Association of Standardization and Certification
NMX-J-677-ANCE-2022
Third Edition

CSA Group
CSA C22.2 No. 280:22
Third Edition

Underwriters Laboratories Inc.
UL 2594
Third Edition

Standard for Electric Vehicle Supply Equipment

December 15, 2022

ANSI/UL 2594-2022

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.

ISBN 978-1-4883-4164-9 © 2022 Canadian Standards Association

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.

To purchase CSA Group Standards and related publications, visit CSA Group’s Online Store at www.csagroup.org/store/ or call toll-free 1-800-463-6727 or 416-747-4044.

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.

To purchase UL Standards, visit UL's Standards Sales Site at http://www.shopulstandards.com/HowToOrder.aspx or call toll-free 1-888-853-3503.

CONTENTS

PROTECTION OF USERS AGAINST INJURY

PERFORMANCE

MARKINGS

INSTRUCTIONS

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

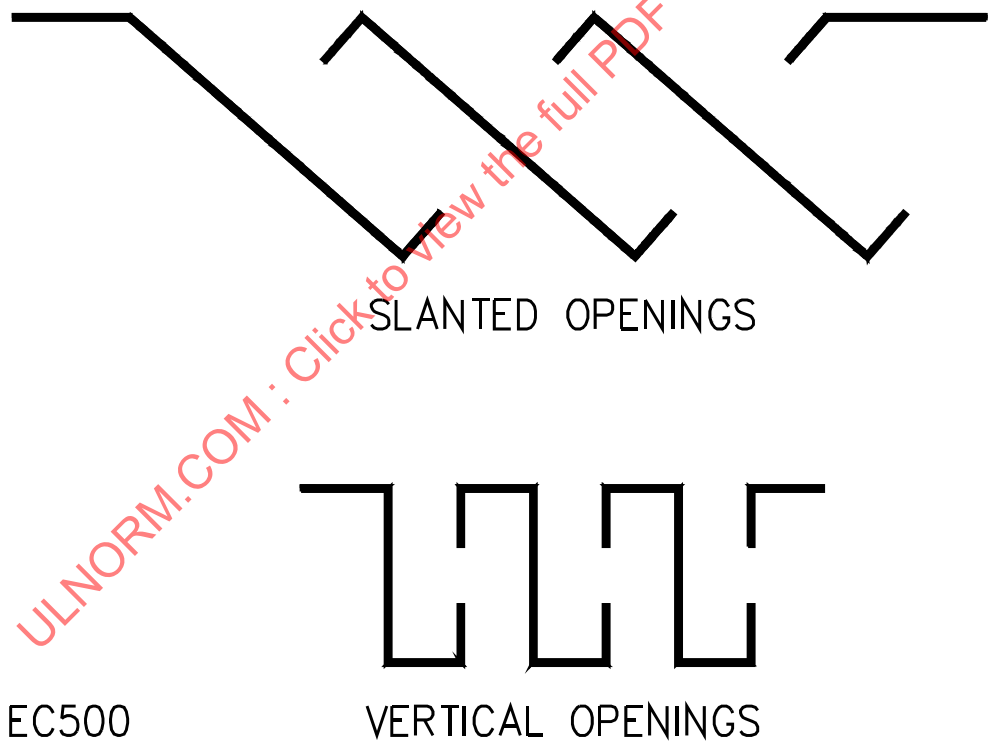
7.5.2.1 Except as indicated in 7.5.2.2, the minor dimension – see 7.5.2.3 – of any ventilation opening in the top of an enclosure directly over an uninsulated live part involving a risk of electric shock shall not exceed 4.8 mm (3/16 inch) unless the configuration is such that the risk of direct vertical 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

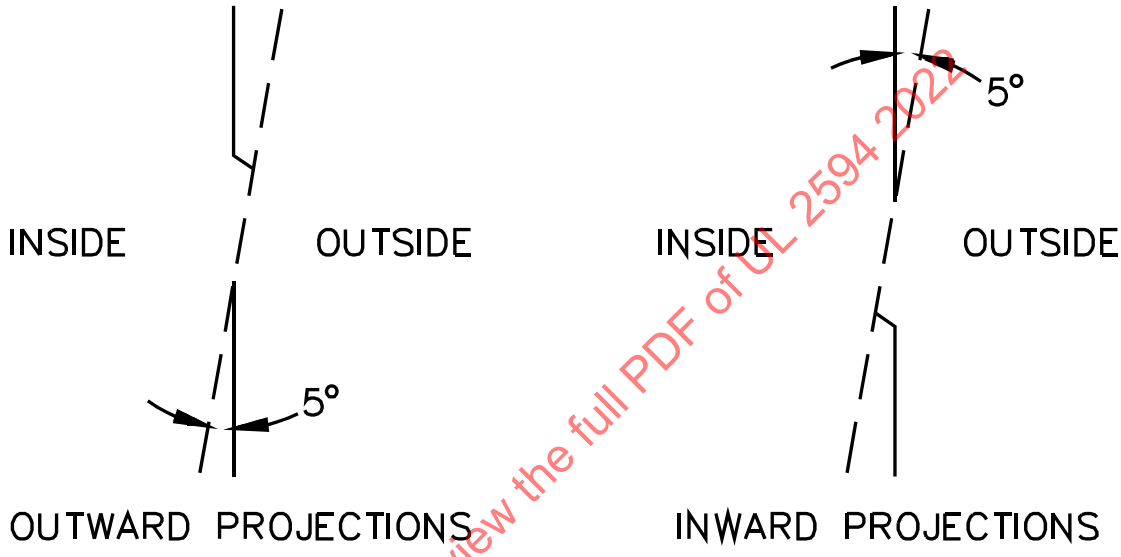
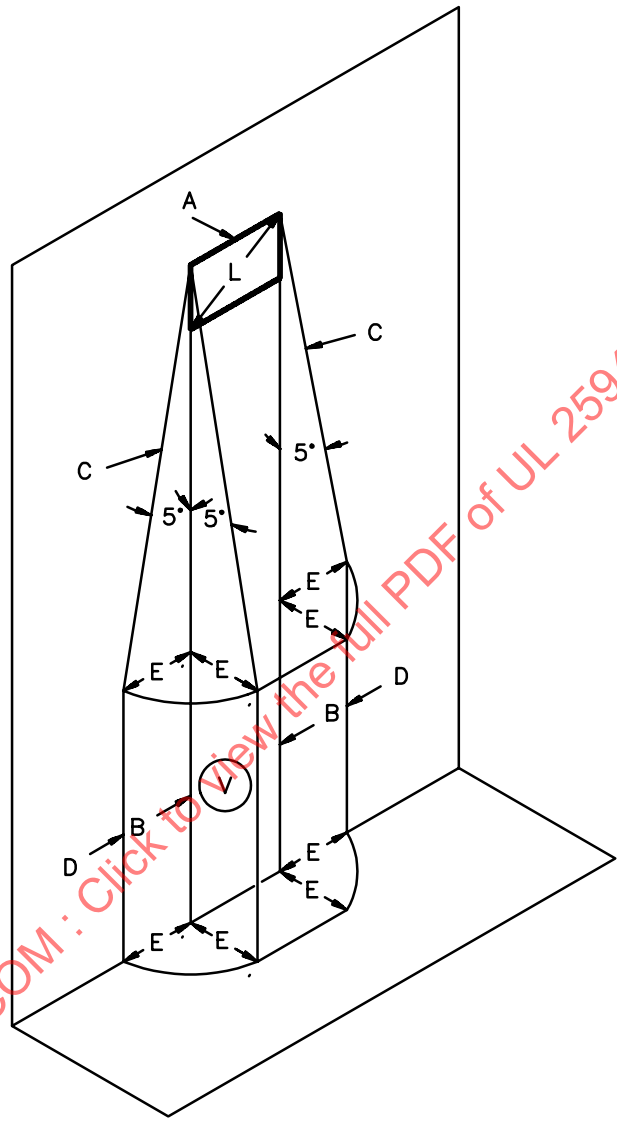


Figure 7.3

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.

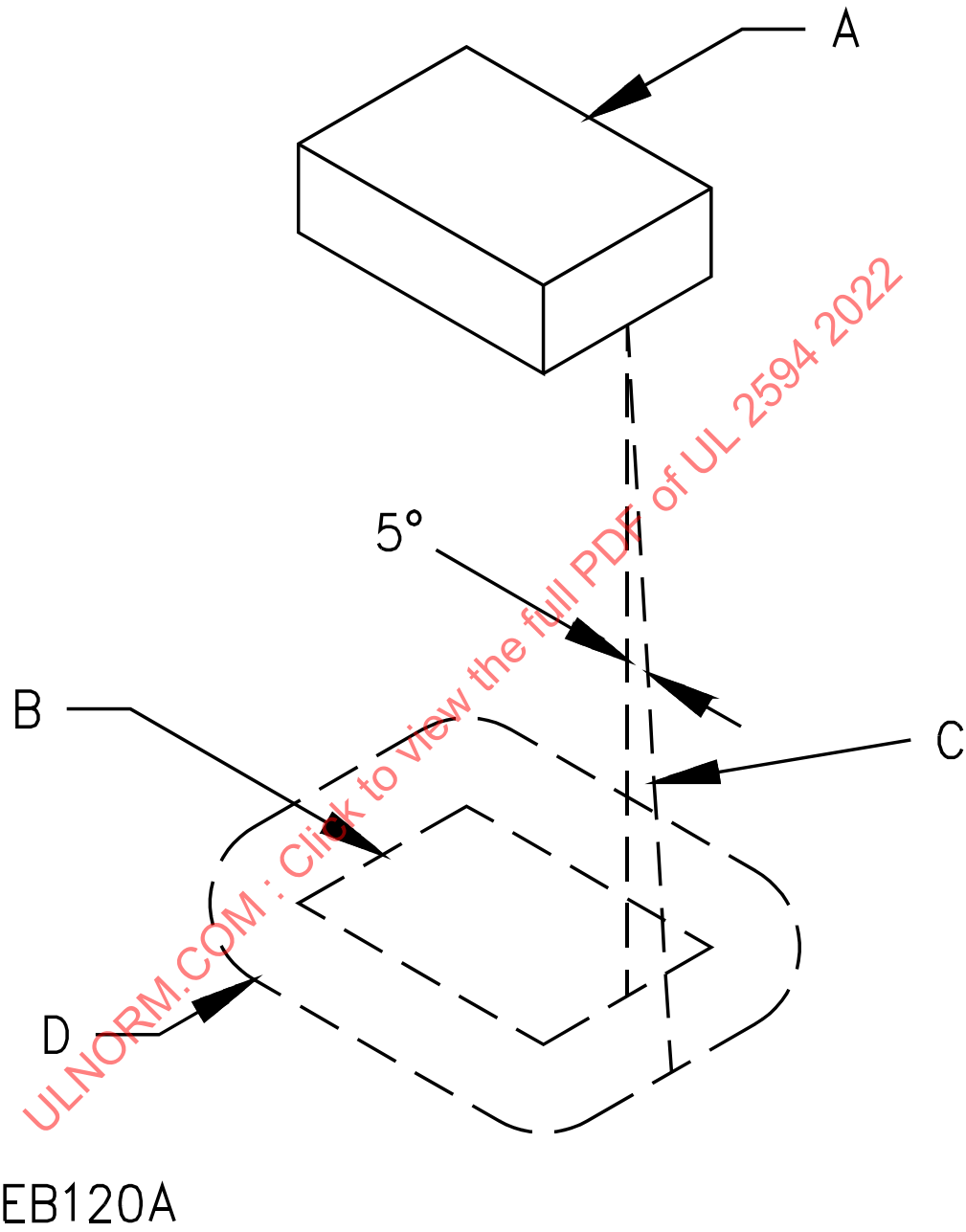
7.5.4.2 Ventilation openings in the bottom panel are allowed when noncombustible baffle plates are provided to reduce the risk of materials from falling directly from the interior of the device onto the supporting surface or any other location under the device. An example of such a baffle is illustrated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

Figure 7.5

Example of a Bottom-Enclosure Baffle

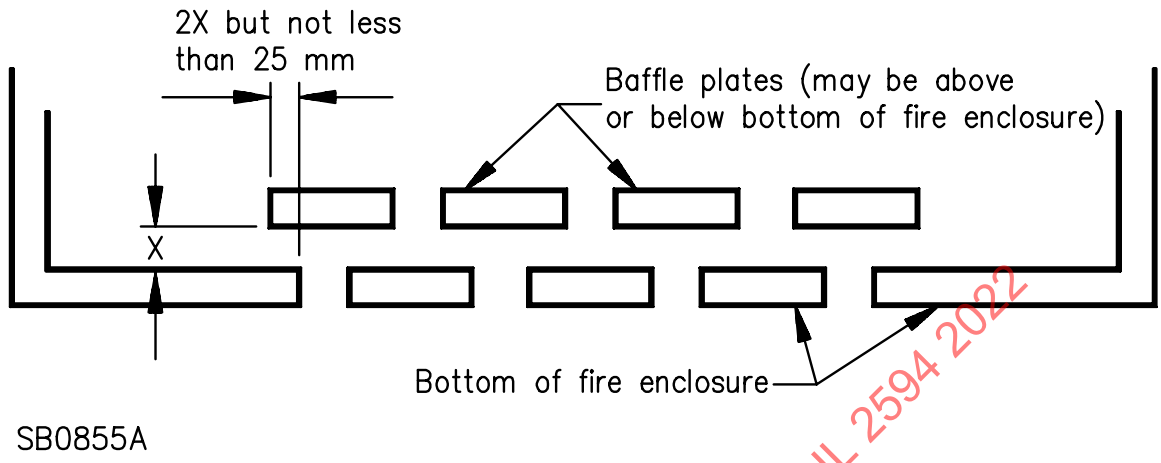


Table 7.5
Perforated Metal Plates for Enclosure Bottom

Minimum thickness,		Maximum diameter of holes,		Minimum spacings of holes center to center,	
mm	(inch)	mm	(inch)	mm	(inch)
0.66	(0.026)	1.14	(0.045)	1.70	(0.067)
				645 mm^2	(233 holes per inch^2)
0.66	(0.026)	1.19	(0.047)	2.36	(0.093)
0.76	(0.030)	1.14	(0.045)	1.70	(0.067)
0.76	0.030)	1.19	(0.047)	2.36	(0.093)
0.81	(0.032)	1.91	(0.075)	3.18	(0.125)
				645 mm^2	(72 holes per inch^2)
0.89	(0.035)	1.90	(0.075)	3.18	(0.125)
0.91	(0.036)	1.60	(0.063)	2.77	(0.109)
0.91	(0.036)	1.98	(0.078)	3.18	(0.125)
0.99	(0.039)	1.60	(0.063)	2.77	(0.109)
0.99	(0.039)	2.00	(0.079)	3.00	(0.118)

7.5.5 Openings for wiring

7.5.5.1 The requirements described in 7.5.5.2 – 7.5.5.11 apply to permanently connected units.

7.5.5.2 Enclosures shall be designed for use with appropriate conductor entry provisions to maintain the specified environmental capability of the particular enclosure type being evaluated.

7.5.5.3 When threads for the connection of conduit are tapped all the way through a hole in an enclosure wall or when an equivalent construction is employed, there shall not be less than three nor more than five threads in the metal, and the construction of the enclosure shall be such that a conduit bushing is capable of being attached as intended. When threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or similar material 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 equivalent to that

provided by a standard conduit bushing with an internal diameter the same as that of the corresponding trade size of rigid conduit.

7.5.5.4 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, and similar material that are supplied as a part of an enclosure shall comply with Annex A, Ref. No. 16 and No. 17.

7.5.5.5 A knockout in a sheet-metal enclosure shall be secured and shall be removable without undue deformation of the enclosure.

7.5.5.6 A knockout shall be provided with a flat surrounding surface so that the conduit bushing is capable of being seated as intended, and shall be located so that installation of a bushing at any knockout to be used during installation does not result in spacing between an uninsulated live part and the bushing to be less than that specified in Spacings, Section 22.

7.5.5.7 Knockouts shall not be provided in a Type 12 enclosure.

7.5.5.8 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as mentioned in 7.5.5.6, it shall be assumed that a bushing having the dimensions specified in Table 7.6 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

7.5.5.9 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum specified in Spacings, Section 22, shall be provided between uninsulated live parts and a conduit bushing installed at any location that shall be used during installation. Permanent marking on the enclosure, a template, or a drawing furnished with the device are ways to specify such a location. The specified location of the openings shall be such that damage to internal parts does not result when openings are made.

Table 7.6
Knockout or Hole Sizes and Dimensions Of Bushings

Metric designator (Trade size)		Knockout or hole diameter		Bushing dimensions			
				Overall diameter		Height	
mm	(inches)	mm	(inches)	mm	(inches)	mm	(inches)
16	(1/2)	22.2	(7/8)	25.4	(1)	9.5	(3/8)
21	(3/4)	27.8	(1-3/32)	31.4	(1-15/64)	10.7	(27/64)
27	(1)	34.5	(1-23/64)	40.5	(1-19/32)	13.1	(33/64)
35	(1-1/4)	43.7	(1-23/32)	49.2	(1-15/16)	14.3	(9/16)
41	(1-1/2)	50.0	(1-31/32)	56.0	(2-13/64)	15.10	(19/32)
53	(2)	62.7	(2-15/32)	68.7	(2-45/64)	15.9	(5/8)
63	(2-1/2)	76.2	(3)	81.8	(3-7/32)	19.1	(3/4)
78	(3)	92.1	(3-5/8)	98.4	(3-7/8)	20.6	(13/16)

7.5.5.10 With respect to the requirement in 7.5.5.9, means shall be provided so that an opening for conduit is capable of being made without subjecting internal parts to contamination resulting from the presence of metallic particles. Compliance with this requirement is possible by the use of a removable, bolted plate.

7.5.5.11 A polymeric- or metal-closure plug for an unused conduit opening shall comply with the requirements in Annex A, Ref. No. 16, and shall maintain the specified environmental capability of the enclosure in accordance with 7.5.5.2.

7.5.6 Drainage openings

7.5.6.1 Type 2 and 3R enclosures shall have provisions for drainage. Drainage openings shall not be less than 3.2 mm in diameter (1/8 inch in diameter) or more than 6.4 mm in diameter (1/4 inch in diameter), unless baffled or provided with a drainage fitting.

7.5.6.2 For Type 2 and 3R enclosures that also meet the requirements of other enclosure types, the drainage openings shall be closed by a removable plug, and instructions shall be provided in accordance with 78.5.

7.5.6.3 Type 2 and 3R enclosures that also meet the requirements of other enclosure types need not have drainage holes if the enclosure is provided with instructions in accordance with 78.6.

7.5.7 Openings for mounting

7.5.7.1 Any openings provided for mounting shall be external to the enclosure cavity or shall comply with 7.5.7.2 – 7.5.7.4.

7.5.7.2 In accordance with 7.5.7.1, for enclosure types 3, 3S, 4, 4X, 6, 6P, 12, 12K, and 13, the mounting means may pass through the enclosure wall into the enclosure cavity if it attaches to an intermediate bracket and is shown to comply with the Additional Environmental Tests, Section 67. The bracket shall then rely on separate mounting hardware to attach it to the building structure. The mounting means shall not have the same mounting hardware pass through the device cavity and attach directly to the building structure.

7.5.7.3 For enclosure types 1, 2, 3R, and 5, mounting means may be provided internal to the equipment cavity if the mounting openings comply with Table 7.7.

7.5.7.4 If mounting openings other than as noted in Table 7.7 are provided for Type 1, 2, 3R, or 5 enclosures, the installation instructions provided with the device shall indicate how to maintain the environmental integrity of the enclosure when mounted. See 77.4.

Table 7.7
Enclosure-Mounting Holes

Minimum linear dimension of enclosure mm (inches)	Area of largest surface of enclosure, mm^2 (square inches)	Maximum number of holes	Maximum total area of holes, mm^2 (square inches)
178 (7)	20, 600 (32)	4	774 (1.2)
457 (18)	87,000 (135)	6	774 (1.2)
1020 (40)	254,000 (1,000)	6	970 (1.5)
Over 1020 (40)	Over 254,000 (1,000)	8	1,290 (2.0)

7.5.8 Glass covered openings

7.5.8.1 Glass covering an opening shall be secured in place so that it is not readily displaced in service, and shall provide mechanical protection for the enclosed parts. Glass for an opening not more than 102 mm (4 inches) in any dimension shall not be less than 1.6 mm (1/16 inch) thick, and glass for an opening not more than 929 cm^2 (144 square inches) in area and having no dimension greater than 305 mm (12 inches) shall not be less than 3.2 mm (1/8 inch) thick. Glass used to cover an area larger than specified above shall not be less than 3.2 mm (1/8 inch) thick and shall:

a) Be of a nonshattering or tempered type that, when broken, complies with Annex A, Ref. No. 18; or

b) Be subjected to the test described in Section 61.

7.6 Mechanical strength of enclosures

7.6.1 An enclosure, whether metallic or nonmetallic, shall comply with the applicable strength of enclosure tests, including the Impact Test, Section 57, Vehicle Drive Over Test, Section 58, and Drop Test, Section 59. See Section 39.

7.7 Environmental considerations

7.7.1 All enclosures shall be rated for one of the enclosure types in Annex A, Ref. No. 19. The enclosure rating shall be appropriate for the intended conditions of use.

7.7.2 All enclosures shall comply with the applicable test requirements for the applicable enclosure type in accordance with Annex A, Ref. No. 19. In addition, the requirements in 7.7.3 – 7.7.5 shall apply to nonmetallic enclosures or metallic enclosures with coatings that require test.

7.7.3 All nonmetallic enclosures, or metallic enclosures with coatings that require test, that are intended for outdoor use shall comply with the UV Exposure Test in Annex A, Ref. No. 20.

7.7.4 For EV cord sets, all nonmetallic enclosures, or metallic enclosures with coatings that require test, shall be subjected to the Chemical Exposure Test, 67.4.

7.7.5 All nonmetallic enclosures, or metallic enclosures with coatings that require test, that are intended for use outdoors, shall be subjected to the Water Exposure Test, 67.2.

7.7.6 A gasket that is provided on an enclosure to meet the environmental construction and performance requirements for that enclosure type shall comply with the Gasket tests in Annex A, Ref. No. 19.

8 Protection of Users – Accessibility and User Servicing

8.1 General

8.1.1 The requirements in this section apply to parts that are accessible to the user. For protection of service personnel requirements, refer to Protection of Service Personnel, Section 32.

8.2 Accessibility

8.2.1 To reduce the risk of unintentional contact that results in electric shock from an uninsulated live part or film-coated wire, an opening in an enclosure shall comply with either:

a) For an opening that has a minor dimension less than 25.4 mm (1 inch), such a part or wire shall not be contacted by the probe illustrated in Figure 8.1, or

b) For an opening that has a minor dimension of 25.4 mm (1 inch) or more, such a part or wire shall be spaced from the opening as specified in Table 8.1.

Table 8.1
Minimum Required Distance From an Opening to a Part That Involves a Risk Of Electric Shock

Minor dimension of opening[a,b]		Minimum distance from opening to part[b]	
mm	(inches)	mm	(inches)
25.4	(1)	165.0	(6-1/2)
31.8	(1-1/4)	190.0	(7-1/2)
38.1	(1-1/2)	318.0	(12-1/2)
47.6	(1-7/8)	394.0	(15-1/2)
54.0	(2-1/8)	444.0	(17-1/2)
c		762.0	(30)

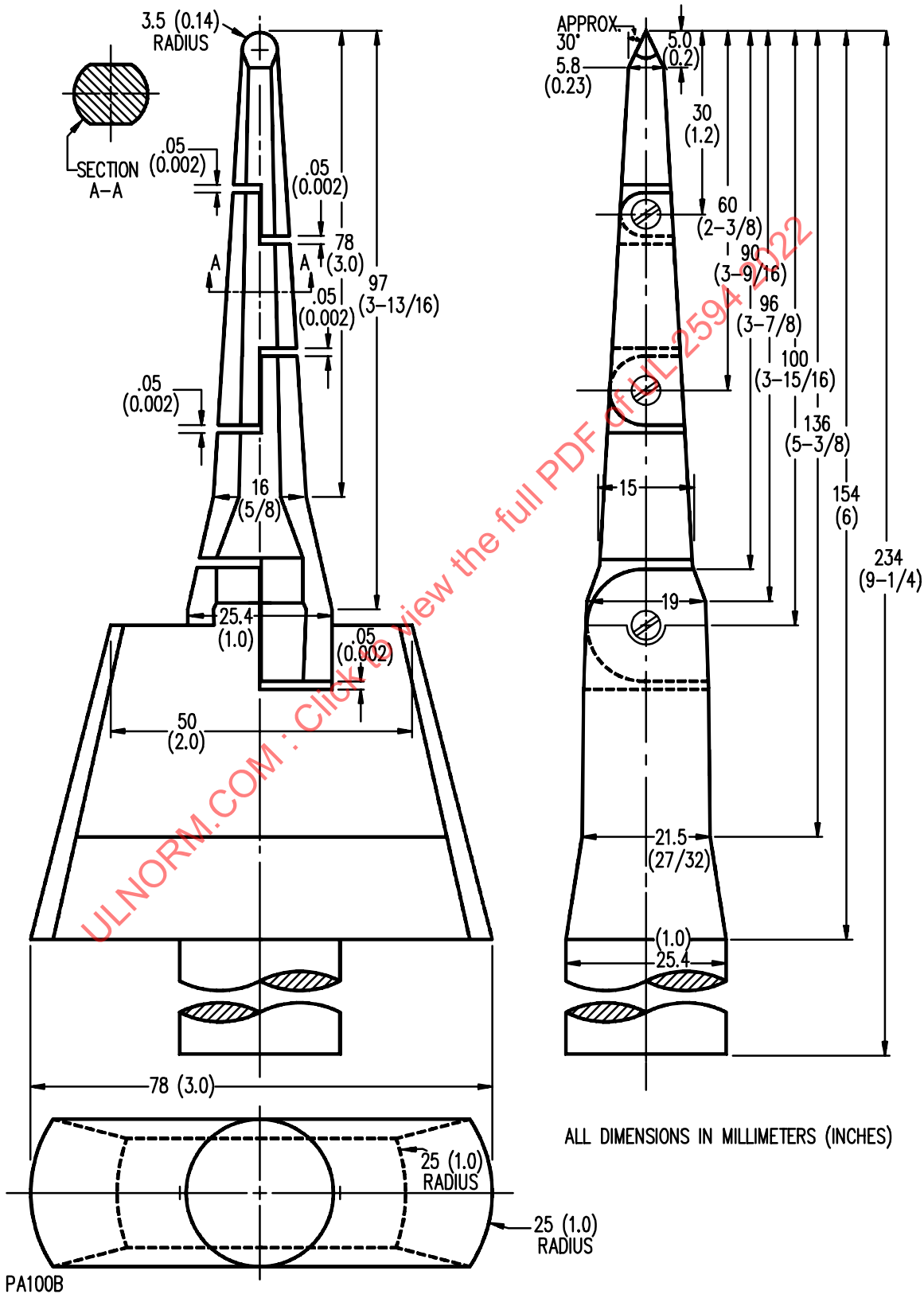
[a] See 8.2.4.

[b] Between 19.1 and 54 mm (3/4 and 2-1/8 inches), interpolation is to be used to determine a value between values specified in the table.

[c] More than 54 mm (2-1/8 inches), and not more than 152.0 mm (6 inches).

Figure 8.1

Articulate Probe



8.2.2 The probe specified in 8.2.1 and illustrated in Figure 8.1 shall be applied to any accessible depth of the opening and shall be rotated or angled before, during, and after insertion through the opening to any position that is required to examine the enclosure. The probe illustrated in Figure 8.1 shall be applied in any possible configuration; and, where required, the configuration shall be changed after insertion through the opening.

8.2.3 The probe mentioned in 8.2.2 shall be used as a measuring instrument to judge the accessibility provided by an opening, and not as an instrument to judge the strength of a material; it shall be applied with a maximum force of 4.4 N (1 pound).

8.2.4 With reference to the requirement in 8.2.1, the minor dimension of an opening is the diameter of the largest cylindrical probe that is capable of being inserted through the opening.

8.2.5 During the examination of a unit to determine whether it complies with the requirement in 8.2.1, a part of the enclosure that is capable of being opened or removed by the user without using a tool shall be opened or removed. A fastener, such as a slotted-head thumb screw, that is turned by hand, does not require the use of a tool.

8.3 User servicing

8.3.1 Service functions that are intended to be carried out by the user, in accordance with the User Maintenance Instructions, Section 79, shall comply with the requirements in 8.3.2 and 8.3.3.

8.3.2 The user shall not have access to any circuits or uninsulated parts that exceed the limits for an LVLE circuit. If the user is intended to access circuits or parts of the device above these limits, an interlock system shall be provided that will completely remove the hazard prior to the user accessing the area.

8.3.3 Any user servicing that is intended to be performed shall not require the use of a tool to access the area where the servicing is to be performed, unless the tool is specified and that tool cannot be used to access any other area of the device.

9 Protection Against Electric Shock

9.1 General

9.1.1 The user shall be protected against the risk of electric shock. All accessible circuits shall have a potential to earth not exceeding 42.4 V peak or 60 V dc.

9.1.2 In addition to the requirement in 9.1.1, the requirements in 9.2 and 9.3 also apply.

9.2 Personnel protection systems

9.2.1 Electric vehicle supply equipment, with the exclusion of EV Power Outlets, shall be provided with a personnel protection system. The personnel protection system shall comply with the requirements in Annex A, Ref. No. 21 and Annex A, Ref. No. 22.

9.2.2 The personnel protection system shall be protected by enclosing the components in an enclosure in accordance with Frame and Enclosure, Section 7.

9.2.3 The interrupting device provided as part of the personnel protection system in fixed in place EVSE can be located in any location. The interrupting device provided as part of the personnel protection system in cord connected EVSE is required to be located at the attachment plug or not more than indicated in (a) and (b) from the attachment plug:

a) For Mexico, 300 mm (12 inches) for all products.

b) For Canada, 1.8 m (6 feet) for all products.

c) For the US:

1) 300 mm (12 inches) for all portable EV Cord Sets; and

2) 1.8 m (6 feet) for fastened in place, cord connected EV Supply Equipment where the EVSE is mounted on a wall or ceiling with the cord managed so it cannot contact the floor. See Installation Instructions, Section 77.

9.3 Stored energy on capacitors

9.3.1 For cord connected products that contain filtering capacitors or other primary capacitors, the stored energy on the capacitors shall not constitute a hazard to the user. When the attachment plug is removed from the receptacle, stored charge on the capacitors can be discharged through the user if the blades of the attachment plug are contacted. The stored charge shall dissipate within one second, in accordance with the Capacitor Discharge Test, Section 50. If the total capacitance is not greater than 0.1 µF, then this test is not necessary.

10 Corrosion Protection Against Electric Shock

10.1 All enclosures shall be provided with the applicable corrosion protection outlined in Annex A, Ref. No. 19.

11 Mechanical Assembly

11.1 Loosening of parts as a result of handling and intended operation of the device shall not result in a risk of fire, a risk of electric shock, or a risk of injury to persons.

11.2 Screws with lock washers applied as intended, screws tightened by means of a power tool, rivets, and staked and upset screws are considered to comply without further evaluation. See 11.3.

11.3 The construction of staked and upset screws shall consist of an interference fit between the nut and bolt resulting in uneasy turning of the screw. This shall be accomplished by the use of a center punch applied to the end of a bolt after assembly, mismatching of the nut and bolt threads, or the equivalent.

11.4 Except as indicated in 11.5, a rotating part that, when loosened, results in a risk of fire, electric shock, or injury to persons shall be assembled so that the direction of the rotation tends to tighten the means that hold the rotating part in place.

11.5 A keyed part, a press fit, a part locked in place with a pin, or equivalent means to hold a rotating part in place is considered to comply with this requirement.

11.6 A switch, fuseholder, attachment plug, or other component that is handled by the operator shall be mounted securely, and shall not turn when handled. In addition, the connection shall comply with the requirements in 11.7.

11.7 The means of securing components mentioned in 11.6 shall include more than friction between surfaces. A lock washer is an example of a means to secure a device having a single hole mounting means.

12 Supply Connections

12.1 Permanently connected devices

12.1.1 General

12.1.1.1 Except as indicated in 12.1.1.2, a permanently connected device shall have provision for connection of a wiring system. This provision shall consist of either wiring terminals as specified in 12.1.1.4 – 12.1.2.15 or wiring leads as specified in 12.1.1.4 and 12.1.3.1 – 12.1.3.6 and a means for connection of cable or conduit as specified in 12.2.1.

In Canada, a supply cord may be provided subject to acceptance by the Authority Having Jurisdiction, if the power supply is marked in accordance with 72.18. In Mexico and the United States, this does not apply.

12.1.1.2 The requirements described in 12.1.1.4 – 12.1.3.6 do not apply to the means for connection to accessible signal circuits.

12.1.1.3 The requirement in 12.1.1.1 applies to the wiring connection means for alternating current and direct current power circuits of a device. These connections are intended to be made in the field when the device is installed.

12.1.1.4 A wiring terminal or lead shall be used for the connection of a conductor having an ampacity based on Annex A, Ref. No. 69.

12.1.2 Wiring terminals

12.1.2.1 A wiring terminal shall comply with the requirements in Annex A, Ref. No. 23 for a wire of each metal for which it is marked. See 72.12.

12.1.2.2 Except as indicated in 12.1.2.3 – 12.1.2.4, a wiring terminal shall be provided with a pressure terminal connector of other than the crimping type and the terminal shall be securely fastened in place – for example, firmly bolted or held by a screw.

12.1.2.3 A pressure terminal connector, including a crimping type, may be field installed in accordance with 12.1.2.7.

12.1.2.4 A wire binding screw may be employed at a wiring terminal intended for connection of a 10 AWG (5.3 mm^2) or smaller conductor where upturned lugs, a cupped washer, or the equivalent is provided to hold the wire in position.

12.1.2.5 Except as indicated in 12.1.2.6, a wiring terminal shall be prevented from turning or shifting in position by a means other than friction between surfaces. This shall be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method.

12.1.2.6 A pressure terminal connector of the type that secures the wire by crimping and used in accordance with the requirements in 12.1.2.7 may turn when the least spacing between adjacent terminals and also between terminals and dead metal parts complies with Spacings, Section 22, for when connectors are oriented in such a position that results in these spacings.

12.1.2.7 As allowed per 12.1.2.2 and 12.1.2.5, a pressure terminal connector is not required to be provided when the conditions in (a) – (e) are complied with:

a) One or more component terminal assemblies shall be available from the device manufacturer or others, and they shall be specified in the instruction manual. See 76.3(f).

b) The fastening hardware such as a stud, nut, bolt, spring, or flat washer, or similar part is mounted on or separately packaged with the device, or specified in the instruction manual.

c) The installation of the terminal assembly shall not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location. The means for securing the terminal connector shall be readily accessible for tightening before and after installation of conductors.

d) Where the pressure terminal connector provided in a terminal assembly requires the use of other than an ordinary tool for securing the conductor, the tool and any required instructions for using the tool shall be included with the device. See 76.3(h).

e) Installation of the pressure terminal connector in the intended manner shall result in a device complying with the requirements of this Standard.

12.1.2.8 An insulating base for support of a pressure terminal connector shall be subjected to the Strength of Terminal Insulating Base and Support Test, Section 60.

12.1.2.9 Except as indicated in 12.1.2.10, a wire binding screw at a field wiring terminal shall not be smaller than No. 10 (4.8 mm diameter).

12.1.2.10 A No. 8 (4.2 mm diameter) screw being used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) conductor, or a No. 8 or 6 (4.2 mm or 3.5 mm diameter) screw being used at a terminal intended for connection of a 16 or 18 AWG (1.3 or 0.82 mm^2) control circuit conductor, is allowed.

12.1.2.11 A wire binding screw shall thread into metal.

12.1.2.12 Except as indicated in 12.1.2.13, a terminal plate tapped for a wire binding screw shall be of metal not less than 1.27 mm (0.050 inch) thick.

12.1.2.13 A terminal plate less than 1.27 mm (0.050 inch) thick may be used in a low voltage, limited energy circuit when the tapped threads withstand the tightening torque specified in Table 12.1 without stripping.

Table 12.1
Tightening Torque for Wire-Binding Screws

Size of terminal screw, number	Wire sizes to be tested [a]		Tightening torque	
	mm^2	AWG	Newton meters	(Pound-inches)
6	1.31 – 0.824 (ST)	16 – 18 (ST)	1.4	(12)
8	2.08 (S) and 1.31 – 0.824 (ST)	14 (S) and 16 – 18 (ST)	1.8	(16)
10	5.26 – 2.08 (S) and 1.31 – 0.824 (ST)	10 – 14 (S) and 16 – 18 (ST)	2.3	(20)

[a] ST – stranded wire; S – solid wire.

12.1.2.14 There shall be two or more full threads in the metal of a terminal plate. When the metal is extruded at the tapped hole, at least two full threads shall be provided.

12.1.2.15 A terminal for connection of a grounded conductor of an alternating current power circuit shall be identified as described in 72.14.

12.1.3 Field wiring leads

12.1.3.1 A field wiring lead shall be rated for the voltage and temperature involved in normal use.

12.1.3.2 A field wiring lead shall be sized appropriately for the rated current anticipated in normal use.

12.1.3.3 A field wiring lead shall be subjected to the test specified in 54.2.4.

12.1.3.4 A field wiring lead provided for connection to an external line voltage circuit shall not be connected to a wire binding screw or pressure terminal connector located in the same compartment as the free end of the wiring lead unless the screw or connector is rendered unusable for field wiring connection or the lead is insulated at the unconnected end, and a marking is provided on the device in accordance with 72.15.

12.1.3.5 The free end of a field wiring terminal that is not used in every installation, such as a tap for a multivoltage transformer, shall be insulated.

12.1.3.6 A field wiring lead for connection of a grounded conductor shall be identified as described in 72.14.

12.1.4 Wiring compartments

12.1.4.1 A wiring compartment on a fixed device shall be located so that wire connections therein are accessible for inspection, without disturbing either factory or field connected wiring, after the device is installed in the intended manner.

12.1.4.2 Wiring compartments, raceways, or similar devices for routing and stowage of conductors connected in the field shall not contain rough, sharp, or moving parts that are capable of damaging conductor insulation.

12.1.5 Openings for conduit or cable connection

12.1.5.1 For a permanently connected device, openings for wiring and conduit shall comply with the requirements specified in 7.5.5.

12.1.6 Wire bending space

12.1.6.1 In Mexico and the United States, a permanently connected device employing pressure terminal connectors for field connection of circuits described in 12.1.1.3 shall be provided with space within the enclosure as specified in 12.1.6.3 – 12.1.6.7 for the installation of conductors, including grounding conductors that are employed in the installation.

In Canada, wire bending space shall comply with the requirements in Annex A, Ref. No. 24.

12.1.6.2 The conductor size used in judging the wiring space shall be based on the use of a conductor sized in accordance with 12.1.1.4.

12.1.6.3 Wire bending space for field installed conductors shall be provided opposite any pressure wire connector as specified in 12.1.6.4 or 12.1.6.5 and opening or knockout for a wireway or conduit in a gutter as specified in 12.1.6.9.

12.1.6.4 When a conductor is capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 12.2. A wire is capable of entering or leaving a top, back, bottom, or side surface when there is an opening for conduit or a wireway.

12.1.6.5 Where a conductor is not capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 12.3. The wire bending space is in accordance with Table 12.3 when a barrier is provided between the connector and the opening, or drawings are provided specifying that the conductors are not to enter or leave the enclosure directly opposite the wire connector. See illustrations A, B, and C of Figure 12.1.

Table 12.2
Minimum Wire-Bending Space for Conductors Through a Wall Opposite Terminals in mm (inches)

Wire size		Wires per terminal (pole)[a]											
AWG or kcmil	mm²	1		2			3			4 or more			
14 –10 AWG	2.1 – 5.3	Not Specified		–			–			–			
8	8.4	38.1	(1-1/2)	–			–			–			
6	13.3	50.8	(2)	–			–			–			
4	21.1	76.2	(3)	–			–			–			
3	26.7	76.2	(3)	–			–			–			
2	33.6	88.9	(3-1/2)	–			–			–			
1	42.4	114	(4-1/2)	–			–			–			
0	53.5	140	(5-1/2)	140			179		(7)	–			
2/0	67.4	152	(6)	152			191		(7-1/2)	–			
3/0	85.0	165	(6-1/2)	165	12.7	(6-1/2)	203		(8)	–			
4/0	107	179	(7)	191	38.1	(7-1/2)	216	12.7	(8-1/2)	–			
250 kcmil	127	216	(8-1/2)	216	50.8	(8-1/2)	229	25.4	(9)	254		(10)	
300	152	254	(10)	254	50.8	(10)	279	25.4	(11)	305		(12)	
350	177	305	(12)	305	76.2	(12)	330	76.2	(13)	355	50.8	(14)	
400	203	330	(13)	330	76.2	(13)	355	76.2	(14)	381	76.2	(15)	
500	253	355	(14)	355	76.2	(14)	381	76.2	(15)	406	76.2	(16)	
600	304	381	(15)	406	76.2	(16)	457	76.2	(18)	483	76.2	(19)	
700	355	406	(16)	457	76.2	(18)	508	76.2	(20)	559	76.2	(22)	
750	380	432	(17)	483	76.2	(19)	559	76.2	(22)	610	76.2	(24)	
800	405	457	(18)	508		(20)	559		(22)	610		(24)	
900	456	483	(19)	559		(22)	610		(24)	610		(24)	
1000	507	508	(20)	–			–			–			
1250	633	559	(22)	–			–			–			
1500	760	610	(24)	–			–			–			
1750	886	610	(24)	–			–			–			
2000	1013	610	(24)	–			–			–			

Table 12.2 Continued on Next Page

Table 12.2 Continued

Wire size		Wires per terminal (pole)[a]			
AWG or kcmil	mm²	1	2	3	4 or more
Note – The table includes only those multiple-conductor combinations that are used. Combinations not specified shall be further evaluated. [a] Wire bending space is not prohibited from being reduced by the number of inches shown in brackets under the following conditions: 1) Only removable or lay-in wire connectors receiving one wire each are used (more than one removable wire connector per terminal is possible) and 2) The removable wire connectors are removed from their intended location without disturbing structural or electrical parts other than a cover, and are installed with the conductor in place.					

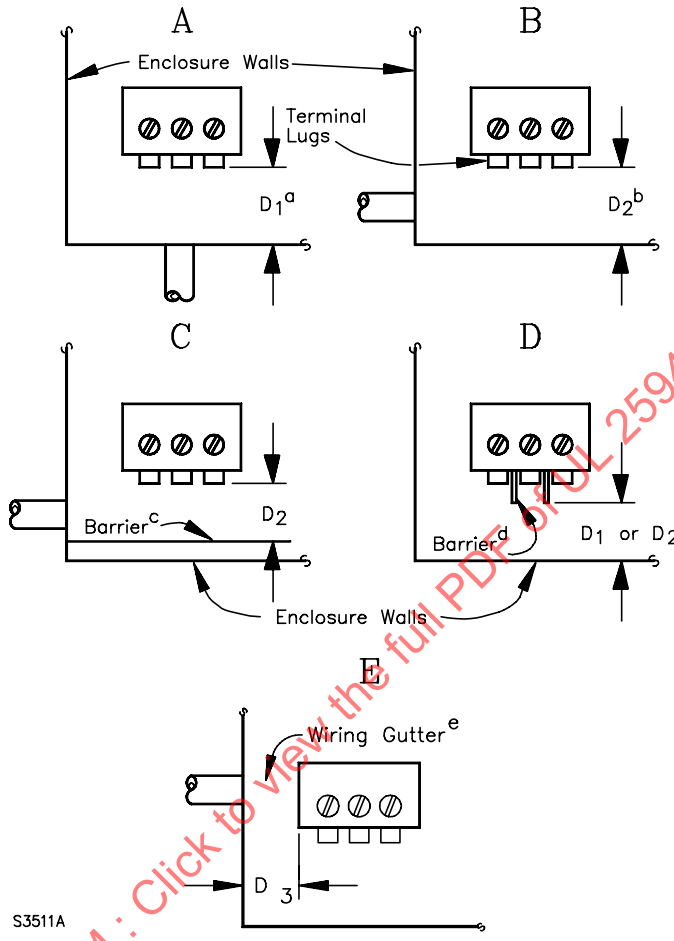
12.1.6.6 When a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance shall be measured from the end of the barrier. See illustration D of Figure 12.1.

Table 12.3
Minimum Width of Gutter and Wire-Bending Space for Conductors Through a Wall Not Opposite Terminals in mm (inches)

Wire size		Wires per terminal (pole)									
AWG or kcmil	mm²	1		2		3		4		5	
14 – 10 AWG	2.1 – 5.3	Not Specified	–	–		–		–		–	
8 – 6	8.4 – 13.3	38.1	(1-1/2)	–		–		–		–	
4 – 3	21.1 – 26.7	50.8	(2)	–		–		–		–	
2	33.6	63.5	(2-1/2)	–		–		–		–	
1	42.4	76.2	(3)	–		–		–		–	
1/0 – 2/0	53.5 – 7.4	88.9	(3-1/2)	127	(5)	178	(7)	–		–	
3/0 – 4/0	85.0 – 107	102	(4)	152	(6)	203	(8)	–		–	
250 kcmil	127	114	(4-1/2)	152	(6)	203	(8)	254	(10)	–	
300 – 350	152 – 177	127	(5)	203	(8)	254	(10)	305	(12)	–	
400 – 500	203 – 253	152	(6)	203	(8)	254	(10)	305	(12)	356	(14)
600 – 700	304 – 355	203	(8)	254	(10)	305	(12)	356	(14)	406	(16)
750 – 900	380 – 456	203	(8)	305	(12)	356	(14)	406	(16)	457	(18)
1000 – 1250	507 – 633	254	(10)	–		–		–		–	
1500 – 2000	760 – 1010	305	(12)	–		–		–		–	
NOTE – The table includes only those multiple-conductor combinations that are frequently used. Combinations not specified shall be further evaluated.											

Figure 12.1

Wire Bending Space



D_1 is the distance between a wire connector or an adjacent barrier and the opposite wall that conductors are intended to pass through.

D_2 is the distance between a wire connector or an adjacent barrier and the opposite wall or barrier that conductors are not intended to pass through.

D_3 is the width of a wiring gutter having a side through which conductors are intended to pass through.

[a] A conduit opening or knockout is provided in the wall opposite the terminal lugs. D_1 shall not be less than the minimum wire bending space specified in Table 12.2.

[b] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. The wall opposite the terminal lugs either is not provided with a knockout or conduit opening or a marking is provided indicating that the conduit opening or knockout is not to be used. D_2 shall not be less than the minimum wire bending space specified in Table 12.3.

[c] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. In addition, a conduit opening or knockout is provided in the wall opposite the terminal lugs, however, a barrier preventing the use of the opening is provided. D_2 shall not be less than the minimum wire bending space specified in Table 12.3.

[d] When a barrier or other means is provided restricting bending of the conductor, the distance D_1 or D_2, as applicable (see notes for D_1 and D_2 above) shall be measured from the end of the barrier.

[e] A conduit opening or knockout is provided in a wiring gutter. The width of the gutter, D_3, shall not be less than the minimum wire bending space specified in Table 12.3.

12.1.6.7 For a device not provided with a conduit opening or knockout, the minimum wiring bending space mentioned in 12.1.6.4 – 12.1.6.6 shall be based on any enclosure wall capable of being used for installation of the conduit, or only specific walls that are to be used as determined by a marking, drawing, or template furnished with the device.

12.1.6.8 The distance mentioned in 12.1.6.3 – 12.1.6.5 shall be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. See illustrations A – C of Figure 12.1. The wire terminal shall be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it is capable of assuming without defeating any means provided to prevent turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or similar part. A barrier, shoulder, or similar part shall be disregarded where the measurement is being made when it does not reduce the radius to which the wire must be bent. Where a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance shall be measured from the wire opening closest to the wall of the enclosure. As an alternate, the requirements of 12.1.6.6 may be used.

12.1.6.9 Except as indicated in 12.1.6.10, the width of a wiring gutter in which one or more knockouts are provided shall be large enough to accommodate (with respect to bending) conductors of the maximum size that are used at that knockout. The values of the minimum required width of a wiring gutter, with respect to conductors entering a knockout, are the same as the values of minimum required bending space given in Table 12.3. See illustration E of Figure 12.1.

12.1.6.10 The wiring space is not required to be of this width when knockouts are provided elsewhere that are in compliance with these requirements, the wiring space at such other point or points is of a width that accommodates the conductors in question, and the knockout or knockouts at such other points are used in the intended wiring of the device.

12.2 Cord connected devices

12.2.1 General

12.2.1.1 For cord connected devices, flexible cords and attachment plugs shall be used for connection to the alternating current input circuit.

12.2.1.2 The cord shall be type G, SEO, SO, STO, SJEO, SJO, SJTO, or W, or a cord that is equally serviceable. The flexible power cord shall terminate at the enclosure of the device. The overall length of the power cord shall comply with one of the following. The overall length of the power cord is measured from the face of the attachment plug to the point where it enters the enclosure:

a) When the interrupting device of the personnel protection system is located within the enclosure of the device, the power cord shall have a length corresponding to the values shown in 9.2.3 and the device shall be marked in accordance with 72.17.

b) When the interrupting device of the personnel protection system is located at the attachment plug, or within the distances required by 9.2.3, the overall cord length shall be a minimum of 1.8 m (6 feet) and shall be no greater than 4.6 m (15 feet).

12.2.1.3 A flexible power cord shall be rated for a voltage not less than the rated voltage of the equipment, and shall have a current rating not less than the current rating of the device.

12.2.1.4 The attachment plug of a supply cord shall be of a non-locking type and shall have a current rating in accordance with 12.2.1.7 and have a voltage rating corresponding to the voltage rating of the device.

In Canada, the requirements in 12.2.1.5 and 12.2.1.6 also apply. In Mexico and the United States, these additional requirements do not apply.

12.2.1.5 A cord connected device having a rating of 208 V, single phase, may be provided with an attachment plug for a supply cord, or an EV receptacle or EV connector at the output, rated 250 V, provided that:

a) There is no evidence of a shock or fire hazard when the device is tested based on a 240 V rating (see 46.1);

b) The supply cord is marked in accordance with 74.23; and

c) The output EV Receptacle or EV Connector is marked in accordance with 74.24.

12.2.1.6 Notwithstanding 12.2.1.5(b), no marking is required on the supply cord if:

a) The device complies with the requirements of the Leakage Current Test (Section 46), the Input Test (Section 48), and the Temperature Test (Section 49); and

b) The output value of the device does not exceed its output rating by more than 10 % while energized from a 240 V source of supply.

12.2.1.7 With reference to 12.2.1.3, the current rating of an attachment plug for the alternating current input circuit shall not be less than 125 % of the rated input current of the device.

12.2.1.8 The attachment plug shall be a grounding type attachment plug.

12.2.2 Strain relief

12.2.2.1 Strain relief shall be provided on the flexible power cord to reduce the risk of mechanical stress being transmitted to terminals, splices, or interior wiring. See Pull Strain Relief Test, 54.2. A knot in the flexible power cord is not considered an acceptable form of strain relief.

12.2.2.2 A metal strain relief clamp or band provided in accordance with 12.2.2.1 shall be provided with auxiliary insulation over the cord if damage to the cord insulation results when the strain relief tests are conducted without auxiliary insulation.

12.2.2.3 Means shall be provided to prevent a flexible power cord from being pushed into the equipment through the cord entry hole if such displacement would:

a) Result in mechanical damage to the cord;

b) Expose the cord to a temperature higher than that for which it is rated; or

c) Reduce spacings below the acceptable minimum values.

To determine compliance, the flexible power cord shall be tested in accordance with 54.3, Push-Back Strain Relief Test.

12.2.2.4 Strain relief bushings used for indoor products shall comply with Annex A, Ref. No. 25. Strain relief bushings used for outdoor products shall comply with the following:

a) The material used to form the strain relief bushing shall have a minimum flammability rating of HB;

b) The Relative Thermal Index (RTI) value of the material, for both electrical and mechanical, shall be higher than the maximum temperature observed on the material during the Temperature Test, Section 49;

c) The strain relief bushing shall be subjected to the Effects of Cyclic Conditions in Annex A, Ref. No. 20, using the Outdoor Use Application conditions;

d) After the strain relief bushing is subjected to (c), the product with the strain relief bushing installed as intended shall be subjected to a repeated Strain Relief Test, Section 54;

e) Following the test in (d), the device shall be subjected to the applicable environmental test in accordance with Annex A, Ref. No. 19;

f) The material shall be subjected to Chemical Exposure Tests in accordance with 67.4 if it is applicable to the product type.

12.2.3 Bushings

12.2.3.1 At the point where the flexible power cord passes through an opening in a wall, barrier, or the enclosure, there shall be a bushing or the equivalent that is secured in place, and that has a smooth, well-rounded surface against which the cord may bear. An insulating bushing shall be provided, if the wall or barrier is of metal, or if the construction is such that the cord could be subjected to strain or motion. For indoor use products, the bushing shall comply with the requirements in Annex A, Ref. No. 25. For outdoor use products, the bushing shall comply with 12.2.2.4 (a) – (c) and (e) – (f).

12.2.3.2 A hole in porcelain, phenolic composition, or other non-conducting material, having a smooth, rounded surface, is considered to be equivalent to a bushing.

12.2.3.3 A bushing of the same material as, and molded integrally with, a flexible power cord, is acceptable if the built up section is not less than 1.6 mm (1/16 inch) thick at the point where the cord passes through the enclosure.

12.2.3.4 At a point of flexure, no additional wires or cables shall be routed through a bushing or opening with the flexible power cord.

12.3 Direct plug-in devices

12.3.1 A product that is constructed with a direct plug-in feature shall not be provided with a means for connection to the alternating current source other than the blades provided for the direct plug-in feature. In addition, the product shall comply with the requirements in 12.3.2 – 12.3.10.

12.3.2 The mechanical assembly of a direct plug-in device intended for indoor use shall be considered acceptable if the device:

a) Complies with the requirements in 12.3.3 – 12.3.10, or

b) Complies with Annex A, Ref. No. 26.

12.3.3 The integral blade assembly of a direct plug-in device shall comply with the construction requirements in Annex A, Ref. No. 27. See 12.3.10.

12.3.4 The mechanical assembly of a direct plug-in device intended for outdoor use shall be considered acceptable if the enclosure complies with the requirements for Additional Environmental Tests, Section 67, in addition to the requirements in 12.3.2.

12.3.5 The maximum acceptable moment, center of gravity, dimensions and weight of a direct plug-in device shall comply with each of the following requirements (see 12.3.6):

a) The quotient of WY/Z shall not exceed 1361 grams (48 ounces);

b) The quotient of WY/S shall not exceed 1361 grams (48 ounces);

c) The product of WX shall not exceed 0.56 N·m (80 ounce-inches); and

d) The weight of the device shall not exceed 794 grams (28 ounces).

In which:

W is the weight of the device in grams (ounces);

Y is the distance illustrated in Figure 12.2 in mm (inches);

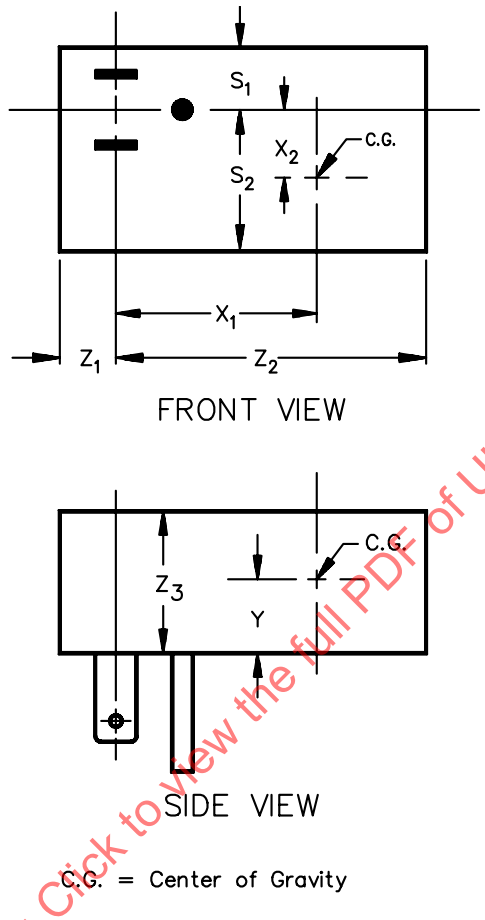
Z is the lesser of Z_1 or Z_2 as illustrated in Figure 12.2 in mm (inches);

S is the lesser of S_1 or S_2 as illustrated in Figure 12.2 in mm (inches);

X is the greater of X_1 or X_2 as illustrated in Figure 12.2 in mm (inches).

Figure 12.2

Dimensions of Plug



12.3.6 The values specified in 12.3.5 shall be determined as follows:

a) For devices with no provision for fastening in place, the product shall be tested with and without the output cord in place. For tests with the output cord in place, four feet of the cord shall be left in place and added to the weight of the overall device for the purposes of the calculation. For tests without the output cord in place, the cord shall be cut off at the enclosure, or at the strain relief means if the strain relief means is outside the enclosure.

b) For devices with directly mounted accessories, the values shall be measured with the accessories in place.

c) A mounting tab shall not be included in the measurements of the linear dimensions for the purpose of determining moments unless:

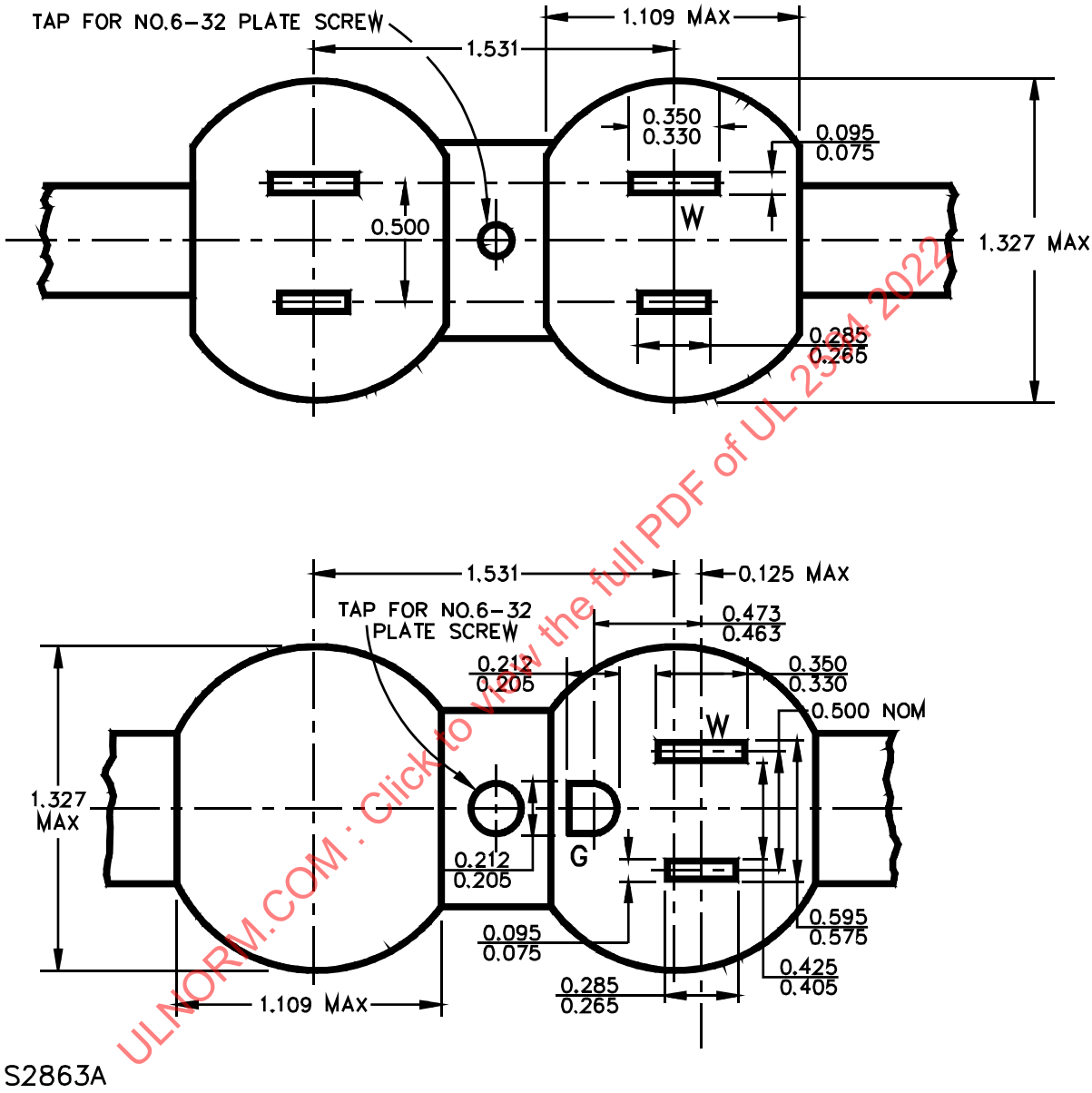
1) The tab and enclosure comply with the Drop Test, Section 59, with one impact on the tab itself, without deformation, and

2) For a polymeric enclosed device having an integral tab, the tab and enclosure do not distort at temperatures to which the material could be subjected under conditions of normal and abnormal use as determined by the Mold Stress Test, Section 66.

12.3.7 When inserted in a parallel blade duplex receptacle, no part of a device, including a mounting tab or output wiring, shall interfere with full insertion of an attachment plug or current tap into the adjacent receptacle unless it renders the adjacent receptacle completely unusable. See Figure 12.3.

Figure 12.3

Parallel Duplex Receptacle



12.3.8 Except as indicated in 12.3.9, the enclosure of the direct plug-in device shall be capable of being gripped for removal from the receptacle to which it is connected, and the perimeter of the face section from which the blades project shall not be less than 7.9 mm (5/16 inch) from any point on either blade.

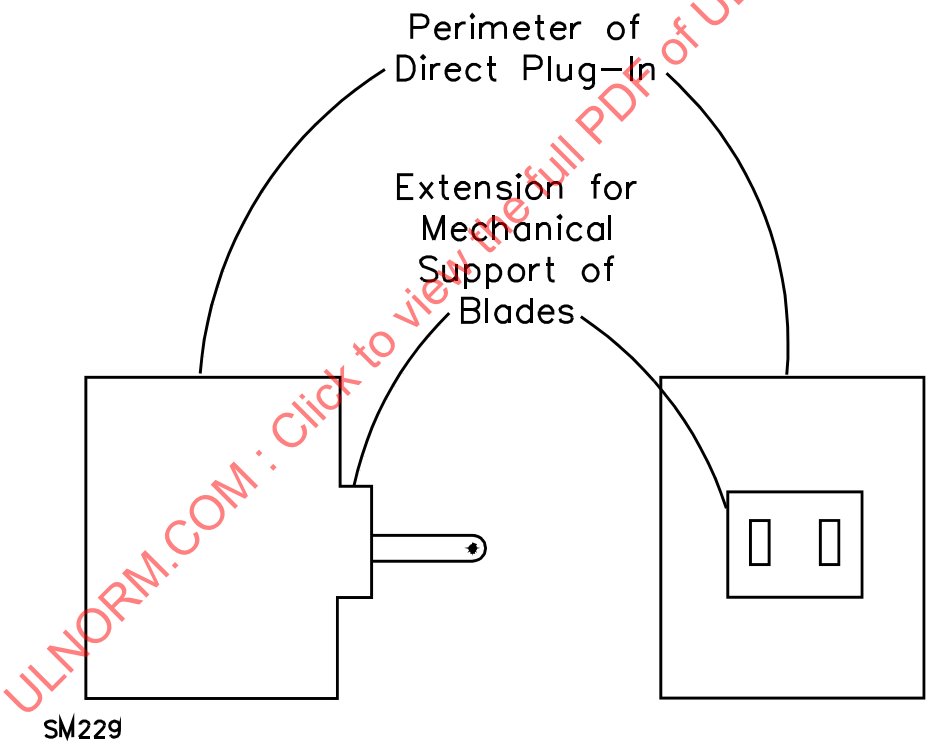
12.3.9 For tab mounted devices, the perimeter of the face section may not be less than 6.4 mm (1/4 inch) from any point on either blade.

12.3.10 With reference to 12.3.8, an extension from the face for mechanical support of the blades shall not be considered in the measurement provided the extension measures 1 mm (0.04 inch) or less from the face section of the direct plug-in device. See Figure 12.4.

12.3.11 In Canada, a device shall not be provided with a means for being fixed in place to a receptacle face. In Mexico and the United States, this does not apply.

Figure 12.4

Extension for Mechanical Support of Blades



13 Output Connections and Wiring

13.1 General

13.1.1 The requirements in 13.1.2 – 13.1.6 apply to the output supply connection means at the EV supply equipment. In addition, 13.1.2 – 13.1.12 apply to the EV cable or wiring from the EV supply equipment to the EV connector if provided; and 13.1.13 – 13.1.14 apply to the EV connector if provided.

13.1.2 The EV supply equipment shall be provided with one of the following means at the output:

a) An EV receptacle in accordance with Annex A, Ref. No. 5.

b) A suitably rated grounding type receptacle in accordance with Annex A, Ref. No. 27.

c) Wire terminals for a permanently connected EV cable. The terminals shall comply with the requirements for wiring terminals in accordance with 12.1.2.

13.1.3 With reference to 13.1.2(c), the permanently connected EV cable shall comply with the strain relief requirements in 13.2 and the requirements for bushings in 13.3.

13.1.4 With reference to 13.1.2(a) and 13.1.2(b), the receptacle shall have a voltage and current rating corresponding to the rated output of the EV supply equipment.

13.1.5 With reference to 13.1.2(a), an EV receptacle shall be designed in accordance with the standardized interface outlined in Annex A, Ref. No. 28 or the connection and interface shall be evaluated based on possible misconnection and shall be marked in accordance with 74.17.

13.1.6 With reference to 13.1.2(a) and 13.1.2(b), the output connection shall be marked with the rated voltage and current that is available at that connection. See 72.1(c).

13.1.7 EV cables provided to complete the connection from the EV supply equipment to the vehicle shall be in accordance with Annex A, Ref. No. 3.

13.1.8 The EV cables shall be type EV, EVJ, EVE, EVJE, EVT, or EVJT, and shall have a minimum voltage rating corresponding to the overall output rating of the EV supply equipment.

13.1.9 The EV cable shall contain conductors that are suitably sized for the intended output rating of the EV supply equipment.

13.1.10 Except as indicated in 13.1.11, the overall length of the EV cable shall not exceed 7.5 m (25 feet) in length. The length is measured from the point where the cable exits the EV supply equipment enclosure for permanently connected EV cable, or from where the cable exits the EV plug enclosure if provided as part of a cable assembly intended to connect to an EV receptacle located on the EV supply equipment, to the point where it enters the EV connector enclosure on the vehicle side of the EV cable.

13.1.11 EV supply equipment provided with a suitable cable management system may have a cable in excess of 7.5 m (25 feet). The cable management system shall control the cable so that it is not allowed to rest on the floor or supporting surface after use.

13.1.12 For EV cables intended to connect to an EV receptacle located on the EV supply equipment, the EV cable shall terminate in an EV plug on the EV supply equipment side. The EV plug shall comply with the applicable requirements in Annex A, Ref. No. 5. The EV plug shall be designed in accordance with the standardized interface outlined in Annex A, Ref. No. 28 or the connection and interface shall be evaluated based on possible misconnection and shall be marked in accordance with 74.17.

13.1.13 For EV cables provided for connection of the vehicle to the EV supply equipment, the EV cable shall terminate on the vehicle side of the cable in an EV connector. The EV connector shall comply with the applicable requirements in Annex A, Ref. No. 5. The EV connector shall be designed in accordance with the standardized interface outlined in Annex A, Ref. No. 28 or the connection and interface shall be evaluated based on possible misconnection and shall be marked in accordance with 74.17.

13.1.14 EV plugs and EV connectors provided as part of the EV supply equipment shall have a minimum voltage and current rating corresponding to the output rating of the EV supply equipment involved.

13.1.15 External connections at the output of EV supply equipment or at the vehicle connector shall be protected by a means that de-energizes the cable conductors and vehicle connector upon exposure to a

strain that results in a short circuit, separation of the cable from the EV supply equipment or the vehicle connector, or access to uninsulated hazardous live parts. In addition, there shall be no exposure to live parts after de-energization occurs. If breakaway couplings are used, they shall comply with Annex A, Ref. No. 5.

13.1.16 Any connection at the output that is not a power-carrying conductor (a signal wire) shall be LVLE.

13.2 Strain relief

13.2.1 An EV cable permanently connected to the EV supply equipment, or an EV cable connected to an EV plug on one end and an EV connector on the other, shall be provided with a means of strain relief in accordance with EV Cable Secureness Test, Section 55.

13.2.2 A metal strain relief clamp or band provided in accordance with 13.2.1 shall be provided with auxiliary insulation over the EV cable if damage to the EV cable insulation results when the strain relief tests are conducted without auxiliary insulation.

13.3 Bushings

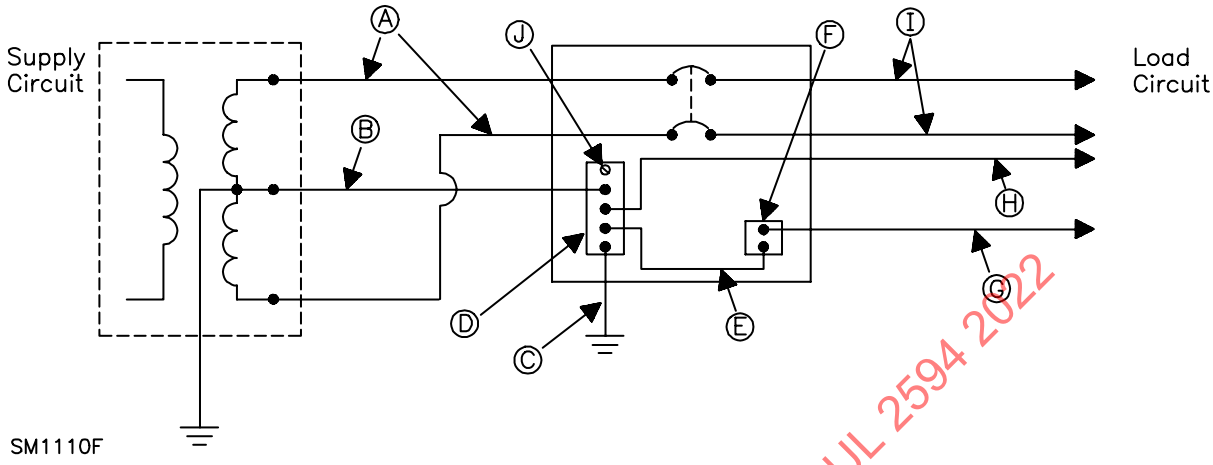
13.3.1 Where the EV cable passes through a wall or enclosure, whether the enclosure of the EV supply equipment or the EV plug or EV connector, a bushing shall be provided to protect the EV cable. The bushing shall comply with the requirements in 12.2.3.

14 Equipment Grounding

14.1 The grounding and bonding terms used in this Standard are in accordance with the UL column in Figure 14.1. The corresponding CSA and ANCE terms are also provided for information.

Figure 14.1

Grounding/Bonding Terms



Note: This figure is only intended to show the use of terminology, it is not intended to represent construction practices.

	UL TERMS	CSA TERMS	ANCE TERMS
A –	Ungrounded service conductor	Ungrounded service conductor	Conductores de fase de la acometida
B –	Grounded service conductor	Grounded service conductor	Conductor de acometida puesto a tierra
C –	Grounding electrode conductor	Grounding conductor	Conductor de electrodo de puesta a tierra
D –	Insulated neutral bus	Neutral bus	Barra para neutro
E –	Bonding jumper	Bonding jumper	Puente de union
F –	Ground bus	Bonding bus/bonding connector	Barra para puesta a tierra
G –	Equipment grounding conductor	Bonding conductor	Conductor de puesta a tierra del equipo
H –	Grounded circuit conductor	Identified circuit conductor	Conductor del circuito puesto a tierra
I –	Ungrounded circuit conductor	Ungrounded circuit conductor	Conductores de fase del circuito
J –	Screw serving as bonding jumper	Screw serving as bonding jumper	Tornillo que sirve como puente de union

14.2 A product shall have provisions for grounding all exposed non-current-carrying conductive parts, and all internal metal parts that are exposed to contact during servicing, that could become energized through an electrical fault. A part shall be considered capable of becoming energized if failure of electrical spacing or insulation or both can result in conductive connection to a current carrying part.

14.3 A dead metal part as described in (a) – (e) need not comply with the requirement in 14.2.

a) A small metal part (such as an adhesive attached foil marking, a screw, or a handle) that is:

1) On the exterior of the enclosure and separated from all electrical components by grounded metal, or

2) Electrically isolated from all electrical components.

b) A panel, cover, or other metal part that is isolated from all electrical components, including wiring, by a barrier of vulcanized fiber, varnished cloth, phenolic composition, or other moisture-resistant insulating material that is not less than 0.8 mm (1/32 inch) thick and is secured in place.

c) A panel, cover, or other metal part that does not enclose an uninsulated live part and that is electrically isolated from other electrical components.

d) A door or the like that can only become energized through a grounded part.

e) A small assembly screw that is positively separated from wiring and all uninsulated live parts.

14.4 Except as indicated in 14.5, all non-current-carrying conductive parts shall be bonded together and connected to the electrical supply equipment grounding means in accordance with Bonding, Section 15. The connection to the electrical supply equipment grounding means is considered the principal equipment ground conductor path and it shall not include a trace on a printed wiring board.

14.5 Products provided with a ground monitor interrupter as part of the Personnel Protection System in accordance with Annex A, Ref. No. 21 and No. 22 may also have a trace as part of the ground path provided the ground monitor interrupter will function correctly if the trace opens under normal operation or abnormal operation.

14.6 Connection to the electrical supply equipment grounding means shall be accomplished as follows:

a) In a product intended to be permanently connected, to:

1) A knockout or equivalent opening means in a metal enclosure intended to be connected to a metal enclosed wiring system suitable for grounding, or

2) The equipment grounding field wiring terminal or lead.

b) In a product provided with a flexible power supply cord and an attachment plug, to the equipment grounding conductor of the flexible power supply cord.

14.7 Except as indicated in 14.8, the equipment grounding connection shall not contain any splices.

14.8 Products provided with a ground monitor interrupter as part of the Personnel Protection System in accordance with Annex A, Ref. No. 21 and No. 22 may have a splice in the ground path provided the ground monitor interrupter will function correctly if the spliced connection is lost.

14.9 An equipment grounding connection shall penetrate a nonconductive coating, such as paint or vitreous enamel.

14.10 An equipment grounding conductor shall be:

a) If insulated, provided with insulation having an outer surface that is green with or without one or more yellow stripes, and

b) Of a size acceptable for the application in accordance with Table 14.1, but shall not be required to be larger than the circuit conductors supplying the equipment.

Table 14.1
Minimum Size of Conductor

Rating of branch-circuit over-current-protective device to which the product is intended to be connected, Amperes	Size of equipment grounding conductor							
	Copper[a,b,c]				Aluminum			
	Wire		Equivalent cross-sectional area		Wire		Equivalent cross-sectional area	
	mm^2	AWG	mm^2	cmil	mm^2	AWG	mm^2	cmil
15	2.08	14	2.02	3987	3.31	12	3.21	6334
20	3.31	12[b]	3.21	6334	5.26	10	5.261	10380
30	5.26	10	5.261	10380	8.37	8	8.367	16510
40	5.26	10	5.261	10380	8.37	8	8.367	16510
60	5.26	10	5.261	10380	8.37	8	8.367	16510
100	8.37	8	8.367	16510	13.3	6	13.30	26240
200	13.3	6	13.30	26240	21.2	4	21.15	41740
300	21.2	4	21.15	41740	33.6	2	33.62	66360
400	26.7	3	26.67	52620	42.4	1	42.41	83690
500	33.6	2	33.62	66360	53.5	1/0	53.41	105600
600	42.4	1	42.41	83690	67.4	2/0	67.43	133100

[a] In Mexico, the metric cross-sectional area is mandatory.

[b] In Canada, the minimum acceptable sizes of grounding conductors are 14 AWG for 20A rated devices and 12 AWG for 30A rated devices.

[c] In Canada, the terminals of a device intended to accommodate an 8 AWG or larger conductor shall also be capable of securing a compact copper stranded construction.

14.11 An equipment grounding conductor of a power supply cord shall be connected to the grounding blade of the attachment plug.

14.12 For a product provided with a flexible power cord, a stud and nut combination used to secure the grounding conductor to the frame shall be secured to the frame by welding the stud in place. The ground conductor shall be connected first and be in contact with the frame and secured in place by a dedicated nut and lock washer. Other bonding jumpers may be connected to the stud, but they shall be connected above the main ground connection and secured by a separate nut and lock washer.

14.13 In a product provided with a flexible power supply cord and an attachment plug, the connection between the dead metal parts required to be grounded and the equipment grounding conductor shall be made by a positive means in accordance with 15.1 and 15.3. The connection shall be made by a means not likely to be removed during ordinary servicing not involving the flexible power supply cord.

14.14 A sheet metal screw shall not be used to connect equipment grounding conductors to enclosures.

14.15 A grounding screw shall engage at least two full threads and shall be used in conjunction with upturned lugs, a cupped washer, or an equivalent method that is capable of retaining a 5.26 mm^2 (10 AWG) conductor under the head of the screw.

14.16 A ferrous metal part in a grounding path shall be protected against corrosion by enameling, galvanizing, plating, or equivalent means.

14.17 A terminal intended for the connection of an equipment grounding conductor shall be identified by:

a) Use of a wire binding screw with a green colored head that is slotted or hexagonal, or both;

b) Use of a threaded stud with a green colored hexagonal nut;

c) Use of a green colored pressure terminal connector;

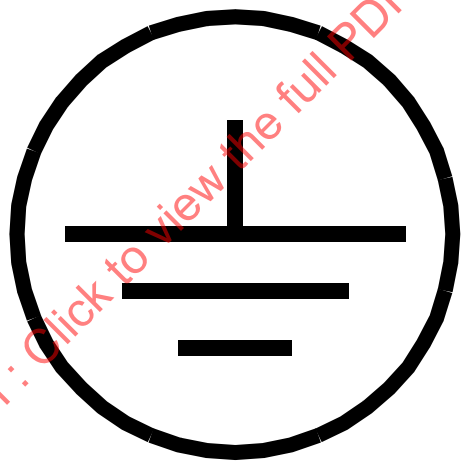
d) Being marked “G”, “GR”, “GND”, “Ground”, “Grounding”, or the like;

e) A marking on a wiring diagram provided on the product; or

f) The grounding symbol illustrated in Figure 14.2 on or adjacent to the terminal or on a wiring diagram provided on the product.

Figure 14.2

Grounding Symbol



15 Bonding

15.1 A conductor, including a strap, jumper, or similar part, that is used only for bonding shall:

a) Be of copper, copper alloy, aluminum, or other material that has been investigated and found acceptable for use as an electrical conductor;

b) Be protected from mechanical damage;

c) Not be secured by a removable fastener used for any purpose other than bonding, unless the bonding conductor is not likely to be omitted after removal and replacement of the fastener; and

d) Have the flexibility needed to withstand mechanical stress due to vibration or flexing during use.

15.2 Metal parts in a bonding path shall be galvanically compatible so as to reduce electrolytic action between dissimilar metals. The combined electrochemical potential between dissimilar metals which are in contact shall be less than 0.6 V as determined in accordance with Figure 15.1. Combinations of metals that fall above the line in the table shall not be used.

Figure 15.1

Electrochemical Potential

Magnesium, magnesium alloys	Zinc, zinc alloys	80 tin/20 Zn on steel, Zn on iron or steel	Aluminium	Cd on steel	Al/Mg alloy	Mild steel	Duralumin	Lead	Cr on steel, soft solder	Cr on Ni on steel, tin on steel, 12% Cr stainless steel	High Cr stainless steel	Copper, copper alloys	Silver solder, austenitic stainless steel	Ni on steel	Silver	Rh on Ag on Cu, silver/gold alloy	Carbon	Gold, platinum	
0	0.05	0.55	0.7	0.8	0.85	0.9	1.0	1.05	1.1	1.15	1.25	1.35	1.4	1.45	1.6	1.65	1.7	1.75	Magnesium, magnesium alloys
	0	0.05	0.2	0.3	0.35	0.4	0.5	0.55	0.6	0.65	0.75	0.85	0.9	0.95	1.1	1.15	1.2	1.25	Zinc, zinc alloys
		0	0.15	0.25	0.3	0.35	0.45	0.5	0.55	0.6	0.7	0.8	0.85	0.9	1.05	1.1	1.15	1.2	80 tin/20 Zn on steel, Zn on iron or steel
			0	0.1	0.15	0.2	0.3	0.35	0.4	0.45	0.55	0.65	0.7	0.75	0.9	0.95	1.0	1.05	Aluminium
				0	0.05	0.1	0.2	0.25	0.3	0.35	0.45	0.55	0.6	0.65	0.8	0.85	0.9	0.95	Cd on steel
					0	0.05	0.15	0.2	0.25	0.3	0.4	0.5	0.55	0.6	0.75	0.8	0.85	0.9	Al/Mg alloy
						0	0.1	0.15	0.2	0.25	0.35	0.45	0.5	0.55	0.7	0.75	0.8	0.85	Mild steel
							0	0.05	0.1	0.15	0.25	0.35	0.4	0.45	0.6	0.65	0.7	0.75	Duralumin
								0	0.05	0.1	0.2	0.3	0.35	0.4	0.55	0.6	0.66	0.7	Lead
									0	0.05	0.15	0.25	0.3	0.35	0.5	0.55	0.6	0.65	Cr on steel, soft solder
										0	0.1	0.2	0.25	0.3	0.45	0.5	0.55	0.6	Cr on Ni on steel, tin on steel, 12% Cr stainless steel
											0	0.1	0.15	0.2	0.35	0.4	0.45	0.5	High Cr stainless steel
												0	0.05	0.1	0.25	0.3	0.35	0.4	Copper, copper alloys
													0	0.05	0.2	0.25	0.3	0.35	Silver solder, austenitic stainless steel
														0	0.15	0.2	0.25	0.3	Ni on steel
															0	0.05	0.1	0.15	Silver
																0	0.05	0.1	Rh on Ag on Cu, silver/gold alloy
																	0	0.05	Carbon
																		0	Gold, platinum

Ag = Silver
Al = Aluminium
Cr = Chromium
Cd = Cadmium
Cu = Copper
Mg = Magnesium
Ni = Nickel
Rh = Rhodium
Zn = Zinc

NOTE. – Corrosion due to electrochemical action between dissimilar metals which are in contact is minimized if the combined electrochemical potential is below about 0.6V. In the following table the combined electrochemical potentials are listed for a number of pairs of metals in common use; combinations above the dividing line should be avoided.

S3426

15.3 Bonding shall be by a positive means, such as by a clamp, rivet, bolt, screw, welded joint, or a soldered or brazed joint using materials having a softening or melting point higher than 454 °C (850 °F). Terminals complying with the applicable requirements in Annex A, Ref. No. 29, are acceptable to connect bonding conductors in sizes 0.824 – 2.08 mm^2 (18 – 14 AWG) under the following conditions:

a) For conductor sizes 0.824 – 1.31 mm^2 (18 – 16 AWG), the minimum connector and tab width shall be 2.8 mm (0.110 in).

b) For conductor size 2.08 mm^2 (14 AWG), the minimum connector and tab width shall be 6.4 mm (0.250 in).

c) Quick connect tabs shall not be less than 0.8 mm (0.032 in) thick.

15.4 A bonding screw shall engage at least two full threads and shall be used in conjunction with upturned lugs, a cupped washer, or an equivalent method that is capable of retaining a 5.26 mm^2 (10 AWG) conductor under the head of the screw.

15.5 A bonding connection means shall penetrate nonconductive coatings, such as paint or vitreous enamel.

15.6 A metal-to-metal hinge-bearing member of a door or cover used as a means for bonding the door or cover shall be of the multiple bearing pin (piano) type.

15.7 Except as indicated in 15.8 and 15.9, in a product provided with a power supply cord and an attachment plug:

a) A copper bonding jumper, including a clamp or strap, shall have a cross-sectional area not less than that of the equipment-grounding conductor of the power supply cord; and

b) An aluminum bonding jumper, including a clamp or strap, shall have a cross-sectional area not less than that of a conductor two AWG sizes larger than the circuit equipment grounding conductor of the power supply cord.

15.8 A conductor, including a strap, jumper, or similar part, having a smaller cross-sectional area is acceptable if it complies with the requirements in the Bonding Conductor Test, Section 62.

15.9 A conductor, including a strap, jumper, or similar part, for a component or electrical enclosure need not be larger than the largest conductors supplying power to the component or components adjacent to the dead metal parts.

15.10 Except as indicated in 15.11 and 15.12, in a product intended to be permanently connected to the electrical supply, a copper or aluminum bonding jumper, including clamp or strap, shall not be smaller than, or have an equivalent cross-sectional area less than, the size specified in Table 14.1.

15.11 A smaller bonding jumper may be used as provided in 15.8 and 15.9.

15.12 A bonding jumper need not be larger than the circuit conductors supplying the equipment.

15.13 If the continuity of a bonding system relies on the integrity of a nonmetallic material, the dimensional stability of the material shall be considered in addition to any other material characteristics that could affect the bond. These material characteristics include the material's mechanical strength, thermal aging characteristics, moisture absorption properties, combustibility, and resistance to impact, distortion, creep, arcing, and ignition. The bonding system, together with the nonmetallic material, shall comply with the Bonding Conductor Test, Section 62.

16 EV Bonding

16.1 If the EV cable and associated connections are provided with the EV supply equipment, means shall be provided for incorporating the bonding means for the vehicle, or the vehicle shall be isolated from the source in accordance with the applicable requirements for personnel protection systems in 9.2.

17 Internal Wiring

17.1 Wires

17.1.1 The internal wiring of a device shall be rated for the particular application with respect to the temperature and voltage, exposure to oil or grease, and other conditions of service to which the wiring is subjected.

17.1.2 With respect to 17.1.1, the effects of vibration, if installed on-board an EV, impact, and exposure shall be evaluated for wires smaller than 0.21 mm^2 (24 AWG).

17.1.3 All wiring shall be polyvinyl chloride (PVC), polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), or neoprene insulated, or shall comply with the vertical wire flame test requirements in Annex A, Ref. No. 30, as evidenced by a surface marking “VW-1”.

17.1.4 The length of a power supply cord inside a device shall be limited to that needed for electrical connections.

17.2 Protection of wires

17.2.1 Internal wiring shall not be accessible when judged in accordance with Protection of Users – Accessibility and User Servicing, Section 8, unless it is located and secured within the enclosure such that the risk of it being subjected to stress or mechanical damage is reduced.

17.2.2 Wires within an enclosure, compartment, raceway, or similar part shall be located or protected to reduce the risk of unintentional contact with any sharp edge, burr, fin, or similar part that damages the conductor insulation.

17.2.3 Internal wiring shall be so routed and secured that neither it nor related electrical connections shall be subjected to stress or mechanical damage.

17.2.4 A hole in a sheet metal wall through which insulated wires pass and on which they bear shall be provided with a smoothly rounded bushing or shall have smooth, rounded surfaces upon which the wires bear, to avoid abrasion of insulation.

17.2.5 A bushing provided in accordance with 17.2.4 shall comply with 12.2.3.

17.2.6 Metal clamps and guides used for routing stationary internal wiring shall be provided with smooth well-rounded edges.

17.2.7 Auxiliary mechanical protection that is not electrically conductive shall be provided under a metal clamp at which pressure is exerted on a conductor having thermoplastic insulation less than 0.76 mm (0.030 inch) thick and no overall braid, and on any wire or wires that are subject to motion.

18 Flammability

18.1 Nonmetallic materials used for insulation, barriers, internal parts, enclosures, decorative parts, and so on, shall comply with the following requirements.

18.2 Nonmetallic materials used to form enclosures shall have a minimum flammability rating in accordance with Table 18.1.

Table 18.1
Flammability Ratings of Enclosures

Product type	Flammability rating
Portable equipment	V-1
Fastened in place equipment	V-1
Fixed in place equipment	5V

18.3 Nonmetallic materials internal to the enclosure, but not intended for direct support of live parts, shall be rated V-2 minimum; however, the internal insulating system of components where component requirements exist need not have a flame class rating. A small part, gasket, or other nonmetallic part that is located such that it cannot propagate flame from one area to another within the equipment, and is not located in close proximity to uninsulated live parts, is not required to have a flame class rating.

18.4 Nonmetallic materials located outside of the enclosure, and not used to complete the enclosure, are considered decorative parts. These parts shall be rated HB minimum, except as indicated in 18.5.

18.5 Cables entering and exiting the enclosure shall be rated FT2 minimum. Other components, such as electric vehicle couplers and attachment plugs, shall comply with the flammability requirements in the applicable component Standard for that component.

18.6 Printed wiring board materials shall be rated V-2 minimum.

18.7 For the requirements outlined in 18.2 – 18.6, the flammability rating of the material shall be provided as part of the material rating, or the flammability rating may be determined by the applicable tests in Annex A, Ref. No. 15.

19 Current Carrying Parts

19.1 A current carrying part shall be of silver, copper, a copper-based alloy, stainless steel, aluminum, or other material determined to be acceptable for the application. Plated iron or steel shall not be used for parts that are depended upon to carry current. Wire binding screws shall not be of iron or steel.

19.2 Iron or steel, if protected against corrosion by zinc, tin, or equivalent plating, can be used for screws, plates, yokes, or other parts that are employed as a means of clamping the conductor, providing such parts are not the primary current carrying members.

19.3 Suitable means shall be provided for retaining live parts within such limits of alignment as to ensure that plugs will enter receptacles, connectors, and the like in the intended manner.

19.4 Uninsulated live parts shall be secured in place so that they do not turn or shift, when turning or shifting results in a reduction in the clearance and creepage distances below those required in Spacings, Section 22.

19.5 A current carrying part shall be prevented from turning relative to the surface on which it is mounted if such turning would adversely affect the performance of the device.

20 Electrical Connections

20.1 The requirements described in 20.2 – 20.7 apply to connections of internal wiring that are factory installed in the device.

20.2 A splice or connection shall be mechanically secure and shall make electrical contact.

20.3 A soldered connection is determined to be mechanically secure when the lead is:

a) Wrapped one full turn around a terminal;

b) Bent at a right angle after being passed through an eyelet or opening, except on printed wiring boards where components are inserted or secured (as in a surface mounted component) and wave- or lap-soldered; or

c) Twisted with other conductors.

20.4 When stranded internal wiring is connected to a wire binding screw, the construction shall be such that loose strands of wire do not contact other uninsulated conductive parts. This shall be accomplished by use of pressure terminal connectors, soldering lugs, crimped eyelets, soldering of all strands together, or by any other equivalent means.

20.5 A nominal 2.8 mm (0.110 inch), 3.2 mm (0.125 inch), 4.8 mm (0.187 inch), 5.2 mm (0.205 inch), or 6.35 mm (0.250 inch) wide quick connect terminal shall comply with Annex A, Ref. No. 29. Other sizes of quick connect terminals shall be investigated with respect to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rise; all tests shall be conducted in accordance with Annex A, Ref. No. 29.

20.6 An open end spade lug shall not be used unless an additional means, such as upturned ends on the lug or bosses or shoulders on the terminal, is provided to hold the lug in place when the binding screw or nut loosens.

20.7 A splice shall be provided with insulation equivalent to that of the wires involved unless permanent spacings are maintained between the splice and other metal parts. Insulation over the splice may have one or more of the following:

a) A splicing device such as a pressure wire connector, employed when insulated for the voltage and temperature to which the device shall be subjected.

b) Insulating tubing or sleeving used to cover a splice shall be used in accordance with 22.2.4.

c) Two layers of thermoplastic tape, or two layers of friction tape, or one layer of friction tape and one layer of rubber tape, where the voltage involved is less than 250 volts. Thermoplastic tape wrapped over a sharp edge shall not be used.

21 Gaskets

21.1 A gasket of elastomeric or thermoplastic material or a composition gasket utilizing an elastomeric material that is provided on an enclosure to meet the environmental construction and performance requirements of this Standard shall be in accordance with Annex A, Ref. No. 31, and considered suitable for this use, or it shall comply with the Gasket Test, in Annex A, Ref. No. 19.

21.2 A gasket shall be secured with adhesive or by mechanical means. The gasket and its securing means shall not be damaged when the joint is opened.

22 Spacings

22.1 General

22.1.1 Except as indicated in 22.1.2, the spacings for a device shall not be less than the applicable values specified in Table 22.1 or as provided in Alternate Spacings – Clearances and Creepage Distances, Section 23. For spacings requirements where liners and barriers are used, see 22.2.1.

22.1.2 The spacings requirements in Table 22.1 do not apply to inherent spacings of a component such as a switch, power switching semiconductor, or similar component. See 22.1.7.

22.1.3 Where an uninsulated live part is not rigidly secured in position by means other than friction between surfaces or where a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that, for any position resulting from turning or other movement of the parts in question, at least the minimum required spacings shall be maintained.

22.1.4 With reference to 22.1.3, a lock washer is not a method of rigidly securing a part.

Table 22.1
Spacings

Potential involved, volts rms (Peak)		Minimum spacings, mm (inch)					
		Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part				Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[a]	
		Through air		Over surface		Shortest distance	
0 – 50	(0 – 70.7)	1.6	(1/16)[b,c]	1.6	(1/16)[b,c]	1.6	(1/16)[b]
Greater than 50 to 150	(70.7 to 212.1)	3.2	(1/8)[b,c]	6.4	(1/4)[c]	6.4	(1/4)
Greater than 150 to 300	(212.1 to 424.2)	6.4	(1/4)	9.5	(3/8)	12.7	(1/2)
Greater than 300 to 600	(424.2 to 848.4)	9.5	(3/8)	12.7	(1/2)	12.7	(1/2)
Greater than 600 to 1000	(848.4 to 1414)	19.1	(3/4)[d]	19.1	(3/4)[d]	19.1	(3/4)

[a] For the purpose of this requirement, a metal piece attached to the enclosure is a part of the enclosure when deformation of the enclosure reduces spacings between the metal piece and uninsulated live parts.

[b] The spacing between field-wiring terminals of opposite polarity and the spacing between a field-wiring terminal and a grounded dead metal part shall not be less than 6.4 mm (1/4 inch).

[c] At closed-in points only, such as a screw and washer construction of an insulated stud mounted in metal, a spacing of 1.2 mm (3/64 inch) meets the intent of the requirement.

[d] Between uninsulated high-voltage parts and (1) uninsulated high-voltage parts of opposite polarity or different potentials, (2) earth-grounded metal parts, (3) uninsulated primary-circuit parts, (4) insulated primary-circuit parts, (5) insulated high-voltage parts of opposite polarity, or of different potentials.

22.1.5 Inherent spacings of the components in accordance with 22.1.2 shall comply with the requirements for the component in question where the spacings are less than the values specified in this Standard. Spacings from such components to another component and to the enclosure shall comply with the applicable spacings specified in this Standard.

22.1.6 With respect to judging spacings, an uninsulated live part is at opposite polarity to uninsulated live parts in another circuit. Spacings shall be based on the highest of the circuit voltages.

22.1.7 Film coated wire is an uninsulated live part when judging spacings.

22.1.8 Spacings at field wiring terminals shall be measured with conductors installed in the terminals. The gauge of these conductors shall be based on the rating of the circuit containing the terminals.

22.1.9 Spacings between uninsulated live parts of different potential and between such parts and dead metal that are capable of being grounded in service are not specified for parts of limited energy circuits in accordance with 5.31.

22.2 Insulation barriers

22.2.1 Except as indicated in 22.2.2 and 22.2.3, an insulating liner or barrier of material such as vulcanized fiber may be employed in lieu of required spacings (see 22.1.1), but not as the sole support of uninsulated live parts involving a risk of fire or electric shock, when it is not less than 0.71 mm (0.028 inch) thick and it is so located that it is not adversely affected by arcing. Other insulating materials used as a barrier or as either direct or indirect support of uninsulated live parts involving a risk of fire or electric shock shall comply with the requirements in Annex A, Ref. No. 20.

22.2.2 Vulcanized fiber not less than 0.33 mm (0.013 inch) thick shall be used only when:

a) In conjunction with an air spacing of not less than 50 % of the minimum through air spacing; and

b) Between a heat sink and a metal mounting surface, including the enclosure, of an isolated secondary circuit rated 50 volts rms or less.

22.2.3 Mica not less than 0.165 mm (0.006 inch) can be used as insulation between a heat sink and a live case of a semiconductor device.

22.2.4 Insulating tubing complying with the requirements in Annex A, Ref. No. 32, shall be used as insulation of a conductor in lieu of the minimum spacings and for capacitor cases in lieu of bonding the case for grounding, only when the following conditions are met:

a) The conductor is not subjected to compression, repeated flexure, or sharp bends;

b) The conductor or case covered with the tubing is well rounded and free from sharp edges;

c) The tubing is used in accordance with the manufacturer's instructions; and

d) The conductor or case is not subjected to a temperature or voltage higher than that for which the tubing is rated.

22.2.5 A wrap of thermoplastic tape, complying with the requirements in Annex A, Ref. No. 33, may be used when all of the following conditions are met:

a) The wrap is no less than 0.33 mm (0.013 inch) thick, is applied in two or more layers, and is used in conjunction with no less than one-half the required through air spacing.

b) The wrap is no less than 0.72 mm (0.028 inch) thick when used in conjunction with less than one-half the required through air spacing.

c) Its temperature rating is no less than the maximum temperature observed during the temperature test.

d) The tape is not subject to compression.

e) The tape is not wrapped over a sharp edge.

23 Alternate Spacings – Clearances and Creepage Distances

23.1 As an alternative to the spacing requirements of Section 22, as applicable, the spacing requirements in Annex A, Ref. No. 34, may be used. The spacing requirements of Annex A, Ref. No. 34 shall not be used for field wiring terminals and spacings to a dead metal enclosure. In determining the pollution degree and overvoltage category, the end use application shall be taken into account and shall be capable of modifying those characteristics given in 23.2 and 23.3.

23.2 The level of pollution for indoor use equipment shall be pollution degree 2. For outdoor use equipment, the level of pollution shall be pollution degree 3. Hermetically sealed or encapsulated enclosures, or coated printed wiring boards in compliance with the Printed Wiring Board Coating Performance Test of Annex A, Ref. No. 34, are pollution degree 1.

23.3 The equipment shall be rated overvoltage category II as defined in Annex A, Ref. No. 34.

23.4 In order to apply Clearance B (controlled overvoltage) clearances, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product.

23.5 All printed wiring boards shall be considered to have a minimum comparative tracking index of 100 without further investigation.

24 Separation of Circuits

24.1 Factory wiring

24.1.1 Except as indicated in 24.1.2, insulated conductors of different circuits within a device, including wires in a terminal box or compartment, shall be either separated by barriers or segregated and shall be so separated or segregated from uninsulated live parts connected to different circuits.

24.1.2 For insulated conductors of different circuits, when each conductor is provided with insulation intended for the highest of the circuit voltages, no barriers or segregation are required.

24.1.3 For the purpose of the requirement in 24.1.1, different circuits include:

a) Circuits connected to the primary and secondary windings of an isolation transformer;

b) Circuits connected to different isolated secondary windings of a multi-secondary transformer;

c) Circuits connected to secondary windings of different transformers;

d) Input and output circuits of an optical isolator; and

e) AC power input and AC power output circuits.

The power circuits outlined in (e) that are not provided with an isolation component – such as a transformer – between the input and output, are not considered different circuits.

24.1.4 Segregation of insulated conductors shall be accomplished by clamping, routing, or an equivalent means that maintains permanent separation from insulated and uninsulated live parts and from conductors of a different circuit.

24.2 Separation barriers

24.2.1 A barrier used to provide separation between the wiring of different circuits shall be grounded metal or insulating material complying with the requirements for flammability classification in Flammability, Section 18, and with the requirements for Insulating Materials, Section 31. The barriers shall be no less than 0.71 mm (0.028 inch) thick, and supported so that it is not capable of being readily deformed so as to defeat its purpose.

24.2.2 A barrier used to provide separation between field wiring of one circuit and field or factory wiring or uninsulated live parts of another circuit shall be spaced no more than 1.6 mm (1/16 inch) from the enclosure walls and interior mechanisms, component-mounted panels, and other parts that serve to provide separated compartments.

24.3 Field wiring

24.3.1 The equipment shall be constructed so that a field-installed conductor of a circuit shall be separated as specified in 24.3.2 or separated by barriers as specified in 24.2.1 and 24.2.2 from:

a) Factory-installed conductors connected to any other circuit, unless the conductors of both circuits are insulated for the maximum voltage of either circuit.

b) An uninsulated live part of another circuit and from an uninsulated live part where short circuit with it results in a risk of fire, electric shock, electrical energy involving high current levels, or injury to persons.

24.3.2 Separation of a field-installed conductor from another field-installed conductor and from an uninsulated live part connected to another circuit shall be accomplished by locating an opening in the enclosure for the conductor opposite to the conductor terminal so that, when the installation is complete, the conductors and parts of different circuits are separated by a minimum of 6.4 mm (1/4 inch). In determining whether a device having such openings complies with this requirement, it shall be wired as in service including 152.4 mm (6 inches) of slack in each conductor within the enclosure. No more than average care shall be exercised in routing the wiring and stowing the conductor slack into the wiring compartment.

24.3.3 With reference to 24.3.2, where the number of openings in the enclosure does not exceed the minimum required for the intended wiring of the device, and where each opening is located opposite a set of terminals, it shall be assumed that a conductor entering an opening shall be connected to the terminal opposite that opening. Where more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than the one opposite the terminal to which it is intended to be connected and the risk of it contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit shall be investigated.

25 Control Circuits

25.1 Secondary control circuits

25.1.1 An LVLE circuit as described in 5.33 or a limited energy circuit as described in 5.31 may be connected to a single point reference ground.

25.1.2 Except as indicated in 25.1.3, an LVLE circuit is not required to be investigated. Printed wiring boards and insulated wire used in such circuits shall be types that are required for the application. See 17.1.1 and 30.1.

25.1.3 Safety circuits shall be judged by the requirements for primary circuits.

25.1.4 Except as indicated in 25.1.5, a control circuit, including associated electronic components on printed wiring boards, is not required to be investigated when the maximum voltage and current are limited as specified in Table 25.1. Printed wiring boards and insulated wires used in such circuits shall be types that are required for the application. See 17.1.1, 17.1.3, and 30.1.

25.1.5 The current values specified in Table 25.1 do not apply when the circuit includes an overcurrent protection device as described in 25.1.9 and 25.1.10.

Table 25.1
Limit for Control Circuits

Maximum voltage	Maximum current
0 – 42.4 V peak	8A
0 – 30 V dc	8A
30 – 60 V dc	$150/V_{max}$

25.1.6 With reference to the current specified in Table 25.1, the maximum current shall be measured under any condition of loading including short circuit using a resistor that shall be continuously readjusted during the 1-minute period to maintain maximum load current, without exceeding the value indicated in Table 25.1.

25.1.7 With reference to the voltage limit specified in Table 25.1, measurement shall be made with the device connected to the rated voltage of the device and with all loading circuits disconnected. Where a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement shall be made from either end of the winding to the tap.

25.1.8 When the control circuit mentioned in 25.1.4 is not limited as to available short-circuit current by the construction of a transformer and the circuit includes either one or more resistors, a fuse, a nonadjustable manual-reset protective device, or a regulating network – see 25.1.12 – the circuits in which the current is limited in accordance with 25.1.9, 25.1.10, or 25.1.11 are not required to be investigated.

25.1.9 A fuse or circuit-protective device provided in the control circuit used to limit the current in accordance with 25.1.8 shall be rated or set at not more than the values specified in Table 25.2.

Table 25.2
Rating for Secondary Fuse or Circuit Protector

Circuit voltage (volts, rms)	Maximum overcurrent protection (amperes)
20 or less	5
More than 20 but not greater than 60	$100/V^{a}$
[a] V is the maximum output voltage, regardless of load, with the primary energized.	

25.1.10 A fuse or circuit protective device may be connected in the primary of a transformer to limit the current in accordance with 25.1.8 when the protection is equivalent to that specified in 25.1.9 as determined by conducting the Overcurrent Protection Calibration Test, Section 71.

25.1.11 One or more resistors or a regulating network used to limit the current in accordance with 25.1.10 shall be such that the current under any condition of load including short circuit does not exceed the values indicated in Table 25.1.

25.1.12 Where a regulating network is used to limit the voltage or current in accordance with 25.1.4 – 25.1.11, and the performance is affected by malfunction, either short circuit or open circuit, of any single component – excluding a resistor – the network shall comply with the environmental tests specified in Annex A, Ref. No. 35.

25.1.13 In a circuit of the type described in 25.1.8, the secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited shall be investigated in accordance with the applicable requirements in this Standard.

25.2 Primary control circuits

25.2.1 A control circuit that extends from the device to a remote control panel, status panel, or similar device shall be protected in accordance with 25.2.2 – 25.2.8 to reduce the risk of fire and electric shock that is capable of resulting from overload and short circuit conditions.

25.2.2 The overcurrent protective device specified in 25.2.1 shall be a supplementary type, thermal link, fuse, or circuit breaker that is intended for branch circuit use. See Overcurrent Protective Devices, Section 28. Where the protective device consists of a fuse, the device shall be marked in accordance with 74.9.

25.2.3 A Class 1 power limited circuit, in accordance with Annex A, Ref. No. 71, used to supply an external control circuit shall be supplied from a source having a rated output of no more than 30 volts and 1000 volt amperes. When the source is other than a transformer, the circuit shall be protected by an overcurrent protection device rated no more than 167 % of the volt ampere rating divided by the rated voltage. The overcurrent device shall not be interchangeable with overcurrent devices of higher ratings.

25.2.4 An external control circuit derived from a Class 2 transformer is not required to be provided with the overcurrent protection specified in 25.2.1.

25.2.5 An external control circuit derived from the secondary of a transformer other than that described in 25.2.3 and 25.2.4 shall be provided with overcurrent protection in accordance with 25.2.6 and 25.2.8. For transformers not having a rating, the rated primary or secondary current mentioned in 25.2.6 and 25.2.8 shall consist of the maximum current during normal operation of the device.

25.2.6 Except as indicated in 25.2.7 and except as described in 25.2.8, a transformer used to supply a control circuit shall be provided with overcurrent protection in the primary circuit rated as indicated in Table 25.3.

25.2.7 Where the rated primary current of the transformer is 9 amperes or more, and 125 % of this current does not correspond to a Standard rating of fuse or circuit breaker, the next higher Standard rating of protective device may be used. Standard ratings of protective devices are specified in Annex A, Ref. No. 70.

Table 25.3
Primary Overcurrent Protection for Control Circuit Transformers

Rated primary current (A)	Maximum rating of overcurrent device, percent of transformer primary current rating
Less than 2	300
2 or more, less than 9	167
9 or more	125

25.2.8 Except as indicated in 25.2.9 and 25.2.10, when a control circuit is derived from the secondary of a transformer that is provided with primary circuit overcurrent protection rated at no more than 250 % of

the rated primary current of the transformer, additional overcurrent protection is not required in the primary circuit when the secondary circuit is protected at no more than 125 % of the rated secondary current of the transformer.

25.2.9 Where the rated secondary current of the transformer is 9 amperes or more and 125 % of this current does not correspond to a Standard rating of fuse or circuit breaker, the next higher Standard rating of protective device may be used. Standard ratings of protective devices are specified in Annex A, Ref. No. 70.

25.2.10 Where the rated secondary current of the transformer is less than 9 amperes, the overcurrent protection in the secondary circuit shall be rated or set at no more than 167 % of the rated secondary current.

26 Switches and controls

26.1 A switch or other control device shall have current and voltage ratings not less than those of the circuit that it controls when the device is operated in its intended manner.

26.2 A primary-circuit switch that controls an inductive load having a power factor less than 75 %, such as a transformer, shall be either rated not less than twice the maximum load current under normal operating conditions, or be investigated for the application.

26.3 A switch used to connect a load to various sources or potentials shall be a type that has been investigated and rated for such use.

26.4 A switch or other device controlling a relay, solenoid coil, or similar device shall have a pilot duty rating intended for the application.

26.5 Each pole of a snap switch rated as a 2-circuit, 3-circuit, or multicircuit switch may control a separate load at the full voltage rating of the switch. Each pole of a snap switch rated as a 240-volt, 2-pole switch may control a separate 120-volt load, and both may control both legs of a single 240-volt load. Each pole of a snap switch rated as a 240-volt, 3-pole switch may control a separate load not exceeding 139 volts, and the three poles may control the three legs of a 3-phase, 240-volt load.

26.6 A 240-volt or 250-volt snap switch used in a circuit involving more than 120 volts to ground shall be rated for such use as indicated by a double underlining under the voltage rating.

26.7 A switch shall not disconnect the grounded conductor of a circuit unless:

a) The switch simultaneously disconnects all conductors of the circuit, or

b) The switch is so arranged that the grounded conductor is not disconnected until the ungrounded conductors of the circuit have been disconnected.

26.8 Solid state switches shall comply with the requirements in this Standard. Mechanical and electromechanical switches shall comply with the applicable requirements for switches such as in Annex A, Ref. No. 36, or Annex A, Ref. No. 37.

26.9 Where a device switch or circuit breaker is mounted such that movement of the operating handle between the on position and off position results in one position being above the other position, the upper position shall be the ON position. This requirement does not apply to a switching device having more than one on position, a double throw switch, a rotationally operated switch, or a rocker switch.

27 Capacitors, Resistors, and Suppressors

27.1 Capacitors

27.1.1 The materials and construction of a capacitor, its case, or both shall be such that emission of flame from the enclosure of the device during malfunction of the capacitor does not occur. See 27.1.3.

27.1.2 The materials and construction of a capacitor or its case within a device shall be such that pressures capable of causing injury to persons do not develop in the capacitor in the event of malfunction of the capacitor or the circuit in which it is connected. See 27.1.3.

27.1.3 Compliance with the requirements described in 27.1.1 and 27.1.2 shall be determined by the Abnormal Tests specified in Section 52.

27.1.4 Under both normal and abnormal conditions of use, including internal shorting of the capacitor, a capacitor containing oil that is more combustible than askarel shall not result in a risk of fire or electric shock and shall be constructed to reduce the risk of expelling dielectric medium from the enclosure of the device. See 27.1.5 and 27.1.6.

27.1.5 With reference to the requirement in 27.1.4, a capacitor complying with the requirements for protected oil-filled capacitors in Annex A, Ref. No. 38, shall be constructed to reduce the risk of expelling the dielectric medium.

27.1.6 With reference to 27.1.4, a device having a capacitor other than that described in 27.1.5 shall be provided with:

a) A complete noncombustible bottom panel below the capacitor;

b) A ventilated, bottom-panel construction complying with 7.5.4.1; or

c) A ventilated, bottom-panel construction complying with the capacitor fault test described in 52.5.

27.1.7 A means such as a bleeder resistor shall be provided to drain the charge stored in a capacitor so that it does not provide a risk of electric shock. See 9.3.1.

27.1.8 Capacitors connected across an input ac circuit shall comply with the requirements for across-the-line capacitors in Annex A, Ref. No. 39.

27.2 Resistors

27.2.1 The assembly of a power resistor, such as a wire wound type requiring a separate support, shall be reliable. The resistor shall be prevented from loosening or rotating by a means other than friction between surfaces.

27.2.2 An assembly employing lock washers complies with the requirement in 27.2.1.

27.3 Suppressors

27.3.1 Suppressors shall be enclosed by housings of noncombustible, moisture-absorption-resistant material. If sheet steel is used, it shall be not thinner than 0.52 mm (0.02 inches).

27.3.2 The housing required by 27.3.1 may be dispensed with if a suppressor is mounted in an enclosure that affords protection equivalent to that of the housing.

28 Overcurrent Protective Devices

28.1 General

28.1.1 Supplementary overcurrent devices are not required unless specifically stated as such in other parts of this Standard or to reduce the risk of electric shock, fire, or injury to persons.

28.2 Supplementary protectors

28.2.1 Supplementary protectors shall not be used for overcurrent protection of circuits defined as "branch circuits" as defined in Annex A, Ref. No. 1.

28.2.2 Supplementary protection devices shall be in accordance with Annex A, Ref. No. 40. Supplementary protection devices that are user replaceable shall be accessible from outside the enclosure, or shall be located behind a hinged cover – see 7.2.1.

28.2.3 Except as indicated in 28.2.4, a supplementary protection device shall not be connected in the grounded (neutral) side of the line.

28.2.4 Additional protection in the grounded side of the supply circuit is allowed when the protection simultaneously disconnects all grounded and ungrounded conductors of the supply circuit.

28.2.5 Where the device has provision for connection of a grounded neutral conductor, individual single-pole circuit breakers may be used as the protection for each ungrounded conductor of a 3-wire single-phase circuit or for each ungrounded conductor of a 4-wire, 3-phase circuit, when no conductor involves a potential to ground in excess of 150 volts. See 74.18.

28.3 Thermal links

28.3.1 Non-resettable thermal links incorporated as overcurrent protection shall comply with the applicable requirements in Annex A, Ref. No. 41.

28.4 Fuses

28.4.1 Fuses used for overcurrent protection shall be plug fuses or cartridge fuses. Plug fuses shall be Edison base or Type S fuses and shall comply with 28.4.2. Cartridge fuses shall be Class CC, G, H, J, K, RK1, RK5, or T, and shall comply with 28.4.3.

28.4.2 Plug fuses shall comply with Annex A, Ref. No. 42 and Ref. No. 43. The fuseholder shall comply with Annex A, Ref. No. 45.

28.4.3 Cartridge fuses shall comply with Annex A, Ref. No. 42 and additionally, the Standard based on fuse class in accordance with Annex A, Ref. No. 46 and No. 48. Fuseholders shall comply with Annex A, Ref. No. 44 and additionally, the Standard based on fuse class in accordance with Annex A, Ref. No. 47.

28.4.4 For plug fuses and cartridge fuses, except as indicated in 28.4.5, a disconnecting means shall be provided on the supply side of each fuse. The disconnecting means shall be such that each individual circuit can be independently disconnected from the source of supply.

28.4.5 For service replaceable fuses, the disconnecting means can be the circuit breaker in the building installation. If so used, no additional disconnecting means is necessary, provided that manufacturer's service instructions inform the service personnel to disconnect power to the unit prior to changing the fuse.

28.4.6 A device shall be constructed so that fuses will be readily accessible when the disconnecting means is opened so that the fuse can be replaced without the service personnel or user inadvertently contacting live parts.

28.4.7 If a Type S fuseholder, or Edison base fuseholder with or without a Type S adapter, is used, the line connection shall be made to the center contact.

28.4.8 A fuse and fuseholder shall have a voltage and current rating not less than those for the circuit in which they are connected. Plug fuses shall not be used in a circuit rated more than 125 volts or 125/250 volts, 3-wire.

28.4.9 Fuses shall be located in all ungrounded conductors.

28.4.10 A device shall be marked in accordance with 74.9 when it is provided with overcurrent protection consisting of an interchangeable fuse that is accessible to the user, whether the user is instructed to change the fuse or not.

28.5 Circuit breakers

28.5.1 Circuit breakers incorporated as overcurrent protection shall comply with the applicable requirements in Annex A, Ref. No. 73.

29 Transformers

29.1 General

29.1.1 A transformer coil, unless inherently moisture resistant, shall be treated with an insulating varnish and baked, or otherwise impregnated to exclude moisture or acid vapor. Film coated magnet wire is moisture resistant for this case.

29.1.2 A thermal cutoff or other device employed to reduce the risk of fire or electric shock due to overheating of a transformer during abnormal operation shall comply with the requirements applicable to such a device in addition to the applicable requirements in this Standard. For example, a thermal cutoff shall comply with the applicable requirements in this Standard and those of Annex A, Ref. No. 41.

29.1.3 A transformer used to supply a signal circuit where the outlet is accessible to the user shall have its primary winding electrically isolated from its secondary winding and shall be constructed as specified in 29.2.1 – 29.2.7 so that there is no electrical connection – under normal and overload conditions – between the primary and secondary windings, between the primary winding and the core, or between separate adjacent secondary windings, where such connection results in a risk of fire or electric shock.

29.1.4 With reference to the requirement in 29.1.3, a transformer complying with the requirements in any of the following Standards complies with this requirement:

a) Annex A, Ref. No. 49 and Ref. No. 50;

b) Annex A, Ref. No. 51; or

c) Annex A, Ref. No. 26.

29.2 Coil insulation

29.2.1 A transformer winding including the start, all taps, finish, and crossover leads up to the point where insulated leads are provided shall be constructed, when used, as specified in Table 29.1.

Table 29.1
Transformer Insulation

	Insulation required	Type of insulation
1.	Insulation between the primary wires of opposite polarity and between secondary wires of opposite polarity having a potential greater than 30 volts, rms (42.4 volts peak)	a, b, c, or d
2.	Insulation between the primary and any secondary winding	a, b, c, or d
3.	Insulation between any winding or lead connections and dead metal parts	b, c, d, e, f, or g
4.	Insulation between the crossover leads and (1) the turns of a different winding, (2) the metal enclosure of a unit, or (3) the core	a, d, e, g, or h

a. Electrical grade paper that is waxed or otherwise treated to retard the absorption of moisture and that has a total thickness of not less than 0.71 mm (0.028 inch); polyethylene terephthalate film, not less than 0.178 mm (0.007 inch) thick; or aramid paper, not less than 0.203 mm (0.0085 inch) thick.

b. A thermoplastic or thermoset coil form not less than 0.71 mm (0.028 inch) thick.

c. A material having a thickness less than 0.71 mm (0.028 inch) is used only when it is equivalent to note a or b and the material has a minimum dielectric breakdown strength of 5000 volts for the thickness used as determined by the test described in Tests on Transformer Insulating Materials, Section 69.

d. Using spacings specified in Table 29.2 in place of the specified insulation is not prohibited.

e. Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.33 mm (0.013 inch) when used in conjunction with an air spacing of one-half that specified in note d.

f. Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.71 mm (0.028 inch) where the insulation is in contact with the enclosure.

g. A material having a thickness less than that specified in notes e and f is not prohibited where it is equivalent to notes e and f and the material has a minimum dielectric breakdown strength of 2500 volts for the thickness used for note e and 5000 volts for the thickness used for note f as determined by the test described in Section 51.

h. Any type and thickness of insulation in addition to the magnet wire coating, or a through air spacing less than that specified in Table 29.2 is not prohibited from being used between a crossover lead and the winding to which it is connected when the construction complies with either of the following:

1) The coil withstands the applicable dielectric withstand potential described in 51.3.1 and 51.3.3. The potential shall be applied between the coil leads with the crossover lead cut at the point where it enters the inner layer.

2) The coil withstands the induced potential described in 51.5.2 and 51.5.5.

Table 29.2
Spacings Within a Transformer

Minimum spacing through air and over surface, mm (inch)	
Potential involved, volts	**Between any uninsulated live part and an uninsulated live part of opposite polarity, or the core[a]**
0 – 50	1.2 (3/64)
Greater than 50 to 125	1.6 (1/16)
Greater than 125 to 250	2.4 (3/32)
Greater than 250 to 600	6.4 (1/4)
Greater than 600 to 1000 V	12.7 (1/2)

NOTE – This table applies only to transformers that are treated with an insulating varnish and baked or otherwise impregnated.

[a] Includes turns of a coil having a magnet wire coating.

29.2.2 Insulating material, such as outer-wrap and crossover-lead insulation, employed to reduce the risk of live parts from becoming accessible through openings in the outer enclosure in accordance with Protection of Users - Accessibility and User Servicing, Section 8, shall comply with note (a) or (c) of Table 29.1.

29.2.3 A flanged bobbin-wound transformer shall be constructed so as to maintain physical separation between the primary and secondary windings. Physical separation accomplished by employing a 3-flange bobbin for winding the primary and secondary windings adjacent to each other is allowed. As an alternative, a telescoping bobbin construction, with each section containing an individual winding, shall be used where the primary winding is wound over the secondary winding or the secondary winding over the primary winding. The bobbin insulation shall comply with note (a), (b), (c), or (d) of Table 29.1.

29.2.4 A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation meets the intent of 29.2.3 when:

a) The tape insulation complies with note (a) or (c) of Table 29.1;

b) The tape insulation provides a continuous overlap on the bobbin flange;

c) The transformer complies with the tests described in the Flanged Bobbin Transformer Abnormal Test, Section 53; and

d) The transformer complies with the induced potential tests described in 51.5.

29.2.5 A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation meets the intent of 29.2.3 when:

a) The tape insulation complies with note (a) or (c) of Table 29.1,

b) The coils are layer wound, and

c) All windings have end turns that are retained by a positive means and the spacing between end margins of the primary and secondary windings comply with item (d) of Table 29.1.

29.2.6 A transformer complying with the requirements in either Annex A, Ref. No. 49 and Ref. No. 50 or Annex A, Ref. No. 26 or Annex A, Ref. No. 51 complies with 29.2.3.

29.2.7 With reference to note (c) in 29.2.4, the Flanged Bobbin Transformer Abnormal Test, Section 53, is not required when the transformer is supplied from an LVLE circuit, or a limited energy circuit, or complies with the requirements in 28.2.

30 Printed Wiring Boards

30.1 Except as indicated in 30.2, a printed-circuit board shall comply with the requirements in Annex A, Ref. No. 52, and shall be classed V-1 in accordance with the requirements in Annex A, Ref. No. 15.

30.2 A printed wiring board located outside an enclosure, such as in an external control circuit, and located in a LVLE circuit or a limited-energy circuit shall be classed as minimum V-2.

30.3 A resistor, capacitor, inductor, or other part that is mounted on a printed-circuit board to form a printed-circuit assembly shall be secured so that it does not become displaced and cause a risk of electric shock or fire by a force that is capable of being exerted on it during assembly, intended operation, or servicing of the power supply.

30.4 Further evaluation shall be conducted for a barrier or a partition that is part of the device assembly and that provides mechanical protection and electrical insulation of a component connected to the printed-circuit board.

31 Insulating Materials

31.1 An insulating material used for supporting live parts and a barrier material shall be moisture-resistant and not be adversely affected by the temperature and stresses to which it is subjected under conditions of use.

31.2 Insulating material shall be judged with respect to the application for which it is to be used. Materials such as mica, some molded compounds, and certain refractory materials are usually used for the sole support of live parts. When an investigation is required to determine whether a material is capable of being used, such investigation shall be conducted in accordance with Annex A, Ref. No. 20. Consideration shall be given to the material's mechanical strength, resistance to hot wire ignition, resistance to high-current-arc ignition, resistance to high-voltage-arc ignition, dielectric strength, insulation resistance, and heat-resistant qualities, in both the aged and unaged conditions; the degree to which the material is enclosed; and any other feature affecting the risk of fire, electric shock, hazardous energy levels, or injury to persons. All factors shall be taken into account with respect to conditions of actual service.

31.3 Ordinary vulcanized fibers used for insulating bushings, washers, separators, and barriers shall not be the sole support for uninsulated live parts.

31.4 A sensor such as a current transformer, transducer, or similar device shall be provided with insulation that has been evaluated for the maximum voltage and temperature involved in its application, while taking into account the presence of other circuits.

32 Protection of Service Personnel

32.1 The requirements in Section 32 apply only to service personnel who find they must reach over, under, across, or around uninsulated electrical parts or moving parts to make adjustments or measurements while the device is energized.

32.2 Live parts shall be so arranged and covers so located as to reduce the risk of electric shock or exposure to energy hazardous parts while covers are being removed and replaced.

32.3 An uninsulated live part involving a risk of electric shock or exposure to hazardous energy shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact by service personnel adjusting or resetting controls, or similar action or performing mechanical service functions with the equipment energized, such as adjusting the setting of a control with or without marked dial settings, resetting a trip mechanism, or operating a manual switch.

32.4 Live parts involving a risk of electric shock, or exposure to hazardous energy, located on the back side of a door or cover shall be either guarded or insulated to reduce the risk of unintentional contact of the live parts by service personnel.

32.5 A component that requires examination, resetting adjustment, servicing, or maintenance while energized shall be so located and mounted with respect to other components and with respect to grounded metal parts that it is accessible for electrical service functions without subjecting the service person to the risk of electric shock or exposure to hazardous energy levels. Access to a component shall not be impeded by other components or by wiring.

32.6 For an adjustment that is to be made with a screwdriver or similar tool when the device is energized, 32.5 requires that protection be provided so that the risk of inadvertent contact with adjacent uninsulated live parts involving a risk of electric shock is reduced, taking into account that misalignment of the tool with the adjustment means is capable of resulting where an adjustment is attempted. This protection shall be provided by locating the adjustment means away from uninsulated live parts or by a guard that reduces the risk of the tool contacting uninsulated live parts.

32.7 A live relay frame or similar device involving a risk of electric shock or exposure to hazardous energy levels and that is capable of being mistaken for dead metal shall be guarded to reduce the risk of unintentional contact by the service person or be marked in accordance with 74.19.

32.8 Moving parts that can cause injury to service personnel that must be in motion during service operations that do not involve the moving parts shall be so located or protected that unintentional contact with the moving parts is not likely.

33 Electronic Protection Circuits

33.1 When circuit analysis or test results indicate that single component failure affects the ability of an electronic or solid-state circuit to perform its back-up, limiting, or other safety related function intended to reduce the risk of fire, electric shock, or injury to persons the circuit shall comply with the requirements in Annex A, Ref. No. 35, including environmental and stress tests applicable to the intended usage of the end-product. When such circuits employ a microprocessor executing software to perform the safety-related function, the software shall comply with the requirements in Annex A, Ref. No. 53.

33.2 When it is determined that environmental tests are required, the protection control shall be subjected to the following tests in accordance with the method described in Annex A, Ref. No. 35:

a) Transient Overvoltage Test;

b) Ramp Voltage Test;

c) Electromagnetic Susceptibility Tests;

d) Electrostatic Discharge Test;

e) Thermal Cycling Test;

f) Humidity Test; and

g) Effects of Shipping and Storage Test.

Before and after each test, the control shall be checked for normal operation.

33.3 The following test parameters shall be used in the investigation of the control covered by 33.1 for compliance with Annex A, Ref. No. 35:

a) Electrical supervision of critical components;

b) Visibility or audibility as a trouble indicator for an electrical supervision circuit;

c) A field strength of 3 volts per meter (0.91 volts per foot) shall be used for the Radiated EMI Test; and

d) Exposure Class H5 shall be used for the Humidity Test.

33.4 The following test parameters shall be used in the investigation of the circuit employing software covered by 33.1 for compliance with Annex A, Ref. No. 53:

a) The requirements for Software Class 1 shall be applied, and

b) A failure in the software during its intended operation does not affect compliance under the following conditions:

1) There is no loss of protective function as specified by the manufacturer, or

2) The EV supply equipment is de-energized such that there is no longer a risk.

34 Cord Reels

34.1 For EV supply equipment provided with a cord reel, the cord reel shall comply with Annex A, Ref. No. 54.

34.2 If the EV supply equipment is provided with hooks, or similar means, for manually winding a cord for storage, whether it is the flexible power cord or the EV cable, the requirement in 34.1 does not apply. The wound cord shall be subjected to temperature rating verification by temperature measurements on the cord during the Temperature Test, Section 49, with 2/3 of the cord length wound as intended.

35 Luminaires

35.1 Electric vehicle supply equipment provided with an external luminaire shall comply with the requirements specified in 35.2 – 35.6. The luminaire shall comply with the applicable requirements in Annex A, Ref. No. 55.

35.2 Luminaires provided as part of the electric vehicle supply equipment shall be provided with overcurrent protection in accordance with Overcurrent Protective Devices, Section 28, unless as indicated in 35.3.

35.3 Except as indicated in 35.4, a luminaire supplied by the same source as the electric vehicle supply equipment shall be provided with a switch rated 20 A minimum on the supply side of the overcurrent protection.

35.4 A switch is not required to be provided if the overcurrent protection can only be accessed after power is removed or if the access panel, cover, or door, is provided with an interlock.

35.5 A luminaire supplied by a separate source from the electric vehicle supply equipment need not be provided with a switch and overcurrent protection when the electric vehicle supply equipment is marked in accordance with 74.21.

35.6 With reference to 35.5, the electric vehicle supply equipment shall be marked in accordance with 74.20.

PROTECTION OF USERS AGAINST INJURY

36 General

36.1 Where the operation or user maintenance of a device involves a risk of injury to persons, means shall be provided to reduce the risk.

36.2 For the purpose of the requirements described in 36.3 – 36.6, the words “injury to persons” are in reference to physical harm to persons other than the physiological effects of electric shock.

36.3 When judging a product with respect to the requirement in 36.1, reasonably foreseeable misuse of the device shall be a factor.

36.4 A functional attachment that is made available or specified by the manufacturer for use with the basic device shall be included in the evaluation of the device. Unless the manufacturer specifies the use of two or more attachments at the same time, only one attachment at a time shall be evaluated with the device.

36.5 Whether a guard, a release, an interlock, or similar device is required and whether such a device is to be used shall be determined from an investigation of the complete device, its operating characteristics, and the risk of injury to persons resulting from a cause other than gross negligence. The investigation shall include evaluating the results of breakdown or malfunction of any component; not more than one component at a time, unless one event contributes to another. Where the investigation shows that breakdown or malfunction of a particular component results in a risk of injury to persons, that component shall be investigated for reliability.

36.6 Specific constructions, tests, markings, guards, and similar specifications are detailed for some common constructions. Specific features and products not covered herein shall be examined and tested to determine whether they are to be used for the purpose.

37 Sharp Edges

37.1 An enclosure, a frame, a guard, a handle, or similar device shall not have sharp edges that constitute a risk of injury to persons in normal maintenance and use.

37.2 Where reference measurements are required to determine that a part as mentioned in 37.1 is not sharp enough to constitute a risk of injury to persons, the method described in Annex A, Ref. No. 56, shall be employed.

38 Enclosures and Guards

38.1 A fan blade or other moving part that is capable of causing injury to persons shall be enclosed or provided with other means to reduce the risk of unintentional contact therewith.

38.2 The degree of protection required by 38.1 depends upon the general construction and intended use of a device.

38.3 Some guards are required to be self-restoring. Other features of guards that shall be evaluated include:

a) Removability without the use of a tool;

b) Removability for servicing;

c) Strength and rigidity;

d) Completeness; and

e) Creation of a risk of injury to persons, such as a pinch point, and the requirement for additional handling because of the increased need for servicing, such as for cleaning, unjamming, or similar service.

39 Strength of Enclosures

39.1 An enclosure provided to reduce the risk of fire, electric shock, injury to persons, or exposure to hazardous energy levels, shall be resistant to damage or deformation from drop impact, ball impact, and vehicle drive over in accordance with 39.2 – 39.4, as applicable for the type of device involved.

39.2 An enclosure shall not be adversely affected by dropping the product in accordance with the Drop Test, Section 59. This test is required for all products that are intended to be carried by hand from location to location, or for any products that are considered to be portable.

39.3 An enclosure shall not be adversely affected by impact of a steel sphere in accordance with the Impact Test, Section 57. This test is required for all products.

39.4 An enclosure shall not be adversely affected after being driven over by a vehicle in accordance with the Vehicle Drive Over Test, Section 58. This test is required for any product that is carried by hand or is considered portable and may be placed on the floor or ground during operation or in between operations.

40 Surface Temperatures

40.1 During the temperature test, the temperature of a surface that is capable of being contacted by the user shall not be more than the value specified in Table 40.1. When the test is conducted at a room temperature of other than 25 °C (77 °F), the results shall be corrected to that temperature. For devices intended for installation outdoors or on-board an EV, the results shall be corrected to 40 °C (104 °F).

Table 40.1
Maximum Surface Temperatures

Location	Composition of surface[a]			
	Metal		Nonmetallic	
Handles or knobs that are grasped for lifting, carrying, or holding	50 °C	(122 °F)	60 °C	(140 °F)
Handles or knobs that are contacted but do not involve lifting, carrying, or holding; and other surfaces subject to contact and user maintenance	60 °C	(140 °F)	85 °C	(185 °F)
Surfaces subject to casual contact but not required to be contacted to operate the device	70 °C	(158 °F)	95 °C	(203 °F)[b]

[a] A handle, knob, or similar device made of a material other than metal that is plated or clad with metal having a thickness of 0.127 mm (0.005 inch) or less is judged as a nonmetallic part.

[b] If intended to be mounted in service, the surface temperature shall not exceed 90 °C (194 °F). See Table 49.1.

41 Stability

41.1 Under all conditions of servicing and intended use after installation, a fully assembled device shall not become physically unstable to the degree that an injury to operators or service personnel results. A device intended to be secured in place is considered to comply with this requirement.

41.2 A device shall not be energized during the stability test. The test shall be conducted under conditions favorable to causing the product to overturn. The following conditions shall be considered such as to result in the least stability:

a) Position of all doors, drawers, casters, and other movable or adjustable parts, including that of the supply cord resting on the surface supporting the device;

b) Connection of or omission of any attachment made available by or specified by the manufacturer;

c) Provision of or omission of any normal load where the product is intended to contain a mechanical load; and

d) Direction in which the device is tipped or the supporting surface is inclined.

41.3 With reference to 41.2(a), where casters are used only to transport the device and jacks are lowered after installation, then the jacks – not the casters – shall be used in the most unfavorable position for the test, consistent with reasonable leveling of the device.

41.4 In conducting the stability test, the device shall be:

a) Placed on a plane inclined at an angle of 10° from the horizontal; or

b) Tipped through an angle of 10° from an at rest position on a horizontal plane.

41.5 With reference to the requirement in 41.4(b), for a device that is constructed so that while being tipped through an angle of 10° a part or surface of the device not normally in contact with the horizontal supporting surface touches the supporting surface before the device has been tipped through an angle of 10°, the tipping shall be continued until the surface or plane of the surface of the device originally in contact with the horizontal supporting surface is at an angle of 10° from the horizontal supporting surface.

42 Mounting Means

42.1 A mounting means for a fixed device shall withstand the load test without permanent deformation, breakage, or cracking of the mounting supports.

42.2 When mounted as specified by the manufacturer, a device shall comply with the Mounting Means Test, Section 64.

43 Strength of Handles

43.1 A handle used to support or carry a device shall withstand a load of four times the weight of the device without damage to the handle, its securing means, or that portion of the enclosure to which the handle is attached. See Strength of Handles Test, Section 65.

44 Height of Coupling Means

44.1 For devices intended to be wall or ceiling mounted, the installation instructions shall contain the statements in 77.5.

44.2 For outdoor use, pedestal mounted devices, the pedestal shall be of such a length that the storage means or location of the coupling device (receptacle, EV connector, or EV receptacle) is located at a height between 600 mm (24 inches) and 1.2 m (4 feet) above grade.

44.3 For indoor use, pedestal mounted devices, the pedestal shall be of such a length that the storage means or location of the coupling device (receptacle, EV connector, or EV receptacle) is located at a height between 450 mm (18 inches) and 1.2 m (4 feet) above grade.

PERFORMANCE

45 General

45.1 A representative sample of a device shall be subjected to the applicable tests described in Sections 46 – Section 71. Unless otherwise specified, all tests shall be conducted at the worst-case voltage specified by the manufacturer.

45.2 Except as indicated in 45.3, a unit marked with a dual frequency rating such as 50/60 hertz or a frequency range such as 50 – 60 hertz, shall have tests conducted at either frequency covered by the marking.

45.3 For a unit marked with a dual frequency rating or a frequency range, the Input Test, Section 48, Temperature Test, Section 49, and the Transformer Burnout Tests, Section 52, shall be conducted at the lowest frequency.

45.4 For each type of product or intended use as described in 6.1.3, 6.2.3, and 6.3.3 specific tests shall be included as applicable. See Annex B for a list of applicable tests and sample requirements.

46 Leakage Current Test

46.1 Except as indicated in 46.2 and 46.3, a cord-connected device rated for a nominal 250-volt or less supply shall be tested in accordance with 46.4 – 46.10. Leakage current shall not be more than 0.75 mA.

46.2 Conductive parts of a unit that complies with the following conditions and that have a leakage current greater than 0.75 mA shall have a leakage current from simultaneously accessible parts to the grounded supply conductor no greater than 3.5 mA. The leakage current between simultaneously accessible parts shall not exceed 0.5 mA.

a) The device requires electromagnetic interference (EMI) suppression filtering for compliance with other requirements;

b) The device is equipped with a grounding type supply cord and plug;

c) There is a low probability that a path for available current through the body exists in the expected environment. When the available current flows to ground, this involves the probability that the user is grounded during the use of the unit;

d) There is a low probability that high leakage conductive parts are contacted during normal use of the unit; and

e) The probability of injury resulting from an involuntary reaction is small.

46.3 For a device that upon loss-of grounding, dependably disconnects all sources that produce leakage current, the leakage current to ground shall not exceed 5 mA with the grounding conductor open and with the loss-of-grounding circuit disabled. The leakage current between simultaneously accessible parts on the unit shall not be more than 5 mA.

46.4 All accessible conductive surfaces shall be tested for leakage currents to determine compliance with 45.1. Where surfaces are simultaneously accessible, they shall be tested:

a) Individually,

b) Collectively (connected together) with the combined current measured to ground, and

c) Point-to-point on the device for leakage current between the simultaneously accessible surfaces.

Surfaces are simultaneously accessible when they are capable of being touched by one or both hands of a person at the same time. Accessible parts within a 100 by 200 mm (4 by 8 inches) rectangle are simultaneously accessible to one hand. The rectangle shall be flexed or bent to closely conform to the surface of the device. Accessible parts that are capable of being touched at the same time by the ends of a string 1.8 m (6 ft) in length are simultaneously accessible to both hands. The grounding pin, blade, or contact of an attachment plug is an accessible part.

46.5 When a conductive part other than metal is used for an enclosure or part of an enclosure, leakage current shall be measured using a metal foil with an area of 100 by 200 mm (4 by 8 inches) in contact with the surface. Where the conductive surface has an area less than 100 by 200 mm (4 by 8 inches) the metal foil shall be the same size as the surface. The metal foil shall conform to the shape of the surface and shall not remain in place long enough to affect the temperature of the unit.

46.6 Typical measurement circuits for leakage current with the ground connection open are illustrated in Figure 46.1 and Figure 46.2. The measurement instrument is defined in Figure 46.3. The meter that is

used for a measurement need only indicate the same numerical value for a particular measurement as does the defined instrument; it need not have all the attributes of the defined instrument.

Figure 46.1

Leakage Current Measurement Circuit Used for Devices Intended for Connection to 120 V Circuits

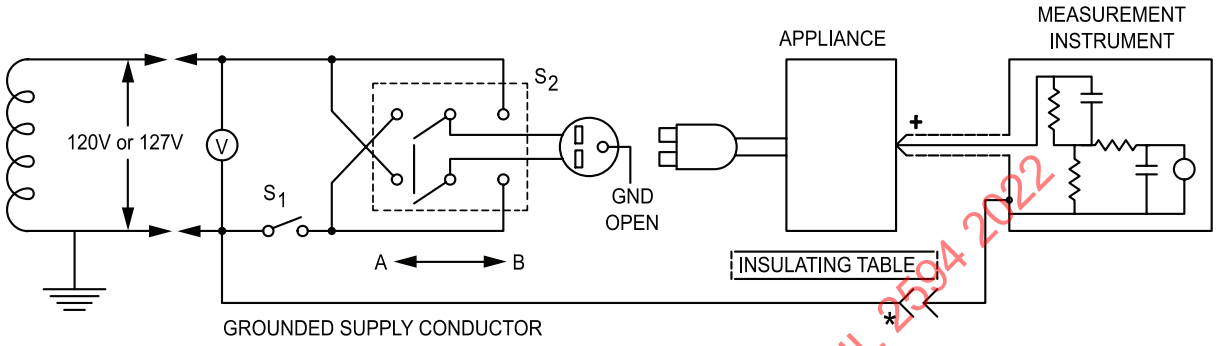
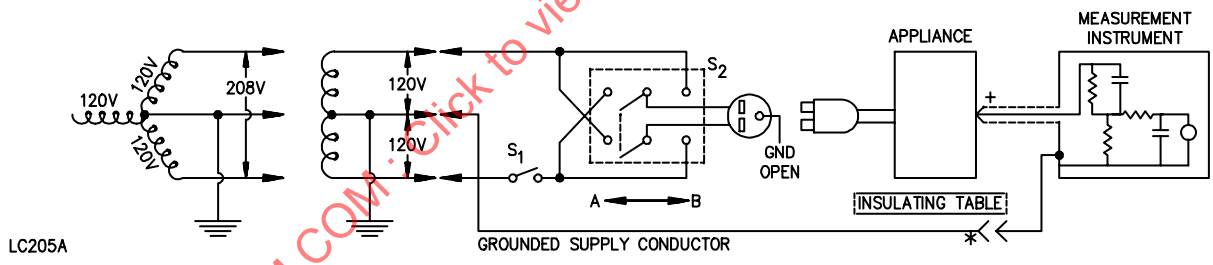


Figure 46.2

Leakage Current Measurement Circuit Used for Devices Intended for Connection to 208 V or 240 V Circuits



* Separated and used as clip when measuring currents from one part of the device to another.

+ Probe with shielded lead

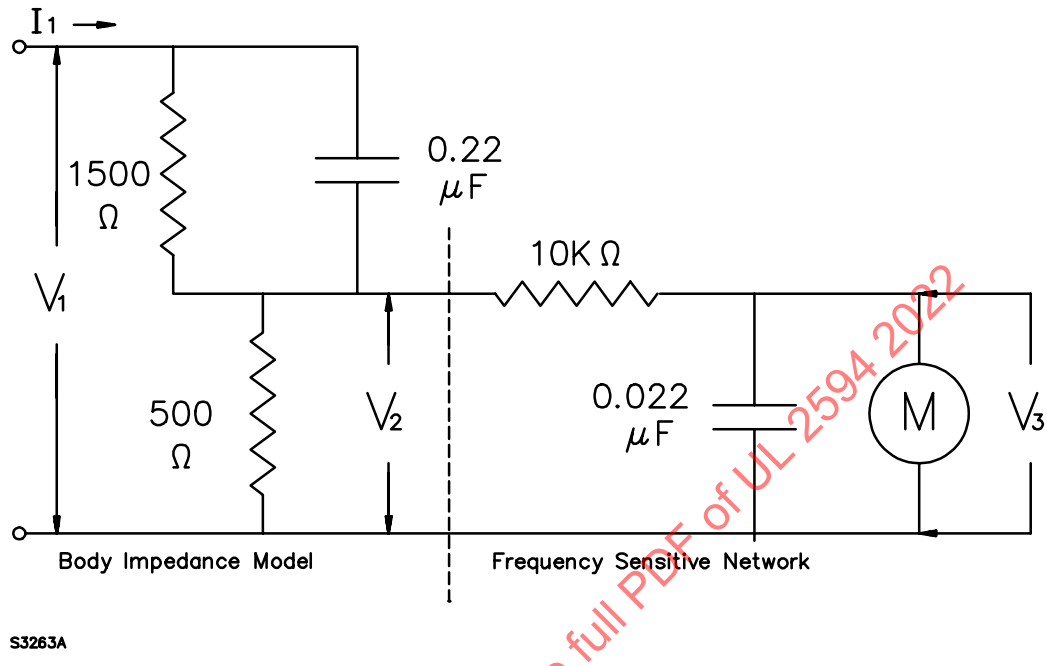
NOTES –

1) All voltages shown in Figure 46.1 and Figure 46.2 are nominal.

2) When it is not feasible to isolate the device from ground, the supply circuit shall be isolated from ground. It is then also sometimes required to reverse the leads of the measurement instrument.

Figure 46.3

Measurement Instrument for Reaction (Leakage) Current



Note – Detailed specifications and guidance for the calibration of this instrument are given in Annex A, Ref. No. 66.

46.7 Unless the measurement instrument is being used to measure leakage current from one part of a device to another, it shall be connected between accessible parts and the supply conductor connected to ground (the grounded or grounding conductor) that has the least extraneous voltages introduced from other equipment operated on the same supply. For products rated 120 volts or 240 volts, with one supply conductor grounded, this is likely to be the grounded supply conductor.

46.8 When there is no grounded conductor connected to the device under test (for example, a 240-volt, 2-conductor product supplied by a 120/240 volt source), then the instrument return lead may be connected to either the grounded or grounding conductor of the supply depending on the other electrical loads connected to the branch circuit and operating at the time the test is conducted. Use the conductor introducing the least extraneous voltage, as indicated by the lowest leakage current reading. In environments having significant extraneous voltage introduced, an isolating transformer reduces the effects of extraneous voltages.

46.9 A sample of a device shall be tested for leakage current starting with the as received condition – the as received condition being without prior energization, except that which occur as part of the production-line testing. The supply voltage shall be adjusted to rated voltage.

The test sequence shall be as follows, with reference to Figure 46.1 and Figure 46.2:

a) With switch S1 open, the device shall be connected to the measurement circuit. Leakage current shall be measured using both positions of switch S2, and with the device switches in all their normal operating positions.

b) Switch S1 shall then be closed, energizing the product. Within 5 seconds, the leakage current shall be measured using both positions of switch S2 and with the product switch in all their normal operating positions.

c) Leakage current shall be monitored until thermal stabilization. Both positions of switch S2 shall be used in determining this measurement. Thermal stabilization shall be obtained by operation as in the normal temperature test.

d) The leakage current shall also be monitored with switch S1 open while the device is at operating temperature and while cooling.

46.10 A sample shall be subjected to the entire leakage current test, as specified in 46.9, without interruption for other tests unless with the concurrence of those concerned, the tests are nondestructive tests.

47 Leakage Current Test Following Humidity Conditioning

47.1 A cord connected device rated 250 volts or less shall comply with the requirements for leakage current in 46.1, following exposure to air having a relative humidity of 88 ±2 % at a temperature of 32 ±2 °C (90 ±4 °F).

47.2 To determine whether a unit complies with the requirement in 47.1, a sample of the unit shall be heated to a temperature just above 34 °C (93 °F) to reduce the risk of condensation of moisture during conditioning. The heated sample shall be placed in the humidity chamber and shall remain for 48 hours under the conditions specified in 46.1. Immediately following the conditioning, the sample shall be removed from the humidity chamber and tested unenergized as described in 46.9(a). The sample shall then be energized and tested as described in 46.9 (b) and (c). The test shall be discontinued when the leakage current stabilizes or decreases.

48 Input Test

48.1 The input current to a device shall be measured with the device operating under conditions of maximum rated load as described in 48.2. The current input shall not be more than 110 % of the rated value.

48.2 Maximum rated load refers to the rated output of the device. During this test, the EV supply equipment shall be connected to a variable resistive load set to draw the maximum rated output from the device.

49 Temperature Test

49.1 Under the conditions specified in 49.2, the device shall not reach a temperature at any point high enough to cause a risk of fire, damage any material used, cause a protective device to operate, or exceed the temperature limits specified in Table 49.1. During this test, the ambient temperature shall be as specified in 49.9.

49.2 The device shall be loaded as indicated in 47.2, and additionally simulated ground fault currents shall be applied. The simulated ground fault current shall be equal to 90 % of the trip setting employed with the device.

49.3 For a fixed device, the ampacity of the conductors connected to the field wiring terminals or leads shall be in accordance with the smallest conductor allowed by the National Installation Codes in Annex A, Ref. No. 1.

49.4 A device intended for mounting or support in more than one position, or in a confined location, shall be tested in a manner representing the most severe conditions. An adjacent mounting or supporting surface shall consist of 1-inch thick trade size soft pine boards.

Table 49.1
Temperature Limits

Materials and Components	°C	(°F)
A. COMPONENTS		
1. Capacitors:		
a. Electrolytic types	65[b]	(149)[b]
b. Other than electrolytic	90[b]	(194)[b]
2. Field wiring terminals	75[c]	(167)[c]
3. Vulcanized fiber employed as electric insulation	90	(194)
4. Relays, solenoids, and similar devices		
a. Class 105 coil insulation systems:		
Thermocouple method	90[a]	(194)[a]
Resistance method	110	(203)
b. Class 130 coil insulation systems:		
Thermocouple method	110[a]	(230)[a]
Resistance method	120	(248)
5. Transformer insulation systems:		
a. Class 105:		
Thermocouple method	90[a]	(194)[a]
Resistance method	95	(203)
b. Class 130:		
Thermocouple method	110[a]	(230)[a]
Resistance method	120	(248)
c. Class 155:		
Thermocouple method	135[a]	(275)[a]
Resistance method	140	(284)
d. Class 180:		
Thermocouple method	150[a]	(302)[a]
Resistance method	160	(320)
e. Class 200:		
Thermocouple method	165[a]	(329)[a]
Resistance method	175	(347)
f. Class 220:		
Thermocouple method	180[a]	(356)[a]
Resistance method	190	(374)
6. Phenolic composition employed as electrical insulation or as a part the deterioration of which results in a risk of fire or electric shock	150[d]	(302)[d]
7. Rubber- or thermoplastic-insulated wire and cord	60 [d,e]	(140)[d,e]
8. Other types of insulated wires	f	f
9. A surface upon which a portable unit is mounted in service, and surfaces that are adjacent to the unit when so mounted	90	(194)
10. Any point on or within a terminal box or compartment of a fixed unit on which field-installed conductors rests	60[c]	(140)[c]
11. Thermoplastic sealing compound	g	g
12. Selenium rectifier	75[d,g]	(167)

Table 49.1 Continued on Next Page

Table 49.1 Continued

Materials and Components	°C	(°F)
13. Power semiconductor	h	h
14. Printed-wiring board	i	i

[a] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature measured by means of a thermocouple is not prohibited from being 5 °C (9 °F) higher than that specified when the temperature of the coil as measured by the resistance method is not more than that specified.

[b] A capacitor that operates at a temperature of more than 65 °C (149 °F) for electrolytic and more than 90 °C (194 °F) for other types is not prohibited from being judged on the basis of its marked temperature limit.

[c] The temperature observed on the terminals and at points within a terminal box of a unit shall not attain a temperature higher than the temperature marking required in items p and q of 76.3.

[d] The temperature limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has heat-resistant properties in accordance with Annex A, Ref. No. 57.

[e] A short length of rubber- or thermoplastic-insulated cord inside the unit is exposed to a temperature of more than 60 °C (140 °F) when supplementary insulation on each individual conductor is rated for the measured temperature and has dielectric properties in accordance with Annex A, Ref. No. 14 and No. 57.

[f] The temperature is not to exceed the temperature limit of the wire except as noted in note e.

[g] The sealing compound temperature limit is 15 °C (27 °F) less than the softening point of the compound as determined in accordance with Annex A, Ref. No. 58.

[h] For a power-switching semiconductor and similar components the temperature limit on the case is the maximum case temperature specified by the semiconductor manufacturer.

[i] For a printed wiring board, the temperature limit is the specified limit of the board.

49.5 Unless investigated and found to meet the intent of the requirement, a supporting means formed of rubber or neoprene material shall be removed prior to the test. Where the supporting means has a metal insert, such as a screw or rivet, the test shall be conducted with the device supported by the metal insert. At the request of the manufacturer, the test may be conducted without any means of support.

49.6 A thermocouple junction and the adjacent thermocouple lead wires shall be held securely in good thermal contact with the surface of which the temperature is being measured. Usually, good thermal contact results from securely taping or cementing the thermocouple in place. Where a metal surface is involved, brazing or soldering the thermocouple to the metal shall be done when required for good thermal contact.

49.7 Coil and winding temperatures shall be measured by thermocouples located on exposed surfaces, except that the resistance method is an alternate method for a coil that is inaccessible for mounting thermocouples, such as a coil immersed in sealing compound, wrapped with thermal insulation, or wrapped with more than two layers of material such as cotton, paper, or rayon more than 0.8 mm (1/32 inch) thick.

49.8 The temperature of a winding shall be determined by the resistance method by comparing the resistance of the winding at a temperature to be determined with the resistance at a known temperature according to the formula:

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

in which:

T is the temperature of the winding in °C;

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

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

t is the room temperature in °C at the beginning of the test; and

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors shall be determined.

The winding shall be at room temperature at the start of the test.

49.9 The values shown in Table 49.1 are the ultimate limits that shall be obtained during the temperature test. The test can be performed at any ambient temperature in the range of 10 °C – 40 °C (50 °F – 104 °F).

49.10 When a device is rated for an ambient temperature higher than 25 °C (77 °F), the rating shall be indicated in the instruction manual in accordance with 76.3(n).

49.11 Thermocouples shall consist of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ a temperature-indicating instrument with thermocouples consisting of 30 AWG iron and constantan wire. Such equipment shall be used whenever referee temperature measurements by thermocouples are required. The thermocouples and related instruments shall be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire shall conform with the requirements for special thermocouples as listed in the Tolerances on Initial Values of EMF versus Temperature tables in Annex A, Ref. No. 59.

49.12 A temperature shall be determined to be constant when three successive readings taken at intervals of 10 % of the previously elapsed duration of the test, but not less than 15 minutes, indicate no continued rise.

50 Capacitor Discharge Test

50.1 In accordance with 9.3.1, a cord connected device that is provided with filtering capacitors, or other primary capacitors, shall comply with this test.

50.2 The device shall be connected to a supply source of rated voltage at 60 Hz. The output shall be connected to a suitable load such that rated current is drawn from the output of the device. A storage oscilloscope shall be connected across the point of disconnection of the supply.

50.3 The device shall be connected to the source of supply and energized with the output open circuit condition. The power shall then be removed and the resulting discharge curve for the stored charge on capacitors shall be measured and captured on the oscilloscope.

In Mexico and the United States, the value of the stored charge shall decay to less than 37 % of its initial value within 1 second.

In Canada, the measured voltage shall be less than 42.4 V after 2 seconds.

50.4 The test shall be repeated with all switches in all possible positions and combinations.

51 Dielectric Voltage Withstand Test

51.1 General

51.1.1 The test potential mentioned in 51.3.1 and 51.4.1 shall be obtained from any convenient source having a capacity of at least 500 volt-amperes. A lower capacity is allowed when a meter is located in the output circuit, and the test potential is maintained except in case of breakdown. The voltage of the source

shall be continuously adjustable. Starting at zero, the applied potential shall be increased at a rate of 200 volts per second until the required test value is reached.

51.1.2 When a direct current potential is used for an ac circuit, a test potential of 1.414 times the applicable rms value of alternating current voltage specified in 51.3.1 and 51.4.1 shall be applied.

51.1.3 Printed-wiring assemblies and other electronic-circuit components that are damaged by application of the test potential or that short-circuit the test potential shall be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand tests are made. Testing for a representative subassembly is an alternative to testing an entire device. Semiconductor devices in the overall device shall be individually shunted before the test is made to avoid destroying them in the case of a malfunction elsewhere in the secondary circuits.

51.2 Maximum voltage measurements

51.2.1 The maximum voltage used as a basis for the calculation of the dielectric voltage-withstand test potentials specified in 51.3.1 and 51.4.1 and determination of the minimum spacings specified in Spacings, Section 22, shall be determined in accordance with 51.2.2 and 51.2.3.

51.2.2 A connector or comparable part that is capable of being disconnected during intended operation shall be both connected and disconnected during the test so that the maximum voltage is obtained.

51.2.3 Where a complex voltage is present, the peak value of the voltage shall be measured, and this value shall be used for calculation of the dielectric voltage-withstand potential and determination of the minimum spacings. For a sinusoidal or a direct current voltage, the rms or average values respectively shall be measured.

51.3 AC and DC power circuits (primary)

51.3.1 Except as indicated in 51.3.2, the ac and dc power circuits of a device shall withstand for 1 minute without breakdown the application of a 60 hertz sinusoidal potential with the device at the maximum operating temperature:

a) One thousand volts plus twice the maximum rated voltage between

1) The primary circuit and dead metal parts,

2) The primary and secondary circuits, and

3) All secondary windings, including any ferro-resonant windings.

b) Five hundred volts between a secondary circuit operating at 50 volts or less and dead metal parts; 1000 volts plus twice the maximum rated secondary circuit voltage between a secondary circuit, including any ferro-resonant windings, operating at more than 50 volts and dead metal parts.

c) One thousand volts plus the rated voltage of a capacitor between the terminals of a capacitor used for radio-interference elimination or arc suppression.

51.3.2 A dc circuit having a potential of 30 volts or less is not required to be tested.

51.3.3 With reference to 51.3.1, the test potential between ac power circuits and dead metal parts shall be based on the phase-to-ground voltage rating. The test potential for other points involving the ac power circuit shall be based on the highest operating voltage of the circuits involved.

51.4 Secondary circuits

51.4.1 Each secondary circuit, other than a power circuit covered in 51.3.1, shall withstand for 1 minute without breakdown the application of a test potential between primary and secondary circuits, between secondary circuits and grounded metal with grounding connections, where present, disconnected, and between isolated secondary windings of transformers. The device shall be at operating temperature during the test. The test potential shall be as indicated in Table 51.1.

Table 51.1
Magnitude of Test Potential for Secondary Circuits

Maximum voltage in the circuit[a,b]	Test potential
30 (42.4 peak), 60 dc, or less	No test
More than 30 (42.4 peak) but not more than 333.3 (471.3 peak) or more than 60 dc	Ten times maximum voltage in circuit (maximum of 1000 volts rms)
More than 333.3 (471.3 peak but not more than 1000 (1414 peak)	Three times maximum voltage in circuit
More than 1000 (1414 peak)	1750 volts plus 1.25 times voltage in circuit

[a] Where the peak voltage is greater than 120 % of 1.414 times the rms voltage, the circuit shall be tested as if the voltage were peak voltage divided by 1.414.

[b] Values are rms unless otherwise indicated.

51.5 Induced potential

51.5.1 When an isolating power transformer waives the test outlined in Transformer burnout test, 52.2, because it is protected by the intended branch circuit protection device, the following test described in 51.5.2 – 51.5.5 shall be conducted.

51.5.2 The primary winding of the transformer shall be subjected to an alternating potential of twice the rated voltage with the ends of all other windings opened. The potential shall be applied for 7200 cycles or for 60 seconds, whichever is less. A sinusoidal source shall be used, and the frequency of the service shall be in the range of 120 – 1000 hertz where required to prevent saturation of the core.

51.5.3 Primary- and secondary-circuit wiring connected to the transformer shall be disconnected for this test.

51.5.4 A 3 phase transformer may be tested with a single phase voltage. The voltage mentioned in 51.5.2 shall be applied successively across each primary winding.

51.5.5 While in the heated condition obtained during the transformer overload test, the test voltage required in 51.5.2 shall be initiated at one-fourth or less of the full value and brought up gradually to the full value in not more than 15 seconds. After being held for the time specified, the voltage shall be reduced slowly, but within 5 seconds, to one-fourth of the maximum value or less, and the circuit opened. The results meet the intent of the requirement when there is no dielectric breakdown.

52 Abnormal Tests

52.1 General

52.1.1 A device shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons – see 52.1.3 – when subjected to the tests specified in 52.2 – 52.9. Separate samples shall be used for conducting these tests.

52.1.2 Following each test, a dielectric voltage-withstand test specified in Section 51 shall be conducted. The potential shall be applied across the points indicated in 51.3.1.

Conducting more than one abnormal test on a sample and then performing the dielectric voltage-withstand test after completion of the abnormal tests for that sample is allowed if agreed to by all parties.

52.1.3 A risk of fire, electric shock, or injury to persons exists when:

a) Flame, burning oil, or molten metal is emitted from the enclosure of the device as evidenced by ignition, glowing, or charring of the cheesecloth or tissue paper, or

b) The insulation breaks down when tested in accordance with 52.1.2 or live parts are made accessible;

52.1.4 During these tests the device shall be placed on a softwood surface covered with a white tissue paper, and a single layer of cheesecloth shall be draped loosely over the entire enclosure. When it is impractical to drape the entire device, cheesecloth is required to be placed only over all ventilation openings. The cheesecloth shall be untreated cotton cloth running 26 – 28 m^2/kg (14 – 15 yards per pound), and having, for any cm^2 (square inch), a count of 5 (32) threads in one direction and 4.3 (28) in the other direction.

52.1.5 For a device having supporting feet made of rubber or neoprene material, the requirement in 49.5 shall apply.

52.1.6 Except as indicated in 52.1.7, the supply circuit shall have branch circuit overcurrent protection, the size of which equals 125 % of the input current rating (20-ampere minimum), except where this value does not correspond with the Standard rating of a fuse or circuit breaker, the next higher Standard device rating shall be used. The test voltage and frequency shall be adjusted to the values specified in 45.1 – 45.3.

52.1.7 When a marking on the product indicates a specific branch circuit protection rating, such protection shall be used.

52.1.8 The enclosure of the device shall be connected directly to ground for these tests through a 3 A ground fuse.

52.1.9 Each test shall be continued until further change as a result of the test condition is reduced significantly (e.g., temperatures have stabilized). When an automatically reset protector functions during a test, the test shall be continued for 7 hours. When a manual reset protector functions during a test, the test shall be continued until the protector is operated for 10 cycles using the minimum resetting time, and not faster than 10 cycles of operation per minute. The following are examples of test terminations:

a) Opening or shorting of one or more components such as capacitors, diodes, resistors, solid state devices, printed wiring board traces, or similar devices.

b) Opening of the intended branch circuit overcurrent protection device described in 52.1.6 – see 52.1.10.

c) Opening of an internal fuse or the 3 A fuse.

52.1.10 With reference to 52.1.9(b), when the branch circuit overcurrent protection device terminates the test, the instruction manual shall contain the information specified in 76.3(s).

52.2 Transformer burnout test

52.2.1 Except as indicated in 52.2.2 – 52.2.9, an adjustable resistive load shall be connected directly to the secondary winding of each transformer and adjusted to result in the load condition described in (a), (b), or (c) below. Opening of the intended branch circuit overcurrent protection device described in 52.1.6 or an internal overcurrent protection device connected in the primary-winding circuit is an example of when this test is terminated.

a) For a transformer having a single isolated secondary winding, the load shall be adjusted to result in maximum volt-ampere output but not result in more than three times the maximum normal alternating current to flow in the primary winding.

b) For a transformer having multiple isolated secondary windings, each secondary winding shall be tested separately; that is, with the winding under test loaded with an alternating current equal to three times the rms value of the secondary current flowing through that winding during maximum normal operation of the device and the other isolated windings, each loaded with an alternating current equal to the rms value of the secondary current flowing through their respective windings during maximum normal operation of the device.

c) For an autotransformer, the conditions specified in (a) shall be used with the supply voltage connected to the outer input legs and the load resistor connected to the outer output legs. See Figure 52.1.

52.2.2 A transformer supplied from either an inverter circuit or other means limiting the current to the transformer to less than three times rated current shall be loaded to a condition resulting in maximum obtainable input current without operation of overcurrent protection devices, where any are present.

52.2.3 A transformer employed in a switch-mode inverter or converter circuit shall be subjected to the transformer overload test described in 52.3.5 in lieu of the transformer burnout test.

52.2.4 Any transformer, including a control circuit transformer or a power transformer used for the transfer of either the input or output power of the device, and having overcurrent protection described in 28.4.3, is not required to comply with 52.2.1.

52.2.5 A transformer that is protected by the intended branch circuit protection device that is sized in accordance with the requirements in 28.4.3 and is provided in a device marked in accordance with 76.3(s) is not required to comply with 52.2.1. See 52.1.10.

52.2.6 An isolating power transformer used for the transfer of either the input or output power of the device shall comply with Annex A, Ref. No. 60 or Ref. No. 61, and shall be subjected to the transformer overload and induced potential tests described in 51.5.1 – 51.5.5 and 52.3.1 – 52.3.4, in lieu of the transformer burnout test.

52.2.7 In lieu of the transformer burnout test, a transformer may be subjected to the transformer overload and induced potential tests described in 51.5.1 – 51.5.5 and 52.3.1 – 52.3.4.

52.2.8 An isolating power transformer used for the transfer of either the input or output power of the device complying with the requirements in either of the following Standards is not required to comply with 52.2.1:

a) Annex A, Ref. No. 49 and Ref. No. 50,

b) Annex A, Ref. No. 51.

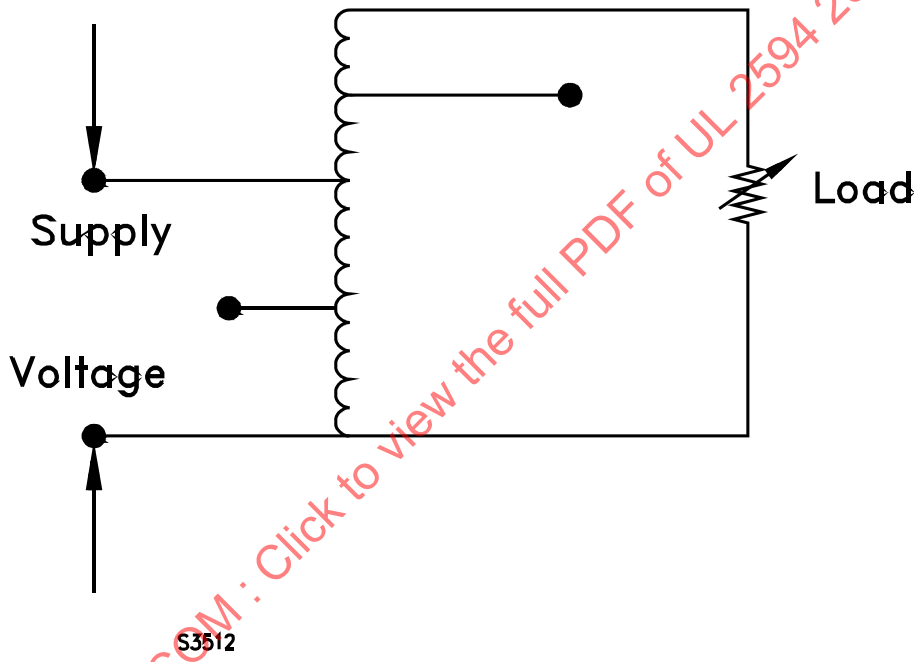
52.2.9 A signal or gate-drive transformer that is rated 10 watts or less and having a secondary circuit that does not extend out of the device is not required to comply with 52.2.1.

52.2.10 A ferro-resonant transformer shall be tested in accordance with 52.2.1 with the secondary winding loaded to maximum input current. The transformer shall be operated continuously until ultimate conditions are observed.

52.2.11 During the tests described in 52.2.1 and 51.2.2, secondary circuit protective devices that are external to the transformer shall be bypassed. Primary circuit protective devices shall be left in the circuit.

Figure 52.1

Autotransformer Burnout Test



NOTE – See 51.2.1(c) for description of test.

52.3 Transformer overload test

52.3.1 When an isolating power transformer is to be tested in accordance with 52.2.7, the tests described in 52.3.2 – 52.3.4 shall be conducted. When a transformer employed in a switch-mode inverter or converter circuit is to be tested in accordance with 52.2.3, the test described in 52.3.5 shall be conducted.

52.3.2 A resistive load shall be connected directly to each transformer secondary winding and adjusted to a value so each secondary winding carries 50 % of rated load until temperatures of the transformer core become stabilized. The load shall then be increased to 200 % of the rated value; no further adjustment of the overload current shall be made. The duration of the overload shall be as specified in Table 52.1. The short circuit method as described in Annex A, Ref. No. 62 is one method used to obtain the 200 % of rated load current. Where the short-circuit test method is used, all secondary windings shall be shorted and the voltage applied to the primary windings shall be adjusted to result in rated current to flow in the secondary windings.

Table 52.1
Overload Test Times

Insulation class	Overload time, minutes
105	30
130	30
155	30
180	26
200	23
220	20

52.3.3 With reference to the requirement in 52.3.2, testing of a transformer rated more than 500 kilovolt-amperes is not required when the test has already been performed with results that meet the intent of the requirement on a smaller transformer rated not less than 500 kilovolt-amperes, when the smaller transformer has the same insulation system and same general construction as the larger transformer, and the temperatures recorded during the temperature test are no greater for the larger transformer than those recorded during the temperature test for the smaller transformer.

52.3.4 Within 1 hour following the overload test, the transformer shall perform as intended in a repeated dielectric voltage-withstand test, except that the test value shall be at 65 % of value specified in Dielectric Voltage-Withstand Test, Section 51, and the induced potential test described in 51.5.1 – 51.5.5.

52.3.5 For a transformer employed in a switch-mode inverter or converter circuit, the power circuit supplied by the transformer shall be connected to a resistive load that draws maximum obtainable output power without causing operation of internal overcurrent protection devices or a protection circuit or resulting in opening of a circuit component such as a diode, resistor, sold state device, or similar device.

52.4 Short circuit test

52.4.1 The device shall be tested as described in 52.4.2. The device shall comply with the requirement in 52.1.1.

52.4.2 With reference to 52.4.1, fuses and other protective devices provided as part of the device shall remain in the circuit. The output connections of the device shall be short-circuited and the device connected to a source of supply adjusted to its highest test voltage. The test shall be continued until the internal protection opens, constant temperatures are attained, or the transformer winding opens. When an automatically reset protector is provided, the test shall be continued for 7 hours. When a manually reset protector is provided the test shall be continued until the protector operates for 50 cycles.

52.5 Capacitor fault test

52.5.1 Where required by 27.1.6, a device having a bottom-ventilated enclosure containing oil-filled capacitors shall be subjected to the performance tests specified for protected, oil-filled capacitors in Annex A, Ref. No. 38. These tests shall be conducted with the capacitors mounted in the device enclosure as intended, and oil leakage from the capacitors passing through the enclosure, where present, shall be extinguished – see 52.1.3(a).

52.6 Forced ventilation test

52.6.1 A device having forced ventilation shall be operated with the fan disconnected. For a device having more than one fan, the test shall be conducted with each fan disconnected, one at a time, or with two or more fans disconnected if they are controlled or powered by the same connection.

52.6.2 A device having filters over ventilation openings shall be operated with the openings blocked to represent clogged filters. The test shall be conducted initially with the ventilation openings blocked 50 %, shall then be repeated under fully blocked condition.

52.7 Component fault tests

52.7.1 A component, such as a capacitor, diode, solid state device, or similar device, connected in the input and output power circuits shall be short- or open-circuited, any two terminals one at a time, during any condition of operation including start-up. This test is not required:

a) Where circuit analysis indicates that no other component or portion of the circuit is overloaded.

b) For electromagnetic radio frequency interference capacitors subjected to the dielectric voltage-withstand test across their terminals in accordance with 51.3.1, resistors, transformers, inductors, and optical isolators.

52.8 Electrolytic capacitor fault test

52.8.1 Except as noted in 52.8.2, for a device having dc electrolytic storage capacitors operating above 60 V dc, the fault test described in 52.8.3 shall be conducted.

52.8.2 This requirement does not apply to a capacitor that complies with the requirements in Annex A, Ref. No. 38. The capacitor shall have an available fault current rating of 10,000 amperes or a lower value where a circuit analysis indicates that because of a series impedance, the lower value is applicable.

52.8.3 With reference to the requirement in 52.8.1, a fault in one of the capacitors in the storage capacitor bank shall be simulated. This shall be accomplished by connecting the capacitor under test in reverse while the input ac supply to the device is not energized. The device shall then be energized and operated as in normal operation.

52.9 Vibration test

52.9.1 An EV cord set shall be subjected to the vibration test described in 52.9.2. After the test:

a) The device shall comply with the requirements in 52.1.1;

b) There shall be no loosening of parts, and

c) The device shall operate normally.

52.9.2 The vibration test shall consist of vibration for 48 hours at a frequency of 22 cycles per second with a displacement of 6.4 mm (1/4 inch) in a vertical plane. The device shall be mounted as intended during the test.

53 Flanged Bobbin Transformer Abnormal Test

53.1 Except as indicated in 53.2 and 53.3, a flanged bobbin transformer required to be tested as provided in 29.2.4(c) – also see 29.2.7 – shall operate for 15 days with the secondary winding or windings loaded to the conditions described below in (a) – (c). A risk of fire or electric shock shall not result from:

a) Short-circuiting the secondary winding;

b) Loading the secondary winding to a current equal to maximum normal current plus X % of the difference between the short-circuit current and the rated current - where X equals 75, 50, 25, 20, 15, 10, and 5, respectively; and

c) Loading the secondary winding to maximum normal current.

53.2 A flanged bobbin transformer used in a circuit where isolation is not required or where the secondary circuit does not extend out of the device – see 29.1.3 – is not required to be subjected to this test.

53.3 A transformer complies with this requirement when it complies with the requirements in either of the following:

a) Annex A, Ref. No. 49 and Ref. No. 50.

b) Annex A, Ref. No. 51.

53.4 The results of the test do not meet the intent of the requirement when the cheesecloth glows, or flames, is charred or a breakdown occurs when the test described in 53.6 is conducted.

53.5 Samples for the 15-day abnormal operation tests shall be prepared as follows:

a) The transformer shall be mounted either in the device enclosure as intended under the conditions described in 52.1.4 or on a test bench with the cheesecloth mentioned in 52.1.4 draped over the transformer.

b) All secondary windings shall be loaded to rated current before the abnormal condition is introduced, and the loads, other than that connected to the winding to be overloaded, shall not be readjusted thereafter.

53.6 While still in a heated condition from the tests described in 53.1, a transformer shall withstand the dielectric voltage-withstand test applied between the primary winding and the secondary winding. The dielectric voltage-withstand-test potential shall be applied to the transformer 1 minute after completion of the abnormal-operation test.

53.7 The abnormal tests shall be conducted with a protective device built into the transformer or with an external protective device used with the transformer in the device connected in either the primary or secondary circuit, or in both. A protective device that is relied upon to open the circuit as a result of an abnormal test shall be one that has been investigated and found to meet the intent of the requirement.

53.8 For the purpose of these requirements, each secondary winding tap and each primary winding tap that is used to supply power to a load in the device is the equivalent of a secondary winding.

53.9 For the sequence of tests described in 53.1, when an abnormal-operation test continues for 15 days without a winding or a protective device opening, the remaining tests are not required to be conducted. For example, when the test described in 53.1(a) continues for 15 days, the tests described in 53.1 (b) and (c) are not required to be conducted.

53.10 To determine whether a transformer complies with the requirement in 53.1, three separate samples shall be subjected to each condition described in 53.1 (a) – (c). For a transformer that employs more than one secondary winding, each of the secondary windings shall be loaded for each condition specified in 53.1 with the other windings loaded to rated current. The test conditions shall be as described in 53.11 – 53.16.

53.11 To determine the short-circuit current value for conducting the tests described in 53.1(b), the transformer shall be at room temperature at the beginning of the measurement, and the short-circuit current shall be measured 1 minute after the voltage is applied to the primary winding. A protective device outside the transformer, where provided by the manufacturer, shall be short-circuited during the measurement of the short-circuit current. When the line fuse or transformer winding opens within 1 minute

after the application of the primary voltage, the short-circuit current is that value recorded just before the line fuse or winding opens. The short-circuit current of any one winding shall be measured with the other secondary windings open-circuited.

53.12 Except as indicated in 53.13, for the loading conditions, a variable resistor shall be connected across the secondary winding. Each test described in 53.1 (a) – (c) shall be continued until a risk of fire develops, the 3-ampere fuse opens, a winding of the transformer or a protective device opens, or 15 days have passed. In conducting the tests described in 53.1 (a) – (c), the variable resistance load shall be adjusted to the required value as quickly as possible and readjusted, where required, 1 minute after voltage is applied to the primary winding.

53.13 For a switch-mode transformer, the load shall be connected to the output of the power supply connected to the transformer.

53.14 When short-circuiting the secondary winding causes one of the windings to open before 15 days, then the next test in the sequence described in 53.1 (b) and (c) that continues for 15 days shall have the variable load resistor reduced to zero impedance at the end of the 15 days to cause the transformer to burn out.

53.15 For a transformer that is provided with a protective device built into the transformer or that is being tested in conjunction with an external protective device, a test described in 53.1 (a) – (c) shall be discontinued when the protective device opens the circuit, and the next test in the sequence shall be started. The protective device mentioned above includes automatic recycling type, manual reset type, or a replaceable type.

53.16 When a protective device opens the circuit or a winding on any sample opens during the 15-day abnormal-operation tests while the samples are unattended, the variable resistor load on the other samples shall be increased, by reducing the resistance, until the protective device opens the circuit or the winding opens, so that the samples are subjected to the dielectric voltage-withstand test described in 53.6 while in a heated condition. The next test in the sequence in 53.1 (b) and (c) that continues for 15 days shall be conducted.

54 Strain Relief Tests

54.1 General

54.1.1 The following tests apply to the flexible power cord connection to the EV supply equipment.

54.1.2 All of the tests can be performed on the same sample, but each test is performed one at a time.

54.1.3 The internal connections shall be disconnected or cut prior to the tests in 54.2 and 54.3.

54.2 Pull strain relief test

54.2.1 After the test outlined in 54.2.2, the flexible power cord shall not have been longitudinally displaced by more than 2 mm (0.08 inch), nor shall there be any indication of strain at the connections due to displacement of the cord, and spacings shall not be reduced, as described in Spacings, Section 22.

54.2.2 The flexible power cord shall be subjected to a steady pull of 150 N (35 pounds force), applied in the most unfavorable direction for a period of 1 minute.

54.2.3 During the test, the flexible power cord shall not be damaged as verified by visual inspection.

54.2.4 A wiring lead intended for field wiring connection shall withstand without damage or displacement a direct pull of 89 N (20 pounds) for 1 minute applied to a lead extending from the enclosure and 45 N (10 pounds) for 1 minute applied to a lead within a wiring compartment.

54.3 Push back strain relief test

54.3.1 A flexible power cord shall be tested in accordance with 54.3.2 without occurrence of mechanical damage to the flexible power cord, exposure of the cord to temperatures higher than the temperature rating of the cord, or reduction of spacings in accordance with Spacings, Section 22.

54.3.2 The flexible power cord shall be held 25.4 mm (1 inch) from the point where the flexible power cord emerges from the product and an attempt shall be made to push it back into the device. When a removable bushing that extends further than 25.4 mm (1 inch) is present, it shall be removed prior to the test. When the bushing is an integral part of the flexible power cord, then the test shall be carried out by holding the bushing. The flexible power cord shall be pushed back into the product in 25.4 mm (1 inch) increments until the flexible power cord buckles or the force to push the flexible power cord into the product exceeds 26.7 N (6 lbf) in Mexico and the United States, or 45 N (10 pounds) in Canada. The flexible power cord within the product shall be manipulated to determine compliance with 54.3.1.

55 EV Cable Secureness Test

55.1 EV cables provided with EV supply equipment, and permanently attached to this equipment, or EV cables provided with EV plugs or EV connectors, shall be subjected to the test outlined in 55.2 – 55.4. After this test, there shall be no axial displacement of the supply conductors, conductor insulation, or outer jacket of the EV cable from the assembled condition exceeding the maximum allowed displacement as specified in Table 55.1. In addition, there shall be no evidence of damage to the EV cable, the enclosure of live parts, the strain relief means, or the grounding path integrity.

55.2 The device shall be assembled as intended onto a 300 mm (12 inch), or longer, length of cable with its conductors positioned as if the conductors were to be connected to the terminals. Screws, nuts, or other hardware shall be tightened according to the manufacturer's instructions. The cable shall be cut at a right angle to its major axis but not stripped.

55.3 The cable clamp shall be held firmly in place. A force equivalent to the pressure of 1.034 N/mm^2 (150 lb/in^2) times the cross sectional area of the EV cable [rounded up to the nearest 22.2 N (5 lb) increment], but not less than 156 N (35 lbs), shall be applied gradually to the EV cable at a point not less than 150 mm (6 inches) from the cable grip in a direction perpendicular to the plane of the opening and in line with the cable. The force shall be applied and sustained for one minute.

55.4 A torque shall also be applied to the EV cable at a point 150 mm (6 inches) from the cable grip as specified in Table 55.1 for one minute in the direction least favorable to the clamp construction.

Table 55.1
Cable Secureness Test Values

Device rating amperes	Torque N·m (ft-lb)	Maximum displacement mm (inches)
15	0.41 (0.3)	2.38 (3/32)
16 – 20	0.54 (0.4)	2.38 (3/32)
21 – 35	0.68 (0.5)	2.38 (3/32)

Table 55.1 Continued on Next Page

Table 55.1 Continued

Device rating amperes	Torque N·m (ft-lb)	Maximum displacement mm (inches)
36 – 70	1.4 (1.0)	2.38 (3/32)
71 – 125	2.7 (2.0)	2.38 (3/32)
126 – 200	5.4 (4.0)	2.38 (3/32)
201 – 400	10.8 (8.0)	4.76 (3/16)
401 – 800	16.3 (12.0)	4.76 (3/16)

56 Grounding Tests

56.1 Ground impedance test

56.1.1 The impedance at 60 hertz between the point of connection of the equipment-grounding means and the metal part that is required to be bonded to ground shall not be more than 0.1 ohm when measured in accordance with 56.1.2. The resistance of the equipment grounding conductor of a power supply cord shall not be included in the resistance measurement.

56.1.2 Compliance with 56.1.1 shall be determined by passing a current of 25 amperes derived from a 60 hertz source with a no-load voltage not exceeding 6 volts between the following points and measuring the voltage across these points: the equipment grounding connection and the metal part in question.

56.1.3 In Canada, the above test shall be performed in accordance with 4.1 of Annex A, Ref. No. 63. In Mexico and the United States, this requirement does not apply.

56.2 Ground continuity test

56.2.1 The ground path for EV supply equipment provided with a permanently attached length of EV cable shall be continuous when required for grounding of the vehicle. Compliance is determined in accordance with the test in 56.2.2.

56.2.2 The ground path from the main ground terminal of the EV supply equipment to the ground pin at the EV connector shall be connected in series with an ac or dc source of voltage less than 30 V, and a means of indicating an unbroken circuit (e.g., an incandescent lamp, a bell, a buzzer). Operation of the indicator shall be evidence of continuity of the ground path under test.

57 Impact Test

57.1 After the test described in 57.2 – 57.5, there shall not be any cracking, breakage, or deformation of the enclosure to the extent that results in making uninsulated live parts or internal wiring accessible to contact in accordance with Protection of Users – Accessibility and User Servicing, Section 8.

57.2 A solid, smooth steel sphere, 50.8 mm (2 inches) in diameter, and weighing approximately 0.54 kg (1.18 pounds), shall fall freely from rest through a vertical distance in accordance with 57.5 onto the enclosure as shown in Figure 57.1.

57.3 Except as indicated in 57.4, for surfaces other than the top of the enclosure, the sphere specified in 57.2 shall be suspended by a cord and shall fall as a pendulum dropping a vertical distance in accordance with 57.5 as shown in Figure 57.2. The enclosure shall be placed so that the surface tested is vertical and in the same vertical plane as the point of support for the pendulum. Parts of the enclosure that could

interfere with the cord of the pendulum shall be removed. During the test, the enclosure shall be placed against a vertical wall.

57.4 A horizontal impact on vertical or sloping surfaces may be performed in place of the pendulum impact in 57.2, by mounting the sample at 90° to its normal position and applying the vertical impact test from 57.2.

57.5 The vertical distance mentioned in 57.2 and 57.3 shall be 1.3 m (51 inches). In Canada, if a surface area is greater than 25800 mm^2 (40 in^2), then the vertical distance shall be increased to 2.6 m (102.4 inches). In Mexico and the United States, this requirement does not apply.

57.6 The test shall be performed on one sample at room temperature and on a second sample conditioned in a cold chamber at minus 30 ± 2 °C (minus 22 ± 4 °F) for 24 hours. For the conditioned sample, the sample shall be removed from the chamber prior to being subjected to the impact force. Gloves shall be worn when handling the conditioned sample to minimize heat transfer.

Figure 57.1

Vertical Impact Test

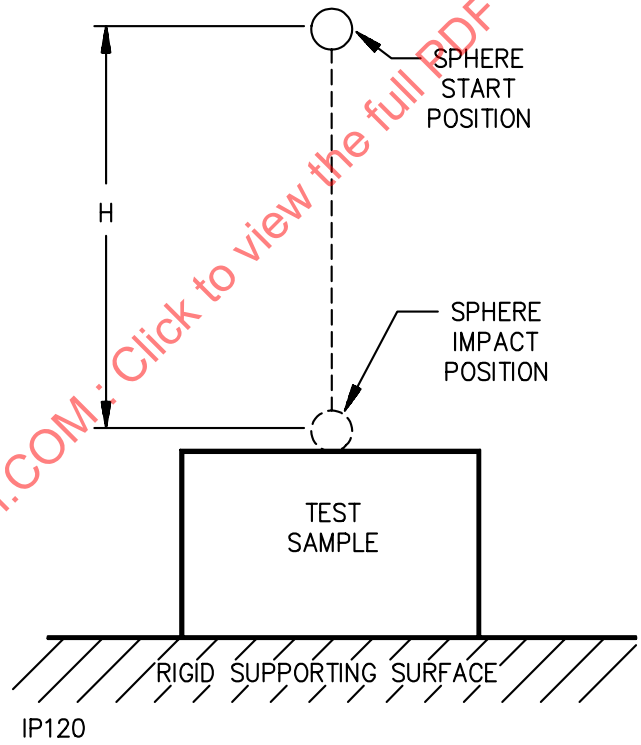
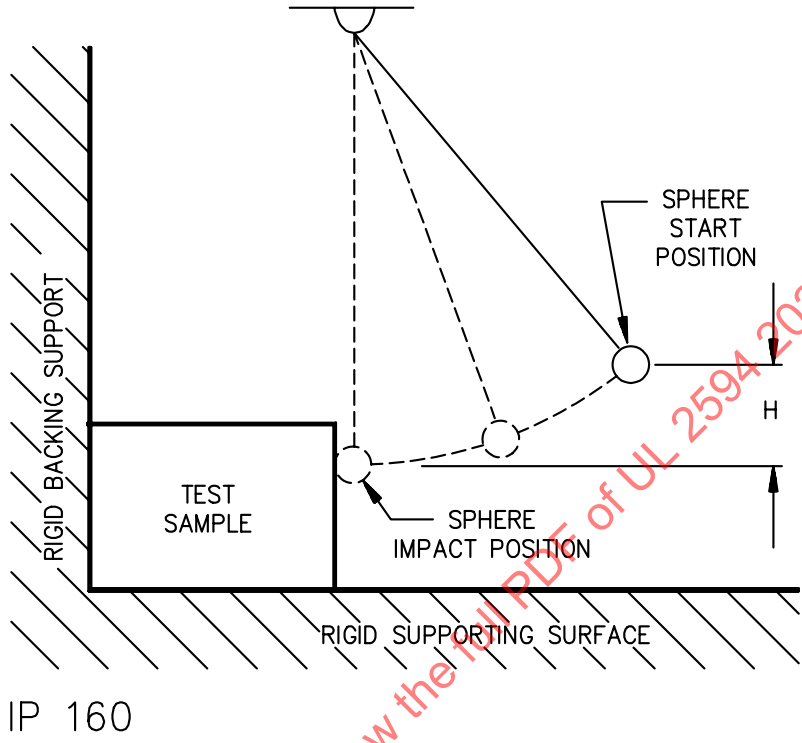


Figure 57.2

Pendulum Impact Test



58 Vehicle Drive Over Test

58.1 As a result of the test outlined in 58.2, there shall not be any cracking, breakage, or deformation of the enclosure to the extent that results in any of the following:

a) Making uninsulated live parts or internal wiring accessible to contact in accordance with Protection of Users – Accessibility and User Servicing, Section 8; or

b) Any other evidence of damage that could increase the risk of fire or electric shock.

58.2 Each of three enclosures, wired as intended, shall be subjected to this test. The enclosures shall be placed on a concrete floor in any normal position of rest. A crushing force of 4893 N (1100 lbf) shall be applied by a conventional automotive tire, P225/75R15, or an equivalent tire suitable for the load, mounted on a steel rim and inflated to a pressure of 218 ± 13 kPa (32 ± 2 psi). The wheel shall be rolled over the enclosure at a speed of 8 ± 2 kmph (5 ± 1.25 mph). Each enclosure shall be oriented in a natural resting position before applying the force. Any position that the product can rest in without outside supports is considered a “natural resting position” for this test. For the test, the device under test shall be held or blocked in the natural resting position so that it does not move substantially during the application of the applied force.

59 Drop Test

59.1 After the test described in 59.2 and 59.3, there shall be no access to hazardous live parts in accordance with Protection of Users – Accessibility and User Servicing, Section 8.

59.2 The test shall be performed on one sample at room temperature (nominal 25 °C or 77 °F) and on a second sample conditioned in a cold chamber at minus 30 ± 2 °C (minus 22 ± 4 °F) for 24 hours. For the

conditioned sample, the sample shall be removed from the chamber prior to being subjected to the drop test. Gloves shall be worn when handling the conditioned sample to minimize heat transfer.

59.3 Two samples shall be subjected to three impacts that result from being dropped onto a concrete surface in positions likely to produce the most adverse results. The height of the drop shall be 100 cm (39.4 inches). Each drop should impact a different part of the sample.

60 Strength of Terminal Insulating Base and Support

60.1 An insulating base or support is considered to comply with the test described in 60.2 when there are no cracks in insulating base materials, no rotation of the insulating base, bosses or recesses or other means to prevent turning perform their intended function, or the like. Minor deformation or deterioration is allowed as long as the performance of the connection is not affected.

60.2 An insulating base or support shall be subjected to the force created when the connectors, securing short lengths of conductors sized as described in 12.1.1.4, are torqued to 110 % of the value marked on the device.

61 Impact on Glass Covers

61.1 With reference to 7.5.8.1(b), a glass covered opening shall withstand an impact as indicated without cracking or breaking to the extent that a piece is released or dropped from its normal position:

a) In Mexico and the United States, 3.38 J (2-1/2 foot-pounds) impact.

b) In Canada, 7.0 ± 0.2 J (5.16 foot-pounds) impact.

61.2 The impact specified in 61.1 shall be applied by means of a smooth, solid steel sphere 50.8 mm (2 inches) in diameter and having 535 g (1.18 pounds) mass. The sphere shall fall freely from rest through a vertical distance of:

a) In Mexico and the United States, 63.5 cm (25 inches).

b) In Canada, 130 cm (51.2 inches).

62 Bonding Conductor Tests

62.1 General

62.1.1 If tests are required to determine the acceptability of the bonding conductor, the bonding connection or conductor shall comply with the tests of 62.2 and 62.3.

62.2 Current test

62.2.1 A bonding conductor shall not open when carrying a current that equals twice the branch circuit protective device rating but not less than 40 amperes, for the time specified in Table 62.1.

Table 62.1
Duration of Current Flow, Bonding Conductor Test

Rating or setting of branch-circuit overcurrent protective device, amperes	Test time, minutes	
	135 % of current	200 % of current
0 – 30	60	2
31 – 60	60	4
61 – 100	120	6
101 – 200	120	8

62.3 Limited short circuit test

62.3.1 A bonding conductor shall not open when subjected to the limited short circuit test described in 62.3.2 and 62.3.3.

62.3.2 Three samples of the bonding conductor shall be subjected to the test. The current shall be as specified in Table 62.2. The test circuit shall have a power factor of 0.9 – 1.0 and shall be limited to the current specified in Table 62.2. The open circuit voltage of the test circuit shall be 100 – 105 % of the rated voltage of the equipment. The bonding conductor shall be connected to the circuit by a series connected nonrenewable fuse that does not open in less than 12 seconds when carrying twice its rated current. One test shall be performed on each sample.

62.3.3 The fuse specified in 62.3.2 shall have a current rating equal to that of the branch circuit overcurrent protective device to which the equipment is intended to be connected, but not less than 20 amperes.

Table 62.2
Circuit Capacity for Short Circuit Test

Rating of unit, volt-ampere		Volts	Capacity of test circuit, amperes
Single phase	3-phase		
0 – 1176	0 – 832	0 – 250	200
0 – 1176	0 – 832	251 – 600	1000
1177 – 1920	833 – 1496	0 – 600	1000
1921 – 4080	1497 – 3990	0 – 250	2000
4081 – 9600	3991 – 9145	0 – 250	3500
9601 or more	9146 or more	0 – 250	5000
1921 or more	1497 or more	251 – 600	5000

63 Evaluation of Reduced Spacings on Printed Wiring Boards

63.1 Printed-wiring board traces on printed wiring boards with deficient spacings shall be short-circuited, one location at a time, and the test shall be conducted in accordance with 52.1.1 – 52.1.3, 52.1.5, 52.1.8, and 52.1.9. As a result of this test:

a) The overcurrent protection associated with the branch circuit to the device shall not open, and

b) A wire or printed wiring board trace shall not open.

When the circuit is interrupted by opening of a component, not including overcurrent protective device, the test shall be repeated twice using new components as required. The same component shall interrupt the test in each iteration.

64 Mounting Means Test

64.1 The mounting means of a fixed in place product shall withstand a force of four times the weight of the equipment, but not less than 4.5 kg (10 lbs), without malfunction of or damage to the mounting means, including any bracket, securing means, or the equipment. When tested as described, the equipment and mounting means shall remain in place with no evidence of damage to the mounting means or the equipment.

64.2 To determine if the equipment complies with 64.1, the equipment shall be mounted in accordance with the manufacturer's installation instructions, using the hardware and construction as prescribed by the manufacturer. If the details of mounting are not specified, 9.5 mm (3/8 inch) thick plasterboard (drywall) on nominal 5 by 10 cm (2 by 4 inch) trade size wood studs spaced on 406 mm (16 inch) centers shall be used as the support surface. The hardware shall be applied as specified in the instructions, and if not otherwise indicated, the securing screws shall be positioned between the studs and secured into the plasterboard. Adjustable equipment shall be adjusted to the position that will give the maximum progression from the wall. The force shall be applied through a (76-mm) 3-inch wide strap at the dimensional center of the equipment and shall be increased over a 5 to 10 second interval until a load equal to the weight of the device plus a force of three times the weight of the device, but not less than 4.5 kg (10 lbs), is applied to the mounting means. The load shall be maintained for one minute.

65 Strength of Handles

65.1 A handle specifically intended for lifting or carrying a portable product shall withstand a force equal to four times the weight of the equipment without breaking when tested in accordance with 65.2.

65.2 The force shall be applied with the handle in the intended carrying position, over a 76 mm (3 inch) length at the center of the handle. The force shall be applied gradually such that the required value is attained in 5 to 10 seconds and then maintained for 1 minute. If more than one handle is provided, the force shall be determined by the percentage of the device weight sustained by each handle with the device in the intended carrying position. If a device with more than one handle can be carried using only one handle, then each handle shall sustain the entire test weight in separate tests.

66 Mold Stress-Relief Distortion Test

66.1 A previously unused sample of the enclosure shall be subjected to the test as outlined in 66.2. After this test, the sample shall not show any signs of distortion, deterioration, shrinkage, warping, or softening, or access to live parts.

66.2 The sample shall be placed in an air circulating oven at a temperature equal to 10° higher than the maximum temperature observed adjusted based on maximum operating ambient temperature) on the enclosure during the temperature test, but not less than 70 °C (158 °F) for all fastened-in place equipment. For EV cord sets, the minimum test temperature shall not be less than 90 °C (194 °F). The sample shall be conditioned in the oven for 7 hours.

67 Additional Environmental Tests

67.1 General

67.1.1 The following tests as applicable shall be performed on a sample of the enclosure. Internal parts or frames are not required to be provided as part of this test; however, they may be required to complete or strengthen an enclosure for the test.

67.1.2 The tests shown in 67.2 – 67.4, shall be applied in accordance with 7.7.

67.2 Water exposure test

67.2.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Water Exposure Test in Annex A, Ref. No. 19, all the minimum property retention requirements in Table 67.1 are met.

Table 67.1
Minimum Property Retention Limitations After Water Immersion Conditioning

Property	Water immersion[a]
Flammability Classification	Unchanged
Tensile or Flexural Strength[b]	50 %
Tensile, Izod, or Charpy Impact[b]	50 %

[a] 7 days at 70 °C.

[b] For functional support, the test methods are Tensile Strength and Flexural Strength. For impact resistance, the test methods are Tensile, Izod, or Charpy Impact.

67.3 UV exposure

67.3.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the UV Exposure/Weathering Test in Annex A, Ref. No. 20, all the minimum property retention requirements in Table 67.1 are met.

67.4 Chemical exposure

67.4.1 Two samples of the material used to form the enclosure shall be subjected to this test. The material shall not show any indication of cracking, deterioration, or other signs of deformation after exposure to the following:

a) One sample shall be subjected to a 40 hour immersion in accordance with Annex A, Ref. No. 67.

b) One sample shall be subjected to a 40 hour immersion in accordance with Annex A, Ref. No. 68.

67.4.2 Two samples of a strain relief or bushing material required to be subjected to chemical exposure in accordance with 12.2.2.4 or 12.2.3.1 shall be subjected to this test. The material shall not show any indication of cracking, deterioration, or other signs of deformation after exposure to the following:

a) One sample shall be subjected to a 40 hour immersion per Annex A, Ref. No. 67.

b) One sample shall be subjected to a 40 hour immersion per Annex A, Ref. No. 68.

68 Tests for Permanence of Cord Tags

68.1 After being tested as described in 68.2 – 68.5, a tag used for a marking is considered to be permanently affixed to a flexible cord if there is no:

a) Tearing at any point for more than 1.6 mm (1/16 inch);

b) Movement of the tag more than 12.7 mm (1/2 inch) along the length of the flexible cord;

c) Shrinkage, wrinkling, cracking, or other deformation that renders the marking illegible; or

d) Visible curling or loosening around the edges of a tag with an adhesive back.

68.2 Nine samples of a cord tag shall be tested as described in 68.5. Each sample shall consist of a length of flexible cord to which the tag has been attached in the intended manner. If the tag is secured by an adhesive, the test shall be conducted no sooner than 24 hours after application of the tag. Three samples shall be tested as received; the additional samples shall be conditioned as described in 68.3 and 68.4 prior to testing.

68.3 Three samples shall be conditioned for 240 hours in an air-circulating oven maintained at a uniform temperature of 87.0 ± 1.0 °C (188.6 ± 1.8 °F). Following removal from the oven, the samples shall remain at a temperature of 23.0 ± 2.0 °C (73.4 ± 3.6 °F) and a relative humidity of 50 ± 5 % for 30 minutes before testing.

68.4 Three additional samples shall be conditioned for 72 hours at a temperature of 32.0 ± 2.0 °C (89.6 ± 3.6 °F) and a relative humidity of 85 ± 5 %. The samples shall be tested within 1 minute after being removed from the humidity chamber.

68.5 Each sample of flexible cord with attached tag shall be tightly suspended and clamped at each end in a vertical plane with the attachment plug pointing upward. A 22.2 N (5 pound) force shall be applied for 1 minute at the uppermost corner of the tag furthest from the cord and within 6.4 mm (1/4 inch) of the vertical edge of the tag. The force shall be applied vertically downward in a direction parallel to the major axis of the cord. Following the test, the sample shall comply with the requirements in 68.1. Manipulation of the tag, such as straightening by hand, is permitted.

69 Tests on Transformer Insulating Materials

69.1 Where required by note (c) or (g) of Table 29.1, the transformer insulating material shall be subjected to the test described in 69.2.

69.2 The insulating material shall be placed between two opposing electrodes. The electrodes shall be cylindrical brass or stainless steel rods 6.4 mm (1/4 inch) in diameter with edges rounded to a 0.8 mm (1/32 inch) radius. The upper movable electrode shall weigh 50 ±2 grams to exert sufficient pressure on the specimen to provide good electrical contact. The test potential shall be increased to the test value and the maximum test potential shall be maintained for 1 second. The result complies when there is no dielectric breakdown.

70 Metallic Coating Thickness Test

70.1 The solution to be used for this test shall be made from distilled water and shall contain 200 grams per liter of chemically pure chromic acid (CrO_3) and 50 grams per liter of chemically pure concentrated sulfuric acid (H_2SO_4). The latter is equivalent to 27 milliliters per liter of chemically pure concentrated sulfuric acid, specific gravity 1.84, containing 96 % of H_2SO_4.

70.2 The test solution shall be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube of approximately 0.64 mm (0.025 inch) inside bore and 140 mm (5.5 inches) long. The lower end of the capillary tube shall be tapered to form a tip, the drops from which shall be approximately 0.025 milliliters. To maintain an effectively constant level, a small glass tube shall be inserted in the top of the funnel through a rubber stopper and its position shall be adjusted so that the rate of dropping is 100 ±5 drops per minute when the stopcock is open. When desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

70.3 The sample and the test solution shall be kept in the test room long enough to acquire the temperature of the room maintained at an ambient temperature of 21.1 – 32.2 °C (70 – 90 °F).

70.4 Each sample shall be thoroughly cleaned before testing. All grease, lacquer, paint, and other nonmetallic coatings shall be removed completely by means of solvents. Samples then shall be thoroughly rinsed in water and dried. The cleaned surface shall not contact the hands or any foreign material.

70.5 The sample to be tested shall be supported 8 – 25 mm (0.7 – 1 inch) below the orifice, so that the drops of solution strike the point to be tested and run off. The surface to be tested shall be inclined approximately 45° from horizontal.

70.6 The stopcock shall be opened and the time, in seconds, required for the dropping solution to dissolve the protective metallic coating and expose the base metal shall be measured. Exposure of the base metal shall be considered as the first appearance of the base metal recognizable by the change in color at that point.

70.7 Each sample of a test lot shall be tested at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface, and at an equal number of points on the outside surface, at places on both surfaces where the metallic coating can be expected to be the thinnest. On enclosures made from precoated sheets, the external corners that are subjected to the greatest deformation may have thin coatings.

70.8 The thickness of the coating being tested shall be calculated by selecting from Table 70.1 the thickness factor appropriate for the temperature at which the test was conducted, and multiplying that thickness factor by the time, in seconds, required to expose base metal as noted in 70.6.

Table 70.1
Thickness of Coatings

Temperature,		Thickness factors, 0.0003 mm (0.00001 inch) per second	
°C	(°F)	Cadmium platings	Zinc platings
21.1	(70)	1.331	0.980
21.7	(71)	1.340	0.990
22.2	(72)	1.352	1.000
22.8	(73)	1.362	1.010
23.3	(74)	1.372	1.015
23.9	(75)	1.383	1.025
24.4	(76)	1.395	1.033
25.0	(77)	1.405	1.042
25.6	(78)	1.416	1.050
26.1	(79)	1.427	1.060

Table 70.1 Continued on Next Page

Table 70.1 Continued

Temperature,		Thickness factors, 0.0003 mm (0.00001 inch) per second	
°C	(°F)	Cadmium platings	Zinc platings
26.7	(80)	1.438	1.070
27.2	(27.2)	1.450	1.080
27.8	(82)	1.460	1.085
28.3	(83)	1.470	1.095
28.9	(84)	1.480	1.100
29.4	(85)	1.490	1.110
30.0	(86)	1.501	1.120
30.6	(87)	1.513	1.130
31.1	(88)	1.524	1.141
31.7	(89)	1.534	1.150
32.2	(90)	1.546	1.160

71 Overcurrent Protection Calibration Test

71.1 A fuse, or circuit protective device, provided in the primary of a transformer for protection of the secondary circuit shall operate to open the circuit in not more than the time indicated in Table 71.1 when the transformer is delivering the specified secondary current.

Table 71.1
Maximum Time to Open

Rated secondary potential, volts	Secondary test current, amperes	Maximum time for overcurrent protective device to open, minutes
20 or less	10	2
20 or less	6.75	60[a]
Over 20	$200/V_{max}$	2
Over 20	$135/V_{max}$	60[a]

[a] After 15 minutes of operation, the current shall be readjusted to the value shown.

71.2 To determine when a fuse or circuit protective device complies with the requirement in 71.1, the transformer shall deliver the test current to a resistance load with the primary connected to a circuit as described in 45.1. During the 2-minute test, the load shall be adjusted continuously to maintain the required test current. During the 60-minute test, the load shall be adjusted once after 15 minutes of operation and the test shall be continued without further adjustment.

71.3 When the fuse or circuit protective device is used to protect more than one secondary winding or taps, each winding or partial winding shall be tested as indicated in 71.1 or 71.2 with the remaining windings delivering rated load.

MARKINGS

Advisory Note: In Canada, there are two official languages, English and French, and in Mexico, the official language is Spanish. Annex C provides translations in French and Spanish of the English markings specified in this Standard. Markings required by this Standard may have to be provided in other languages to conform with the language requirements of the country where the product is to be used.

72 General

72.1 A device shall be legibly and permanently marked, where readily visible during use, with:

a) The manufacturer's name, trade name, or trademark or other descriptive marking by which the organization responsible for the device is able to be identified;

b) The catalog number or an equivalent designation, where practicable;

c) The electrical rating in both volt and amperes for the input and output of the device;
In Canada, products with a rating of 127 Vac or less shall have a nominal voltage rating marked within the range of 108 – 125 Vac, single phase. In Mexico and the United States, this requirement does not apply.

d) The environmental enclosure type. See 73.1;

e) Ambient temperature rating, if the ambient temperature extends outside the range of minus 30 °C to 40 °C (minus 22 °F to 104 °F); and

f) The date or other dating period of manufacture not exceeding any three consecutive months.

The date of manufacture may be abbreviated, or may be in a nationally accepted conventional code or in a code affirmed by the manufacturer, provided that the code does not repeat in less than 20 years, and does not require reference to the production records of the manufacturer to determine when the product was manufactured.

72.2 When a manufacturer produces devices at more than one factory, each device shall have a distinctive marking, to identify it as the product of a particular factory.

72.3 All EV supply equipment shall be marked with the words "For use with Electric Vehicles." This marking shall be visible during intended use.

72.4 All EV supply equipment shall be marked with the words "Ventilation Not Required." This marking shall be visible during normal use.

72.5 Markings may be located on a tag that is attached to the power supply cord and complies with the requirements in Tests for Permanence of Cord Tags, Section 68.

72.6 A pressure sensitive label or a label secured by cement or adhesive shall comply with the applicable requirements for indoor and outdoor use labels in Annex A, Ref. No. 64.

72.7 A marking that is required to be permanent shall be molded, die-stamped, paint-stenciled, stamped, or etched metal that is permanently secured, or indelibly applied lettering on a label secured by adhesive that, upon investigation, is found to be suitable for the application. Ordinary usage, including likely exposure to weather and other ambient conditions, handling, storage, and the like, of the equipment is considered in the determination of the acceptability of the application.

72.8 With reference to the requirement in 72.1(c), the symbols described in (a) and (b) are used for markings:

a) A circuit intended to be connected to an alternating-current supply shall be identified by markings indicating that the supply shall be alternating current. The markings shall include the supply-circuit frequency or supply-circuit frequency-range rating (cycles per second, cycles/second, hertz, c/s, cps, or Hz). The symbol illustrated in Figure 72.1 is an example for this marking. See 72.9.

b) The number of phases shall be indicated if the device is designed for use on a polyphase circuit. The symbol illustrated in Figure 72.2 is an alternative for the word “phase.” See 72.9.

Figure 72.1

Alternating Current Supply Symbol

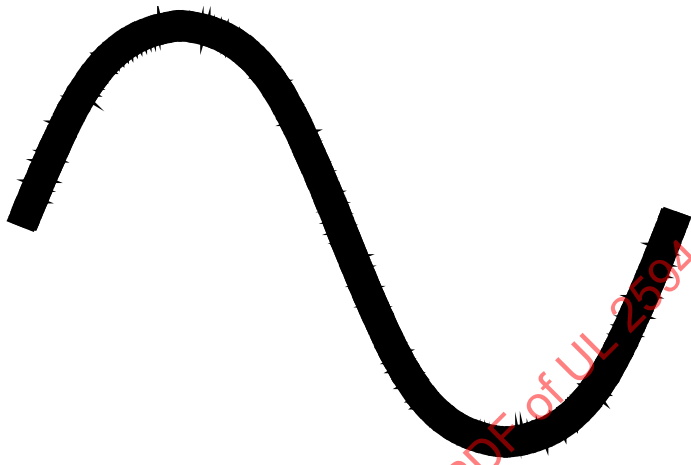
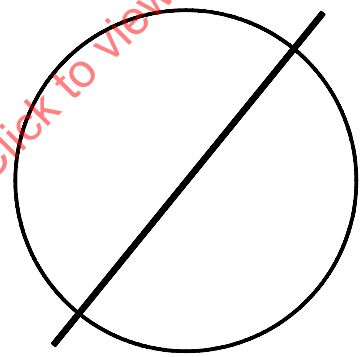


Figure 72.2

Phase Symbol



SM510

72.9 When the symbol referenced in 72.8 (a) or (b) is used, the information described in 76.3(k) shall be provided.

72.10 The operating positions of a handle, knob, or other means intended for manual operation by the user shall be marked.

72.11 Wiring terminals shall be marked to indicate the proper connections for the device, or a wiring diagram coded to the terminal marking shall be securely attached to the equipment.

72.12 Equipment field-wiring terminals shall be marked with the following: