless of the materials, shall not be provided with ventilation openings unless designated as Type 1 or Type 2 enclosures.

7.5.2 Enclosure top ventilation openings

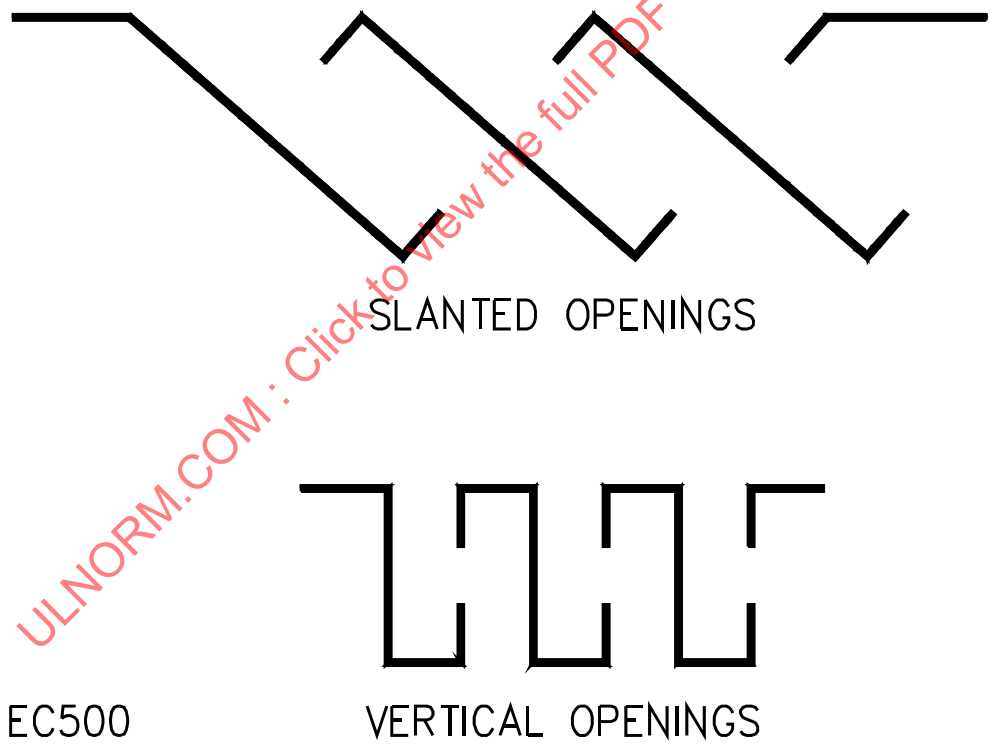
7.5.2.1 Except as indicated in 7.5.2.2, the minor dimension – see 7.5.2.3 – of any ventilation opening in the top of an enclosure directly over an uninsulated live part involving a risk of electric shock shall not exceed 4.8 mm (3/16 inch) unless the configuration is such that the risk of direct vertical entry of a falling object to uninsulated live parts is reduced by means of a trap or restriction. See Figure 7.1 for examples of top surface ventilation openings that reduce the risk of direct entry.

7.5.2.2 The 4.8 mm (3/16 inch) limitation specified in 7.5.2.1 does not apply for ventilation openings located 1.8 m (6 feet) or higher from the floor, when the device is installed in accordance with the manufacturer's instructions. Such ventilation openings shall comply with the accessibility requirements in Protection of Users – Accessibility and User Servicing, Section 8.

7.5.2.3 With reference to the requirement in 7.5.2.1, the minor dimension of a ventilation opening is the diameter of the largest cylindrical probe that is capable of being inserted through the opening.

Figure 7.1

Cross Section of Top Opening Designs



7.5.3 Enclosure side ventilation openings

7.5.3.1 The ventilation openings on the sides of an enclosure shall comply with one of the following:

a) They shall not exceed 4.8 mm (3/16 inch) in any dimension;

b) They shall not exceed 1 mm (0.04 inch) in width regardless of length;

c) They shall be provided with louvers that are shaped to deflect outwards an external vertically falling object – see Figure 7.2; or

d) They shall be so located that an object, upon entering the enclosure, is unlikely to fall on uninsulated live parts involving a risk of fire or electric shock – see 7.5.3.2.

7.5.3.2 Where a portion of the side of the enclosure falls within the area as traced out by the 5° angle in Figure 7.3, the limitations for bottom ventilation openings shall apply to that portion of the side.

Figure 7.2

Examples of Louver Designs

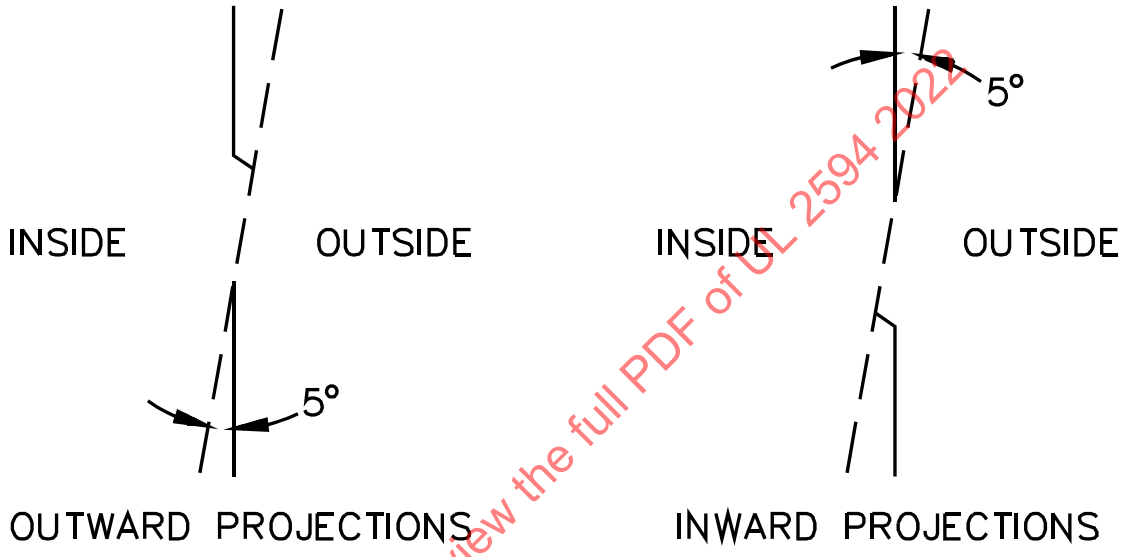
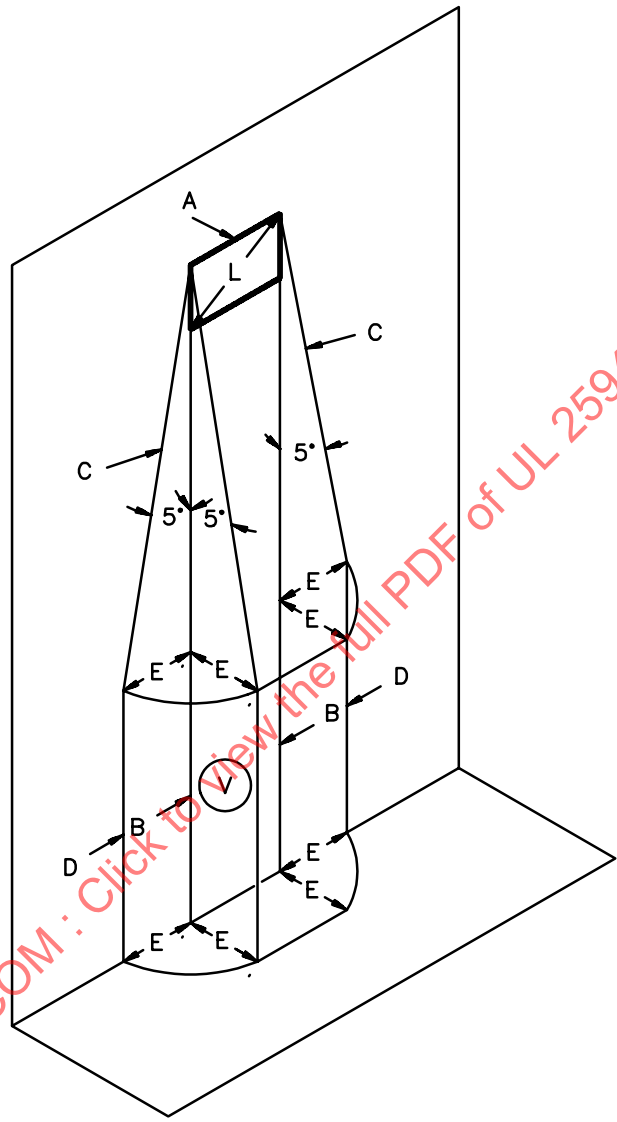


Figure 7.3

Cross Section of Side Opening Designs



S3162A

A – Enclosure side opening

B – Vertical projection of the outer edges of the side opening

C – Inclined lines that project as a 5° angle from the edges of the side opening to points located E distance from B

D – Line which is projected straight downward in the same plane as the enclosure side wall

E – Projection of the opening (not to be greater than L)

L – Maximum dimension of the enclosure side opening

V – Volume in which bare parts at hazardous voltage are not located

7.5.4 Enclosure bottom ventilation openings

7.5.4.1 Except as indicated in 7.5.4.2 – 7.5.4.4, the requirement in 7.5.1.1 requires a complete noncombustible bottom or a construction employing individual noncombustible barriers under components, groups of components, or assemblies, as specified in Figure 7.4.

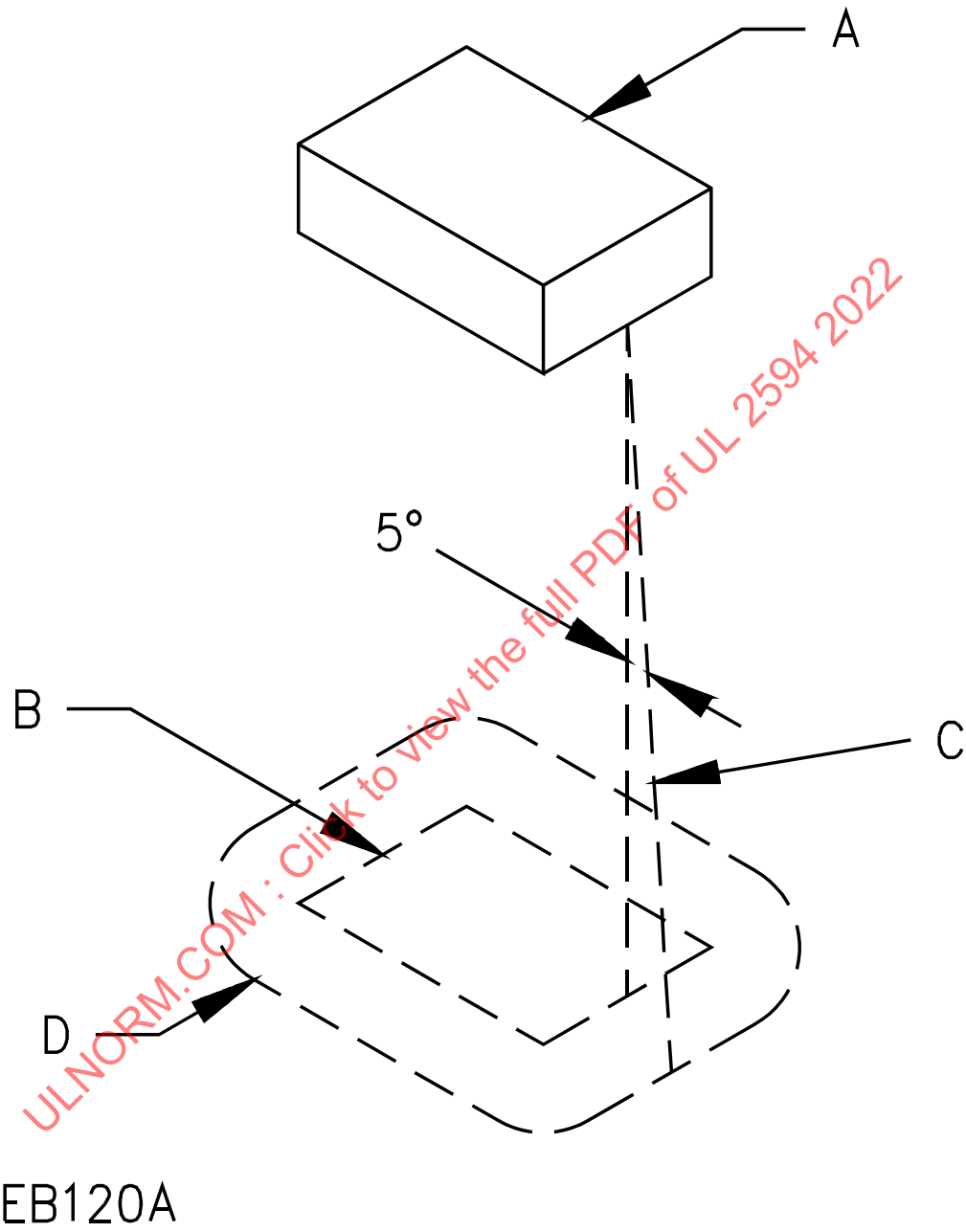
7.5.4.2 Ventilation openings in the bottom panel are allowed when noncombustible baffle plates are provided to reduce the risk of materials from falling directly from the interior of the device onto the supporting surface or any other location under the device. An example of such a baffle is illustrated in Figure 7.5.

7.5.4.3 Ventilation openings in the bottom of an enclosure are also allowed when the openings incorporate a perforated metal plate as described in Table 7.5, or a galvanized or stainless steel screen having a 2 by 2 mesh per millimeter (14 by 14 mesh per inch) constructed of wire with a diameter of 0.4 mm (0.018 inch) minimum.

7.5.4.4 Products intended to be mounted on a noncombustible surface, where the noncombustible surface completes the enclosure, are not required to comply with 7.5.4.1 when marked in accordance with 74.22.

Figure 7.4

Enclosure Bottom



A – Region to be shielded by barrier. This consists of the entire component when it is not otherwise shielded, and of the unshielded portion of a component which is partially shielded by the component enclosure or equivalent.

B – Projection of outline of component on horizontal plane.

C – Inclined line which traces out minimum area of barrier. When moving, the line is always: (1) tangent to the component, (2) 5° from the vertical, and (3) so oriented that the area traced out on a horizontal plane is maximum.

D – Location (horizontal) and minimum area for barrier. The area is that included inside the line of intersection traced out by the inclined line C and the horizontal plane of the barrier.