



UL 2750

STANDARD FOR SAFETY

Wireless Power Transfer Equipment for Electric Vehicles

UL Standard for Safety for Wireless Power Transfer Equipment for Electric Vehicles, UL 2750

First Edition, Dated November 29, 2023

Summary of Topics

This is the First Edition of UL 2750, the Standard for Wireless Power Transfer Equipment for Electric Vehicles, dated November 29, 2023.

The new requirements are substantially in accordance with Proposal(s) on this subject dated August 25, 2023.

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INTRODUCTION

1 Scope

1.1 The requirements in this Standard cover wireless power transfer (WPT) equipment for transferring power to a stationary electric vehicle. WPT equipment consists of two devices, the power source and a ground assembly, as a minimum. The WPT equipment may also be provided with a third device, the mating vehicle assembly. These requirements are also suitable for covering each individual device as a stand-alone product. This equipment is intended to have a maximum rated input voltage to the power source of 1000 V ac, 50 or 60 Hz. The output ratings are specified by the manufacturer.

1.2 These products are intended to be installed in accordance with the National Electrical Code, NFPA 70. These products are intended for use in accordance with the Federal Radiation Control for Health and Safety Act of 1968 and 21 CFR, Chapter 1, Subchapter J, Radiological Health.

1.3 The power source may be cord and plug connected, or permanently connected, to the branch circuit. This equipment is suitable for indoor use only or outdoor use, in both residential and public applications.

1.4 Efficiency of the power transfer from the off board equipment to the vehicle, the means to insure or assist with proper alignment of the ground assembly and the vehicle assembly, and the physiological effects of the electromagnetic radiation emitted by this system have not been evaluated and these concepts are not included in the scope of this evaluation.

1.5 Informative Annex [A](#) at the end of this Standard covers specific information related to interoperability concepts as outlined in SAE J2954, the Standard for Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology. This annex addresses interoperability of a system that is intended to be SAE J2954 interoperable and the annex may be used in part or in whole at the discretion of the manufacturer of the WPT system.

1.6 This Standard does not cover off board conductive chargers, which are covered in the Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202; or off board conductive supply equipment, which is covered in the Standard for Electric Vehicle (EV) Supply Equipment, UL 2594.

1.7 This Standard does not address reverse power flow from the vehicle through the WPT offboard equipment.

1.8 This Standard does not address dynamic wireless power transfer which occurs while the electric vehicle is moving.

2 Components

2.1 A component of a product covered by this Standard shall:

- a) Comply with the requirements for that component as specified in this Standard;
- b) Be used in accordance with its rating(s) established for the intended conditions of use; and
- c) Be used within its established use limitations or conditions of acceptability.

2.2 A component of a product covered by this Standard 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;

b) Is superseded by a requirement in this Standard; or

c) Is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

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

2.4 A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable UL standard(s) that cover devices that provide those functions.

3 Units of Measure

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

4 Referenced Publications

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

4.2 Products covered by this Standard shall comply with the referenced installation codes and standards noted in this clause as referenced in the individual clauses of this Standard.

4.3 The following publications are referenced in this Standard:

ASTM D471, *Standard Test Method for Rubber Property-Effects of Liquids*

ASTM E162, *Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*

IEC 61508-1, *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems – Part 1: General Requirements*

IEEE C57.12, *Test Code for Dry-Type Distribution and Power Transformers*

ISA MC96.1, *Temperature Measurement Thermocouples*

ISO 26262, *Road Vehicles – Functional Safety*

ISO 12100, *Safety of Machinery – General Principles for Design – Risk Assessment and Risk Reduction*

NFPA 70, *National Electrical Code (NEC)*

SAE J2954, *Recommended Practice for Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology*

SAE J2847/6, *Communication for Wireless Power Transfer Between Light-Duty Plug-In Electric Vehicles and Wireless EV Charging Stations*

UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*

UL 62, *Flexible Cable*

UL 83, *Thermoplastic-Insulated Wires and Cables*

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 157, *Gaskets and Seals*

UL 224, *Extruded Insulating Tubing*

UL 248-1, *Low Voltage Fuses – Part 1: General Requirements*

UL 248-4, *Low Voltage Fuses – Part 4: Class CC Fuses*

UL 248-5, *Low Voltage Fuses – Part 5: Class G Fuses*

UL 248-6, *Low Voltage Fuses – Part 6: Class H Non-Renewable Fuses*

UL 248-8, *Low Voltage Fuses – Part 8: Class J Fuses*

UL 248-9, *Low Voltage Fuses – Part 9: Class K Fuses*

UL 248-11, *Low Voltage Fuses – Part 11: Plug Fuses*

UL 248-12, *Low Voltage Fuses – Part 12: Class R Fuses*

UL 248-15, *Low Voltage Fuses – Part 15: Class T Fuses*

UL 248-17, *Low Voltage Fuses – Part 17 : Class CF Fuses*

UL 248-20, *Low Voltage Fuses – Part 20: Electric Vehicle (EV) Fuses*

UL 310, *Electrical Quick Connect Terminals*

UL 486A-486B, *Wire Connectors*

UL 486E, *Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors*

UL 489, *Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures*

UL 506, *Specialty Transformers*

UL 510, *Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape*

UL 514A, *Metallic Outlet Boxes*

UL 514B, *Conduit, Tubing and Cable Fittings*

UL 635, *Insulating Bushings*

UL 723, *Test for Surface Burning Characteristics of Building Materials*

UL 746A, *Polymeric Materials – Short Term Property Evaluations*

UL 746B, *Polymeric Materials – Long Term Property Evaluations*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 796, *Printed-Wiring Boards*

UL 810, *Capacitors*

UL 840, *Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*

UL 991, *Tests for Safety Related Controls Employing Solid-State Devices*

UL 969, *Marking and Labeling Systems*

UL 1077, *Supplementary Protectors for Use in Electrical Equipment*

UL 1310, *Class 2 Power Units*

UL 1411, *Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances*

UL 1561, *Dry-Type General Purpose and Power Transformers*

UL 1876, *Isolating Signal and Feedback Transformers for Use in Electrical Equipment*

UL 1998, *Software in Programmable Components*

UL 2097, *Reference Standard for Double Insulation Systems for Use in Electronic Equipment*

UL 2353, *Single and Multi-Layered Insulated Winding Wire*

UL 2734, *Connectors and Service Plugs for use with On Board Electric Vehicle Charging Systems*

UL 4248-1, *Fuseholders – Part 1: General Requirements*

UL 4248-4, *Fuseholders – Part 4: Class CC*

UL 4248-5, *Fuseholders – Part 5: Class G*

UL 4248-6, *Fuseholders – Part 6: Class H*

UL 4248-8, *Fuseholders – Part 8: Class J*

UL 4248-9, *Fuseholders – Part 9: Class K*

UL 4248-11, *Fuseholders – Part 11: Type C (Edison Base) and Type S Plug Fuses*

UL 4248-12, *Fuseholders – Part 12: Class R*

UL 4248-15, *Fuseholders – Part 15: Class T*

UL 4248-17, *Fuseholders – Part 17: Class CF Fuses*

UL 5085-1, *Low Voltage Transformers – Part 1: General Requirements*

UL 5085-3, *Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers*

UL 60691, *Thermal-Links – Requirements and Application Guide*

UL 60730-1, *Automatic Electrical Controls for Household and Similar Use – Part 1: General Requirements*

UL 60950-1, *Information Technology Equipment – Safety – Part 1: General Requirements*

5 Definitions

5.1 For the purposes of this Standard, the following definitions apply. The term “device” is used to indicate a part of the overall WPT equipment and refers to the power source, the ground assembly and/or the vehicle assembly. The term “equipment” is used to represent the interconnected devices consisting of a power source and ground assembly with or without a corresponding vehicle assembly.

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.

5.4 BONDING JUMPER – A conductor, including a strap or similar part, that is used to provide the required electrical conductivity between metal parts required to be bonded.

5.5 CLASS 2 CIRCUIT – A circuit involving a potential of not more than 42.4 volts peak or 60 V dc supplied by:

- a) An energy-limiting Class 2 transformer;
- b) A non-energy-limiting transformer and an overcurrent protective device that has been evaluated for limiting energy to Class 2 levels; or
- c) The combination of an isolated transformer secondary winding and a fixed impedance or reliable regulating network which complied with the applicable performance requirements for an energy-limiting Class 2 transformer.

5.6 ELECTRIC VEHICLE (EV) – An over-the-road automotive-type vehicle for highway use, such as a passenger automobile, bus, truck, van, or similar vehicle, which receives primary or supplementary propulsion power from an electric motor that draws current from a rechargeable storage battery located on board the vehicle. This term is used to cover electric vehicles, hybrid electric vehicles and plug-in hybrid electric vehicles.

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

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

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

5.10 FIXED – A mounting means that requires a tool to remove the device from its mounted position.

5.11 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 earth.

5.12 GROUND ASSEMBLY – The coil and other circuits connected to the output side of the power source and located on the ground and intended to be under the vehicle when transferring power.

5.13 GROUNDED – Connected to earth or to some conducting body that serves in place of earth.

5.14 GROUNDED CONDUCTOR – A circuit conductor that is intentionally grounded.

5.15 GROUNDING CONDUCTOR – The conductor used to connect the non-current carrying metal part of equipment, raceways, and other enclosures to the equipment grounded conductor, the grounding electrode conductor, or both at the service equipment or at the source of a separately derived system.

5.16 INSULATION CLASSES – The following insulation classes are used to describe insulation between different circuits:

a) Basic Insulation – the insulation required for the proper functioning of a device, and for basic protection against electrical hazards.

b) Supplementary Insulation – An independent insulation provided in addition to the basic insulation to protect against electric shock hazards in the event the basic insulation fails.

c) Double Insulation – 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.

d) Reinforced Insulation – 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 shall not be tested as supplementary or basic insulation.

5.17 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.

5.18 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. Such a part is considered hazardous if the potential difference, under normal or abnormal conditions, is capable of causing an electric shock.

5.19 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 [58.8](#); or

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

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

5.21 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.

5.22 POWER SOURCE – The electrical device that delivers power to the ground assembly. It need not be a separate device and may be located integral to the ground assembly.

5.23 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, or a circuit that used programmable components to shut down a hazardous circuit would be a safety circuit.

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

5.25 VEHICLE ASSEMBLY – The coil and other circuits connected to the vehicle circuits and located on board the vehicle.

CONSTRUCTION

6 General

6.1 Unless otherwise stated, compliance with the requirements in this Standard is determined by evaluation and testing on a representative model of the WPT equipment under evaluation. For all WPT equipment that is equipped with a mated vehicle assembly, the WPT equipment is evaluated based on that specific configuration. For all WPT equipment that consists of a power source and a ground assembly only, and are intended to be used with various vehicle assemblies, the manufacturer shall provide a suitable vehicle assembly for test in accordance with [7.2](#).

6.2 For WPT equipment that is intended to be designed in accordance with SAE J2954, and intended to be compatible with SAE J2954 vehicle equipment, the vehicle assembly, used for the testing as indicated in [6.1](#), shall be constructed in accordance with the reference vehicle assembly as defined in SAE J2954. For systems that are proprietary, or are not intended to comply with SAE J2954, a suitable vehicle assembly as anticipated by the equipment under evaluation shall be provided.

6.3 Devices shall be investigated based on the intended use of the device. Intended use shall be specified as indoor use only or outdoor use, except that vehicle assemblies are always considered outdoor use devices. Construction requirements apply to all devices unless otherwise noted. All indoor use only devices shall be evaluated based on an expected ambient temperature of 0 °C to 40 °C (32 °F to 104 °F). Outdoor devices shall be evaluated based on an expected ambient temperature of minus 30 °C to 40 °C (minus 22 °F to 104 °F). Ambient temperature ranges specified by the manufacturer that extend outside

these limits – above the upper limit, below the lower limit, or both – are allowed provided they comply with the requirements of this Standard when tested for that ambient range. See [57.1\(e\)](#).

6.4 WPT equipment may be movable or permanent. Movable equipment is cord and plug connected and may be fastened in place. Permanent equipment is permanently wired and fixed in place. Equipment may be considered fixed in place if it is of a size and weight such that it cannot be easily moved and it is floor or ground supported.

6.5 Equipment covered by these requirements is intended for use in non-classified (ordinary) locations. If equipment is intended to be used in a commercial repair facility, it shall be evaluated in accordance with [6.6](#) and [6.7](#) and marked in accordance with [58.9](#).

6.6 For floor supported devices that are intended to be used in a commercial repair facility, there shall be no arcing and sparking parts – such as switches, relays, and the like – located in the area from the floor level to a height of 460 mm (18 inches) above floor level. Wall mounted devices used in a commercial repair facility shall be provided with installation instructions in accordance with [61.2](#). If arcing and sparking parts cannot be inherently omitted from the classified area, then the device shall comply with [6.7](#).

6.7 Devices with arcing and sparking parts located within the defined classified area within a commercial repair facility shall be evaluated and found to be suitable for use in a Class I, Division 2 location. The requirements for that classified area use are outside the scope of this Standard.

6.8 Various requirements in this Standard will reference tolerances or dimensions which refer to a three-dimensional coordinate system based on X, Y, and Z dimensions. The coordinate system is defined based on the intended installation of the equipment with a vehicle parked over the ground assembly. The “X” dimension is from front to back of the vehicle; the “Y” dimension is from left to right of the vehicle, and the “Z” dimension is based on the distance between the ground assembly and the vehicle assembly. For all WPT equipment, the manufacturer shall indicate the optimal point of alignment, the point that results in maximum power transfer, and the manufacturer shall specify the maximum offset from that optimal point of alignment for the X, Y, and Z dimension. For the purposes of this evaluation, the maximum worst case alignment should be indicated.

6.9 The intended installation of the ground assembly shall be defined as buried (beneath the driving surface), flush (part of the driving surface) or surface mounted installation. Installation instructions shall indicate the method of installation as specified by the manufacturer. That installation type will be used for the evaluation. If a ground assembly can be installed in more than one way, then the evaluation shall take this into account.

6.10 No user modification of the equipment shall be permitted. The user shall not be instructed on how to modify the equipment, adjust operational parameters, or deactivate any safety circuits or functions. User instructions shall indicate that no modification is allowed. See Instructions Pertaining to a Risk of Fire, Electric Shock, or Injury to Persons, Section [60](#).

6.11 The equipment shall not attempt to transfer power until a vehicle is detected and is properly positioned above the ground assembly. This does not pertain to low power excitation used for alignment assistance. If the means of detection is provided in the power source and/or ground assembly, then the detection means shall comply with the requirements in this Standard. Detection means provided in the vehicle are outside the scope of this Standard, however, in these cases, a communication or data link from the vehicle to the ground assembly or power source shall be in place such that the off board devices can verify that a vehicle is properly parked before energizing the ground assembly for power transfer.

6.12 WPT equipment covered by this Standard shall be evaluated for functionality and reliability of all safety critical circuits, components, and functions, that are used to protect people and property. This is

accomplished through the requirements in Risk Assessment and Functional Safety, Section [20](#), and the requirements of this Standard.

6.13 During power transfer, various parameters shall be monitored to insure safe operation. Parameters to be monitored are based on manufacturer's design, and can include, but are not limited to, foreign object detection (metallic objects), living object detection, temperature monitoring, vehicle presence verification, and the like. Any safety critical parameter that is outside the specified range based on the design of the equipment shall cause the equipment to stop the power transfer function. See Risk Assessment and Functional Safety, Section [20](#).

6.14 With reference to [6.13](#), monitoring of parameters where the monitoring means located on board the electric vehicle is outside the scope of this Standard. However, risk to the user shall be mitigated as indicated by Risk Assessment and Functional Safety, Section [20](#), and the mitigation means shall not rely solely on communication from the vehicle.

7 Foreign Object Detection and Living Object Detection

7.1 Foreign object detection

7.1.1 Foreign objects that are located in the area under the vehicle that may cause burn hazards to humans, after the charge event, ignition hazards of the material itself or surrounding combustible materials, or melt into or otherwise damage the nonmetallic materials associated with the ground assembly shall be detected by Foreign Object Detection (FOD) systems located in the offboard WPT equipment. If FOD is provided in the off board WPT system, or as part of the vehicle assembly when it is included in the WPT system, then the FOD system shall be tested in accordance with Clause 16.2.1 of SAE J2954:2022. Any part of the FOD system that is reliant upon software controls or programmable components to comply with these requirements shall be tested in accordance with Section [20](#).

7.2 Living object detection

7.2.1 Any Living Object Detection (LOD) system provided in the offboard WPT equipment, or in vehicle assemblies that are included in the WPT equipment under evaluation, shall be evaluated to show reliability. This is accomplished by testing in accordance with SAE J2954:2022, Appendix C. Any part of the LOD system that is reliant upon software controls or programmable components to comply with these requirements shall be in accordance with Section [20](#).

8 Materials

8.1 General

8.1.1 Materials may be metallic or nonmetallic for any part of the equipment. The requirements in Sections [8.2](#) and [8.3](#) apply as applicable.

8.1.2 Materials shall be suitable for the expected environment, including ambient temperature, environmental considerations, anticipated abuse, and the like.

8.2 Metallic materials

8.2.1 General

8.2.1.1 Metallic materials used in WPT equipment can be used as supporting framework, enclosures, back plates (shields), and other parts. For a specific use, the material shall comply with the requirements in the applicable section. Within this section, the requirements pertain to the material itself and protection of the material.

8.2.2 Material requirements

8.2.2.1 Metallic materials used in WPT equipment shall be able to withstand the anticipated forces and abuses associated with normal intended use. This is judged by the requirements in this Standard.

8.2.2.2 Metallic materials used as enclosures or supporting framework shall not be constructed of magnesium.

8.2.2.3 Metallic materials shall be used in combinations that reduce or eliminate the galvanic actions that can cause corrosion.

8.2.2.4 Metallic materials shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion protection can be found in UL 50E.

8.2.2.5 Metallic materials are considered to comply with flammability requirements without test.

8.3 Nonmetallic materials

8.3.1 General

8.3.1.1 Nonmetallic materials used in WPT equipment can be used as supporting framework, enclosures, insulation barriers, and other parts. For a specific use, the material shall comply with the requirements in the applicable section. Within this section, the requirements pertain to the material itself and protection of the material.

8.3.2 Material requirements

8.3.2.1 Nonmetallic materials used in WPT equipment shall be able to withstand the anticipated forces and abuses associated with normal intended use. This shall also be considered with respect to aging of the materials. This is judged by the requirements in this Standard.

8.3.2.2 Nonmetallic materials used for enclosures, insulation barriers, or supporting framework shall be judged in accordance with the applicable requirements in UL 746C.

8.3.2.3 Nonmetallic materials used in wireless power transfer equipment shall have a flammability rating in accordance with [8.3.4](#).

8.3.2.4 The polymeric materials employed for enclosures and insulation shall be suitable for anticipated temperatures encountered in the intended application. Enclosures shall have a Relative Thermal Index (RTI) with impact suitable for temperatures encountered in the application but no less than 80 °C (176 °F), as determined in accordance with UL 746B.

8.3.2.5 Nonmetallic materials that are subject to exposure to environmental conditions, direct sunlight or water exposure, shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with UL 746C. Indoor use only equipment is not required to comply with this requirement.

8.3.2.6 Materials employed for direct support of live parts at hazardous voltage, shall additionally meet the criteria outlined in the Material Property Considerations, Table 6.1, in UL 746C, unless employed as part of a component that has been evaluated to a suitable component standard.

8.3.3 Insulating material and barriers

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

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

8.3.3.3 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.

8.3.4 Flammability of materials

8.3.4.1 Nonmetallic materials used for insulation, barriers, internal parts, enclosures, decorative parts, and the like, shall comply with the following requirements.

8.3.4.2 Nonmetallic materials used to form enclosures shall have a minimum flammability rating in accordance with [Table 8.1](#). This requirement applies to all devices covered by this Standard.

Table 8.1
Flammability Ratings of Enclosures

Product type	Flammability rating
Movable equipment	V-0
Permanent equipment	5V-A
Vehicle Mounted Equipment	5V-A

8.3.4.3 Nonmetallic materials internal to the enclosure shall be rated V-2 minimum. This requirement does not apply to components that comply with the applicable component standard.

8.3.4.4 With respect to [8.3.4.3](#), 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 rating.

8.3.4.5 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 [8.3.4.6](#).

8.3.4.6 Cables, other than power supply cords, entering and exiting the enclosure shall be rated FT2 or VW-1 as a minimum.

8.3.4.7 Printed wiring board materials shall be rated V-1 minimum.

8.3.4.8 For the requirements outlined in [8.3.4.2](#) – [8.3.4.7](#), the flammability rating of the material shall be provided as part of the component or material rating or the flammability rating may be determined by the applicable tests in UL 94. As an alternative, the requirement in [8.3.4.2](#) may be judged by the applicable end product flame test in UL 746C.

8.4 Current carrying parts

8.4.1 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.

8.4.2 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.

8.4.3 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 and Separation of Circuits, Section [19](#).

8.4.4 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.

9 Frame and Enclosure

9.1 General

9.1.1 Each device within WPT equipment shall be provided with an enclosure that houses 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 to mitigate the risk of fire, electric shock, and access to hazardous energy, shall comply with the applicable enclosure requirements specified in this Standard.

9.1.2 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.

9.1.3 The frame, chassis, or enclosure of a device shall not be used to carry current during normal operation.

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

9.1.5 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.

9.2 Metallic enclosures

9.2.1 A metallic enclosure shall comply with the requirements for mechanical strength in Section [9.4](#).

9.2.2 A metallic enclosure shall comply with the applicable environmental considerations for the intended use in accordance with Section [9.5](#).

9.2.3 The thickness of cast metal for an enclosure shall be as specified in [Table 9.1](#). Enclosures may have a lesser thickness if it can be shown that it provides equivalent protection to the thicknesses indicated in [Table 9.1](#).

Table 9.1
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.

9.2.4 Sheet metal enclosures shall comply with the requirements in [9.2.5](#) – [9.2.8](#).

9.2.5 With reference to [9.2.4](#), the thickness of a sheet metal enclosure shall not be less than that specified in [Table 9.2](#) and [Table 9.3](#).

9.2.6 [Table 9.2](#) and [Table 9.3](#) 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.

9.2.7 With reference to [Table 9.2](#) and [Table 9.3](#), 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.

9.2.8 With reference to [9.2.7](#) and [Table 9.2](#) and [Table 9.3](#), 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 9.2
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 ^c		
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)		

Table 9.2 Continued on Next Page

Table 9.2 Continued

Without supporting frame ^a		With supporting frame or equivalent reinforcing ^a		Minimum thickness, mm (inch)	
Maximum width ^b cm (inches)	Maximum length ^c cm (inches)	Maximum width ^b cm (inches)	Maximum length ^c cm (inches)		
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 9.2.7 and 9.2.8.

^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 0.8 mm (0.032 inch) thick when uncoated.

Table 9.3
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 cm (inches)	Maximum length ^c cm (inches)	Maximum width ^b cm (inches)	Maximum length ^c cm (inches)	
7.6 (3.0)	Not limited	17.8 (7.0)	Not limited	0.58 ^d (0.023)
8.9 (3.5)	10.2 (4.0)	21.6 (8.5)	24.1 (9.5)	
10.2 (4.0)	Not limited	25.4 (10.0)	Not limited	0.74 (0.029)
12.7 (5.0)	15.2 (6.0)	26.7 (10.5)	34.3 (13.5)	
15.2 (6.0)	Not limited	35.6 (14.0)	Not limited	0.91 (0.036)
16.5 (6.5)	20.3 (8.0)	38.1 (15.0)	45.7 (18.0)	

Table 9.3 Continued on Next Page



Table 9.3 Continued

Without supporting frame ^a		With supporting frame or equivalent reinforcing ^a		Minimum thickness mm (inches)
Maximum width ^b cm (inches)	Maximum length ^c cm (inches)	Maximum width ^b cm (inches)	Maximum length cm (inches)	
20.3 (8.0)	Not limited	48.3 (19.0)	Not limited	1.14 (0.045)
24.1 (9.5)	29.2 (11.5)	53.3 (21.0)	63.5 (25.0)	
30.5 (12.0)	Not limited	71.1 (28.0)	Not limited	1.47 (0.058)
35.6 (14.0)	40.6 (16.0)	76.2 (30.0)	94.0 (37.0)	
45.7 (18.0)	Not limited	106.7 (42.0)	Not limited	1.91 (0.075)
50.8 (20.0)	63.4 (25.0)	114.3 (45.0)	139.7 (55.0)	
63.4 (25.0)	Not limited	152.4 (60.0)	Not limited	2.41 (0.095)
73.7 (29.0)	91.4 (36.0)	162.6 (64.0)	198.1 (78.0)	
94.0 (37.0)	Not limited	221.0 (87.0)	Not limited	3.10 (0.122)
106.7 (42.0)	134.6 (53.0)	236.2 (93.0)	289.6 (114.0)	
132.1 (52.0)	Not limited	312.4 (123.0)	Not limited	3.89 (0.153)
152.4 (60.0)	188.0 (74.0)	330.2 (130.0)	406.4 (160.0)	

^a See [9.2.7](#) and [9.2.8](#).

^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.

9.3 Nonmetallic enclosures

9.3.1 A nonmetallic enclosure shall comply with the requirements for mechanical strength in Section [9.4](#).

9.3.2 A nonmetallic enclosure shall comply with the applicable environmental considerations for the intended use in accordance with Section [9.5](#).

9.3.3 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 [50](#).

9.3.4 The minimum thickness of a nonmetallic enclosure shall be such as to comply with the requirements of [9.3.1](#) – [9.3.3](#).

9.3.5 A polymeric material enclosure having in any single unbroken section, a projected surface area greater than 1 m² (10 square feet) or a single linear dimension greater than 1.8 m (6 feet) shall have a flame-spread rating of 200 or less when tested in accordance with the:

- a) UL 723, or
- b) Radiant-panel furnace method in ASTM E162.

9.4 Strength of enclosures

9.4.1 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 ball impact, vehicle drive over, and drop, if applicable, in accordance with [9.4.2](#) – [9.4.4](#), as applicable for the type of device involved.

9.4.2 An enclosure shall not be adversely affected by impact of a steel sphere in accordance with the Impact Test, Section [45](#). This test is required for all devices. If any openings are covered by glass, the Glass Cover Impact Test, Section [46](#), is also required.

9.4.3 An enclosure shall not be adversely affected after being driven over by a vehicle in accordance with the Vehicle Drive Over Test, Section [47](#). This test is required for all ground assemblies.

9.4.4 An enclosure shall not be adversely affected after being dropped in accordance with the Drop Test, Section [48](#). This test is required on all devices that are considered movable.

9.5 Environmental considerations

9.5.1 Ingress protection

9.5.1.1 WPT equipment can be for indoor use only or for outdoor use. Outdoor use equipment is inherently considered to be suitable for indoor use.

9.5.1.2 All enclosures shall be rated for one of the enclosure types in UL 50E. The enclosure rating shall be appropriate for the intended conditions of use. See [9.5.1.3](#).

9.5.1.3 All enclosure types provide a degree of protection to the user against incidental contact with the enclosed equipment. Protection against specific environmental conditions for each enclosure type is defined in [Table 9.4](#). The enclosure type rating is applicable only after proper installation of the equipment.

9.5.1.4 Enclosures intended for products that are to be used indoors only, shall be, as a minimum, rated Type 1,2,5,12,12K, or 13. Products rated for these enclosure types shall be marked in accordance with [58.10](#).

9.5.1.5 Power source enclosures intended for outdoor use shall be rated Type 3, 3R, 3S, 3X, 3RX, 3SX, 4, 4X, 6, or 6P. Ground assemblies and vehicle assemblies shall be rated Type 3, 3S, 3X, 3SX 4, 4X, 6, or 6P.

9.5.1.6 With reference to enclosure Types 3S and 3SX, this enclosure type is provided with external operating mechanisms. Type 3S and 3SX enclosures require that these operating mechanisms be operable when ice laden or after the ice has been removed in accordance with the manufacturer's instructions.

9.5.1.7 All enclosures shall comply with the applicable test requirements for the applicable enclosure type in accordance with UL 50E. In addition, the requirements in [9.5.1.8](#) shall apply to nonmetallic enclosures of ground and vehicle assemblies.

Table 9.4
Enclosure Types and Intended Use

Provides a degree of protection against the following environmental conditions	Type of enclosure															
	1	2	3	3X	3R	3RX	3S	3SX	4	4X	5	6	6P	12	12K	13
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Falling dirt	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dripping and light splashing of non-corrosive liquids		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rain, snow, and sleet ^a			X	X	X	X	X	X	X	X		X	X			
Rain, snow, and sleet ^b							X	X								
Circulating dust, lint, fibers, and flyings ^c			X	X			X	X	X	X		X	X	X	X	X
Settling airborne dust, lint, fibers, and flyings ^c			X	X			X	X	X	X	X	X	X	X	X	X
Windblown dust			X	X			X	X	X	X		X	X			
Hosedown and splashing water									X	X		X	X			
Oil and coolant seepage														X	X	X
Oil or coolant spraying and splashing																X
Corrosive agents				X		X		X		X			X			
Occasional temporary submersion												X	X			
Occasional prolonged submersion													X			

^a External operating mechanisms are not required to be operable when the enclosure is ice covered.

^b External operating mechanisms are operable when the enclosure is ice covered.

^c These fibers and flyings are nonhazardous materials and are not considered Class III type ignitable fibers or combustible flyings. (For Class III type ignitable fibers or combustible flyings, see the National Electrical Code, Article 500.

9.5.1.8 For ground and vehicle assemblies, all nonmetallic enclosures shall be subjected to the Chemical Exposure Test, Section [51](#).

9.5.1.9 All mechanical and electrical parts mounted on or through an enclosure shall comply with the applicable tests for the enclosure type.

9.5.1.10 A gasket that is provided on an enclosure to meet the environmental construction and performance requirements for that enclosure type shall comply with the applicable gasket tests in UL 50E.

9.5.2 Openings in enclosures

9.5.2.1 General

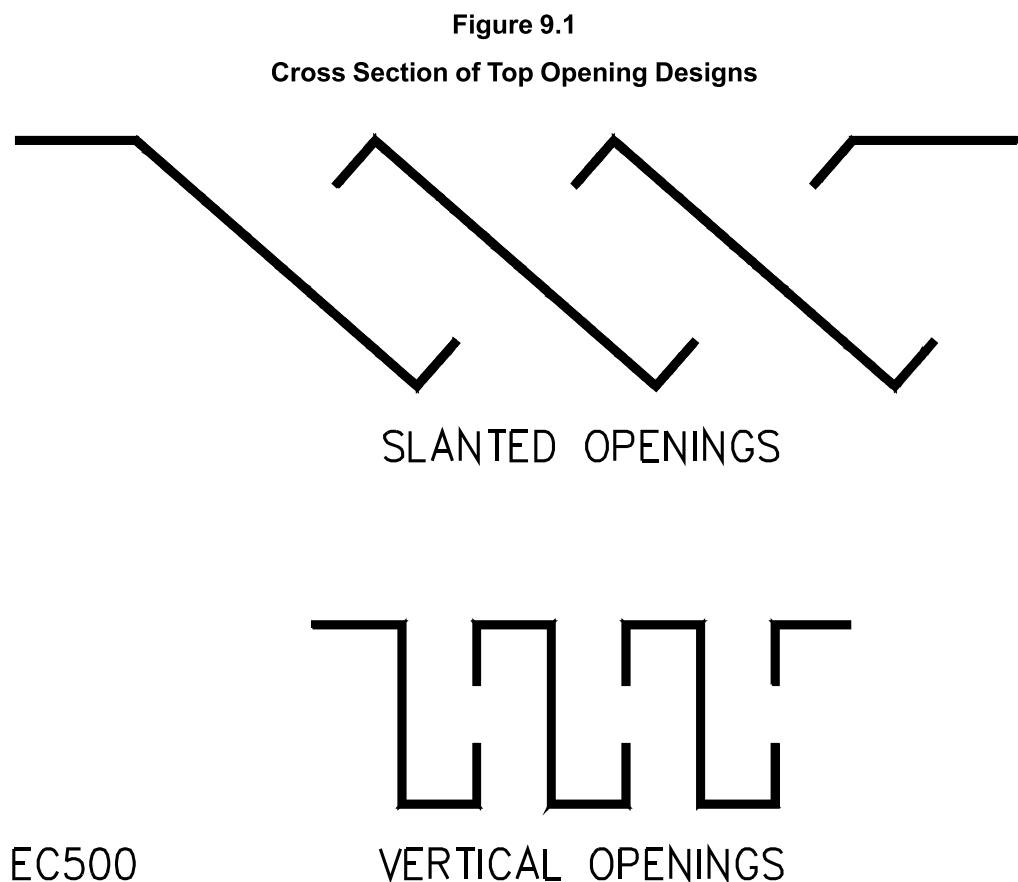
9.5.2.1.1 The enclosure of a device shall be designed and constructed to reduce the risk of emissions of flame, molten metal, flaming or glowing particles, or flaming drops.

9.5.2.1.2 Enclosures of power sources, regardless of the materials, shall not be provided with ventilation openings unless the enclosure is in accordance with the applicable enclosure type when tested as a ventilated opening as indicated in UL 50E. For any ventilation openings provided, the openings shall comply with [9.5.2.2](#). Ground assemblies and vehicle assemblies shall not be provided with ventilation openings regardless of Type designation.

9.5.2.2 Ventilation openings

9.5.2.2.1 The minor dimension – see [9.5.2.2.2](#) – 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 9.1](#) for examples of top surface ventilation openings that reduce the risk of direct entry.

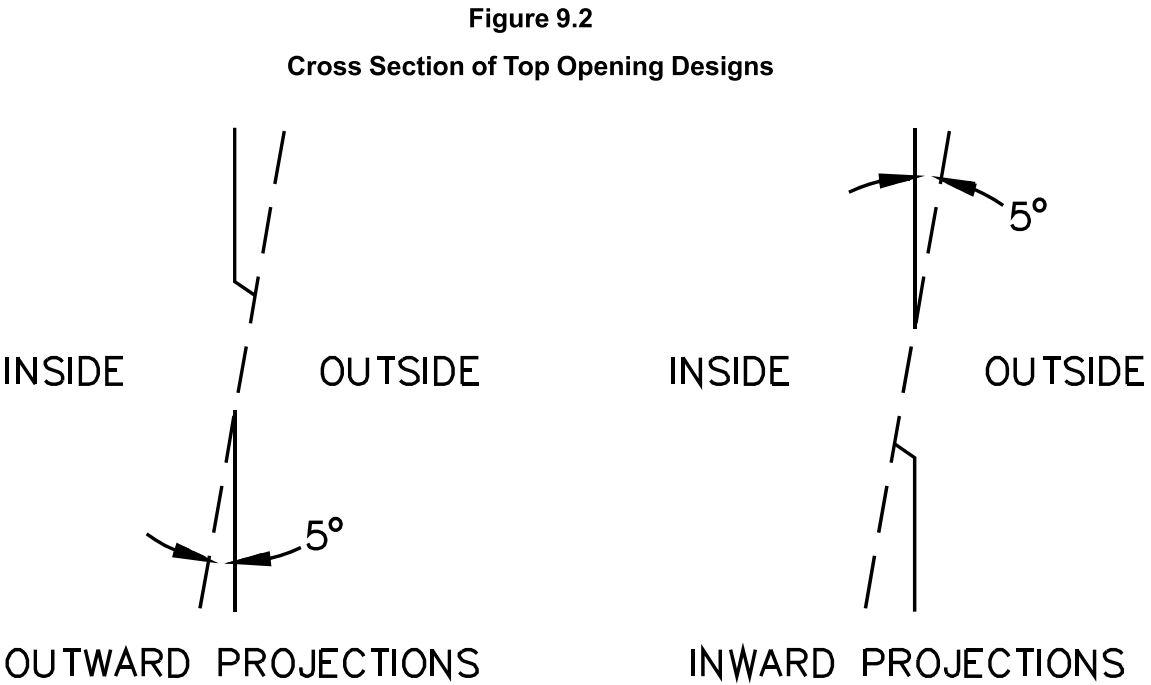
9.5.2.2.2 With reference to the requirement in [9.5.2.2.1](#), the minor dimension of a ventilation opening is the diameter of the largest cylindrical probe that is capable of being inserted through the opening.



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

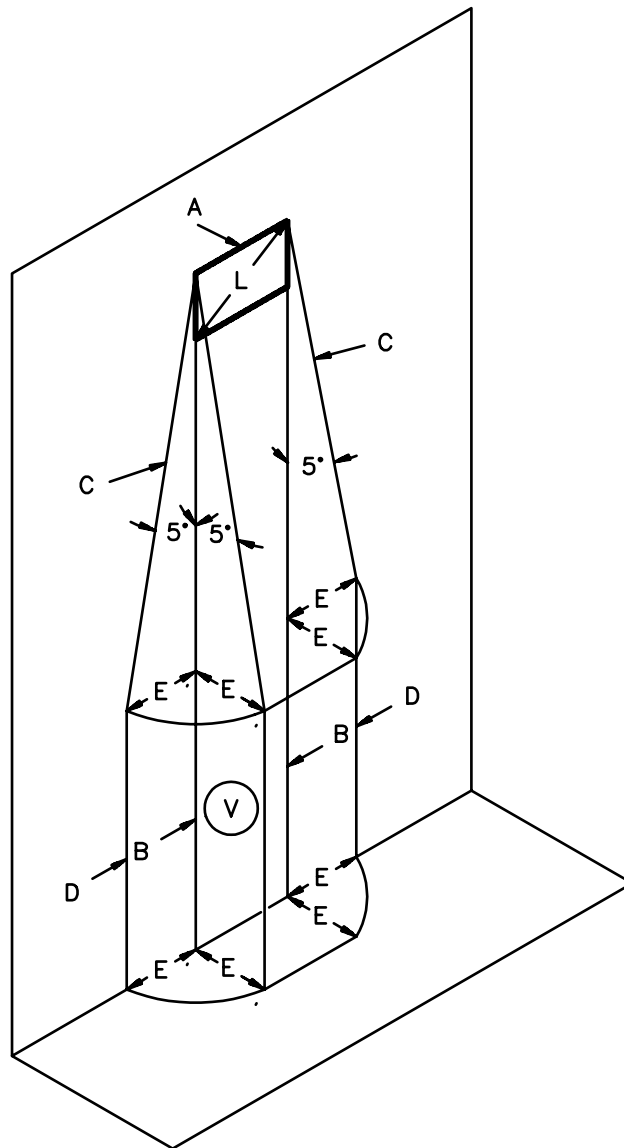
- a) They shall not exceed 4.8 mm (3/16 inch) in any dimension
- b) They shall be provided with louvers that are shaped to deflect outwards an external vertically falling object – see [Figure 9.2](#); or
- c) They shall be so located that an object, upon entering the enclosure, is unlikely to fall on uninsulated live parts involving a risk of fire or electric shock – see [9.5.2.2.4](#).

9.5.2.2.4 Where a portion of the side of the enclosure falls within the area as traced out by the 5 degree angle in [Figure 9.3](#), the limitations for bottom ventilation openings shall apply to that portion of the side.



EC513

Figure 9.3
Cross Section of Top Opening Designs



S3162A

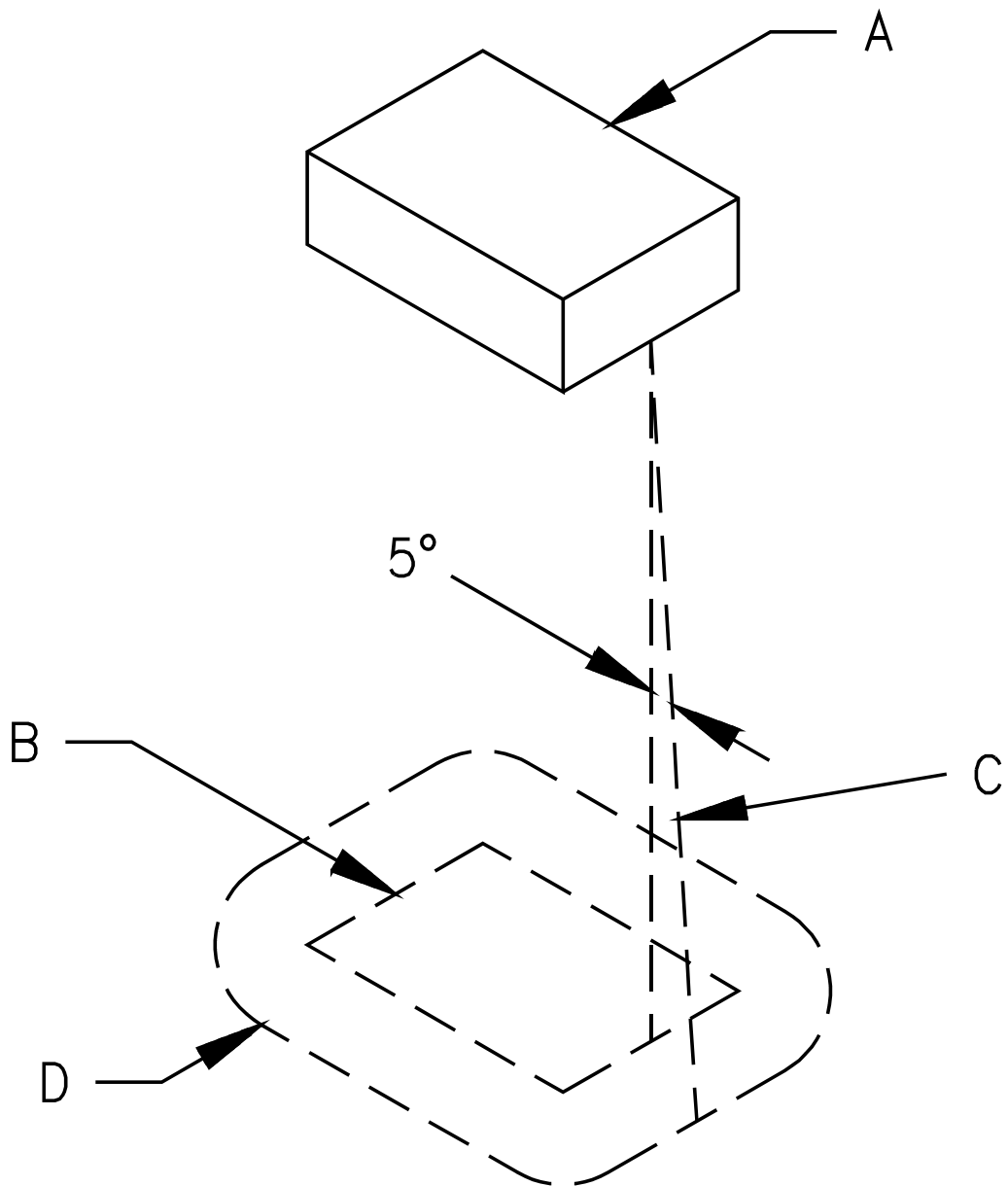
- A – Enclosure side opening
- B – Vertical projection of the outer edges of the side opening.
- C – Inclined lines that project as a 5 degree angle from the edges of the side opening to points located E distance from B
- D – Line which is projected straight downward in the same plane as the enclosure 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

9.5.2.2.5 The requirement in [9.5.2.1.1](#) requires a complete noncombustible bottom or a construction employing individual noncombustible barriers under components, groups of components, or assemblies, as specified in [Figure 9.4](#), unless complying with [9.5.2.2.6](#) or [9.5.2.2.7](#).

9.5.2.2.6 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 9.5](#).

9.5.2.2.7 Ventilation openings in the bottom of an enclosure are allowed when the openings incorporate a perforated metal plate as described in [Table 9.5](#), 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.

Figure 9.4
Enclosure Bottom



EB120A

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 horizontal plane.

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

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

Figure 9.5
Example of a Bottom Enclosure Baffle

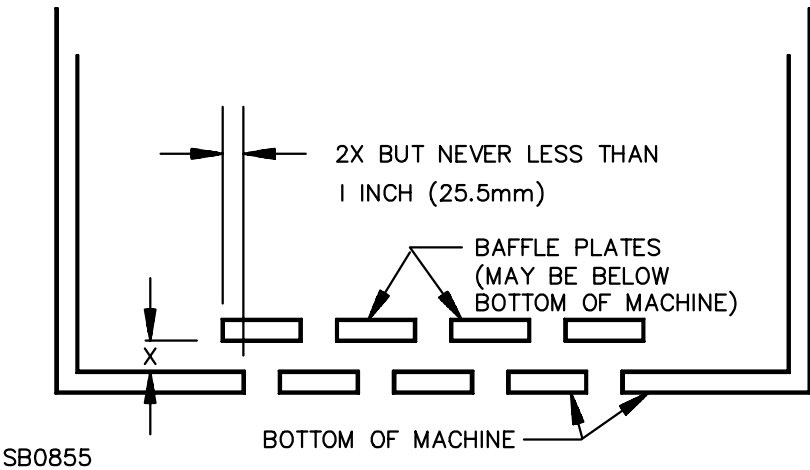


Table 9.5
Perforated Metal Plates for Enclosure Bottom

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)

9.5.2.3 Drainage Openings

9.5.2.3.1 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.

9.5.2.3.2 For Type 2, 3R and 3RX enclosures that also meet the requirements of other enclosure types, the drainage openings shall be closed by a removable plug when used as the other enclosure type that does not allow drainage openings, and instructions shall be provided in accordance with [61.7](#).

9.5.2.3.3 Type 2, 3R and 3RX 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 [61.8](#).

9.5.2.4 Openings for Mounting

9.5.2.4.1 Any openings provided for mounting shall be external to the enclosure cavity or shall comply with [9.5.2.4.2](#) – [9.5.2.4.4](#).

9.5.2.4.2 In accordance with [9.5.2.4.1](#), for enclosure types 3, 3X, 3S, 3SX, 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 applicable tests for that enclosure type in UL 50E. 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.

9.5.2.4.3 For enclosure types 1, 2, 3R, 3RX, and 5, mounting means may be provided internal to the equipment cavity if the mounting openings comply with [Table 9.6](#).

9.5.2.4.4 4 If mounting openings other than as noted in [Table 9.6](#) are provided for Type 1, 2, 3R, 3RX, or 5 enclosures, the installation instructions provided with the device shall indicate how to maintain the environmental integrity of the enclosure when mounted. See [61.4](#).

Table 9.6
Enclosure Mounting Holes

Maximum linear dimension of enclosure mm (inch)	Area of largest surface of enclosure, mm ² (square inch)	Maximum total area of holes, mm ² (square inch)	Maximum area of any one hole mm ² (square inch)
457 (18)	87 000 (135)	193 (0.30)	45.2 (0.07)
Over 457 (18)	Over 87 000 (135)	335 (0.52)	83.9 (0.13)

9.5.2.5 Openings for wiring

9.5.2.5.1 The requirements described in [9.5.2.5.2](#) – [9.5.2.5.11](#) apply to permanently connected units.

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

9.5.2.5.3 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.

9.5.2.5.4 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 UL 514A or UL 514B.

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

9.5.2.5.6 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 and Separation of Circuits, Section [19](#).

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

9.5.2.5.8 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as mentioned in [9.5.2.5.6](#), it shall be assumed that a bushing having the dimensions specified in [Table 9.7](#) is in place, in conjunction with a single locknut installed on the outside of the enclosure.

9.5.2.5.9 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum specified in Spacings and Separation of Circuits, Section [19](#), 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 9.7
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)

9.5.2.5.10 With respect to the requirement in [9.5.2.5.9](#), 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.

9.5.2.5.11 A polymeric- or metal-closure plug for an unused conduit opening shall comply with the requirements in UL 514A, and shall maintain the specified environmental capability of the enclosure in accordance with [9.5.2.5.2](#).

10 Mechanical Assembly

10.1 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.

10.2 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 [10.3](#).

10.3 The construction of staked and upset screws is to 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.

10.4 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. 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.

10.5 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 [10.6](#).

10.6 The means of securing components mentioned in [10.5](#) 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.

11 Accessibility

11.1 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 11.1](#), 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 11.1](#).

Table 11.1
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 11.4 . ^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).			

11.2 The probe specified in [11.1](#) and illustrated in [Figure 11.1](#) 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 11.1](#) shall be applied in any possible configuration; and, where required, the configuration shall be changed after insertion through the opening.