UL 9741

STANDARD FOR SAFETY

Electric Vehicle Power Export Equipment (EVPE)

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UL Standard for Safety for Electric Vehicle Power Export Equipment (EVPE), UL 9741

First Edition, Dated September 29, 2023

Summary of Topics

This is the First Edition of ANSI/UL 9741, Standard for Electric Vehicle Power Export Equipment (EVPE) dated September 29, 2023.

The new requirements are substantially in accordance with Proposal(s) on this subject dated October 21, 2022 and June 26, 2023.

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CSA Group
CSA C22.2 No. 348:23
First Edition

ULSE Inc.
UL 9741
First Edition

Electric Vehicle Power Export Equipment (EVPE)

September 29, 2023

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Approved American National Standard

ANSI/UL 9741-2023

Commitment for Amendments

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This ANSI/UL Standard for Safety consists of the First Edition.

The most recent designation of ANSI/UL 9741 as an American National Standard (ANSI) occurred on September 29, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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PREFACE

This is the harmonized CSA Group and ULSE Standard for Electric Vehicle Power Export Equipment (EVPE). It is the first edition of CSA C22.2 No. 348 and the first edition of UL 9741.

This harmonized standard was jointly prepared by a working group formed of experts representing CSA Group and ULSE and reviewed and approved by the CSA Technical Committee on Industrial Products and the ULSE Technical Committee for Electric Vehicle Power Export Equipment (EVPE).

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

This standard was reviewed by the CSA Subcommittee on Electric Vehicle Power Export 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 is published as an identical standard for CSA Group and ULSE.

An identical standard is a standard that is exactly the same in technical content except for national differences resulting from conflicts in codes and governmental regulations. Presentation is word for word except for editorial changes.

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.

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INTRODUCTION

1 Scope

1.1 The requirements of this standard apply to off-board unidirectional and bidirectional equipment rated 1000 Vac and 1500 Vdc or less, that transfers electrical energy between an electric vehicle and off board loads as well as operating in parallel with an electric power system, such as the electric utility grid, using a permanently attached vehicle connector. Equipment that has optional bidirectional functionality serves as both Electric Vehicle Power Export Equipment (EVPE) and electric vehicle supply equipment (EVSE). The products to which these requirements apply are intended to be installed in accordance with the National Electrical Code, NFPA 70, and CSA C22.1, Canadian Electrical Code, Part I.

1.2 The requirements of this standard are intended to apply to equipment for indoor or outdoor use.

1.3 The requirements for equipment without power export functionality are contained in the Standard for Electric Vehicle Supply Equipment, NMX-J-677 ANCE/CSA C22.2 No. 280/UL 2594 or the Standard for DC Charging Equipment for Electric Vehicles, NMX-J-817 ANCE/CSA C22.2 No. 346/UL 2202.

1.4 Some configurations of equipment to which the requirements of this Standard apply have functionality as described below:

a) The equipment can be supplied by DC power from the vehicle and acts as a standalone piece of equipment provided with a converter and provides AC and/or DC power to AC and/or DC receptacles for the connection to external loads;

b) The equipment can be supplied by AC power from the vehicle and acts as a standalone piece of equipment, provided with optional voltage conditioning equipment, and provides AC power to AC receptacles for the connection to external loads;

c) The equipment can be supplied by DC power from the vehicle and is provided with a converter that is permanently connected to the premise and provides AC or DC power to loads that are not interconnected (electrically connected) to the grid connected part of the premise wiring system;

d) The equipment can be supplied by AC power from the vehicle and is provided with an optional converter and is permanently connected to the premise and provides AC or DC power to loads that are not interconnected (electrically connected) to the grid connected part of the premise wiring system;

e) The equipment can be supplied by DC power from the vehicle and is provided with an inverter that is permanently connected to the premise, and provides AC power to premise wiring systems through a transfer switch;

f) The equipment can be supplied by AC power from the vehicle and is provided with optional voltage conditioning equipment and is permanently connected to the premise, and provides AC power to premise wiring systems through a transfer switch;

g) The equipment can be supplied by DC power from the vehicle and is provided with an inverter for converting to AC power and is permanently connected to the premise wiring system with capability to operate in parallel with the area electric power system (AREA EPS) but is prevented from export to the utility grid by PCS control;

h) The equipment can be supplied by AC power from the vehicle and is provided with optional voltage conditioning equipment and is permanently connected to the premise wiring system with capability to operate in parallel with the AREA EPS but is prevented from export to the utility grid by PCS control;

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i) The equipment can be supplied by DC power from the vehicle and the equipment is provided with a grid-tie inverter for converting to AC power and is permanently connected to the premise wiring system, with capability to operate in parallel with the AREA EPS but not islanding (no back-up during grid outage);

j) The equipment can be supplied by AC power from the vehicle and is provided with optional voltage conditioning equipment and is permanently connected to the premise wiring system, with capability to operate in parallel with the AREA EPS but not islanding (no back-up during grid outage);

k) The equipment can be supplied by DC power from the vehicle and the equipment is provided with a grid-tie inverter for converting to AC power and is permanently connected to the premise wiring system, with capability to operate in parallel with the AREA EPS with islanding (back-up during grid outage);

l) The equipment can be supplied by AC power from the vehicle and is provided with optional voltage conditioning equipment and is permanently connected to the premise wiring system, with capability to operate in parallel with the AREA EPS with islanding (back-up during grid outage);

m) The equipment can be supplied by DC power from the vehicle to other inverter/converter/power conditioning equipment that is grid interactive with capability to operate in parallel with the AREA EPS for supplying AC power to the grid, and for other special purpose requirements; and

n) The equipment can be supplied by AC power from the vehicle and is permanently connected to the premise wiring system and uses EV on-board interactive inverters that meet SAE J3072 performance requirements including communications protocols appropriate for the EV-EVPE equipment interface and that operates in parallel with the AREA EPS.

All the above equipment configurations, (a) through (n), may also provide power to the electric vehicle for the purpose of charging the on-board battery. All equipment is provided with a function that will cause a disconnect between the vehicle and the load if power from the vehicle exceeds specific limits. Some products may be able to operate in multiple modes.

1.5 The power export functionality includes enable and disable functions to limit or prevent export to the utility grid for locations that are not capable of or permitted to receive back feed power. This functionality is addressed using requirements of the Standard for Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources, UL 1741.

1.6 The equipment performs power conversion and Interconnection Systems Equipment (ISE) functionality. These functions may be located within one piece of equipment or within multiple pieces of equipment.

1.7 Equipment that is not a complete assembly and depends upon installation in an end product for compliance with the requirements in this standard is evaluated under the requirements of this Standard and the standard for the end product.

1.8 These requirements do not apply to battery chargers. The requirements for these products can be found in the Standard for Battery Chargers for Charging Engine-Starter Batteries, UL 1236, the Standard for Industrial Battery Chargers, UL 1564, or CSA C22.2 No. 107.2, Battery Chargers.

2 Glossary

2.1 In the text of this standard, the term "unit" refers to any product covered by this Standard. The letters "EV" refer to an electric vehicle, a hybrid electric vehicle, or plug-in versions of these vehicles. For the purpose of this Standard, the following definitions apply.

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

2.3 BARRIER – A part inside an enclosure that reduces access to a part that involves a risk of fire, electric shock, injury to persons, or electrical energy-high current levels.

2.4 BASIC INSULATION – The insulation required for the proper functioning of a device, and for basic protection against electrical hazard.

2.5 BRANCH CIRCUIT – The portion of the premise wiring system beyond the final overcurrent protective device on the power-distribution panel that protects the circuit to the field-wiring terminals in a permanently connected unit or to the receptacle outlet for a cord-connected unit.

2.6 CELL – Two electrodes of dissimilar material separated from one another by a common ionically conductive electrolyte, that is intended to convert chemical energy directly into electrical energy.

2.7 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 rated Measurement Indication Unit (MIU) value of a charging circuit-interrupting device. The device is identified by the letters CCID followed by the differential trip current rating of either 5 or 20 indicating the tripping rating in MIU.

2.8 CLASS 2 TRANSFORMER – A step-down transformer complying with the applicable requirements in:

a) CSA C22.2 No. 66.1/UL 5085-1 and CSA C22.2 No. 66.3/UL 5085-3, or

b) UL 1310 or CSA C22.2 No. 223.

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

2.10 DISTRIBUTED ENERGY RESOURCE (DER) – A source of electric power that is not directly connected to a bulk power transmission system.

Note: Distributed energy resources include distributed generation and energy storage technologies.

2.11 ELECTRIC POWER SYSTEM (EPS) – Equipment or facilities that deliver electric power to a load:

a) Area EPS – The most common example of an area EPS is an electric utility facility.

b) Local EPS – An EPS contained entirely within a single premise or group of premises.

2.12 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 power from an electric motor that draws current from a rechargeable storage battery. This term is used to cover electric vehicles, hybrid electric vehicles and plug-in versions of these vehicles.

2.13 ELECTRIC VEHICLE POWER EXPORT (EVPE) – All off-board equipment used to provide EV power to external electrical loads operating at 30 Vac / 60 Vdc or more.

NOTE: EVPE and EVSE functionality may be provided by a single piece of equipment referred to as a bidirectional EVSE.

2.14 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) – The conductors, including the ungrounded, grounded, and equipment grounding conductors, and the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the electric vehicle. This includes all off board

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equipment whether unidirectional or bidirectional, and includes power conditioning functions, metering functions, safety functions, and supportive communications and controls.

2.15 ELECTROLYTE – A semisolid, liquid, or aqueous salt solution that makes ionic conduction between positive and negative electrodes of a cell possible.

2.16 ENCLOSURE – That portion of a unit 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.

2.17 EXPOSED – Visible and able to be contacted by an accessibility probe. See Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8.

2.18 FIELD-WIRING LEAD – Any lead to which a supply, load, or other wire is intended to be connected by an installer.

2.19 FIELD-WIRING TERMINAL – A terminal to which a supply, load, or other wire is intended to be connected by an installer.

2.20 FIXED UNIT – A unit that is intended to be permanently connected electrically.

2.21 GROUND FAULT (GF) – An unintentional electrical path between a part operating normally at some potential to ground, and ground.

2.22 GROUNDING MONITOR/INTERRUPTER (GM/I) – A device that monitors equipment grounding continuity in a charging system, and either prevents the charger 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.

2.23 GRID SUPPORT UTILITY-INTERACTIVE INVERTER / GRID SUPPORT UTILITY-INTERACTIVE ISE – An inverter or ISE intended for use in parallel with area EPS that complies with the interconnection requirements of the area EPS, in Supplement SA for Grid Support Utility-Interactive Equipment, Supplement SB for Grid Support Utility-Interactive Inverters and Converters based upon IEEE 1547-2018, IEEE 1547.1-2020, or CSA C22.3 No. 9, as applicable.

2.24 GUARD – A part that reduces access to a component that results in a risk of injury to persons. See Enclosures and Guards, Section 41.

2.25 INTERACTIVE EQUIPMENT – Generic reference for equipment that operates in parallel with an EPS. Some examples are: utility interactive, grid-tie, grid support utility-interactive or special purpose utility- interactive equipment including generation sources such as inverters, converters, or rotating generators. Another example is ISE that performs interconnection monitoring, protection and control that may be used in conjunction with DERs to address the requirements for interactive equipment.

2.26 INTERCONNECTION SYSTEM EQUIPMENT (ISE) – A component or system of components that performs protective and control functions used to interconnect a distributed resource to an EPS. ISE may be a control subassembly(s) of an inverter or non-inverter distributed energy resource (DER).

2.27 INVERTER – An electronic device that changes dc power to ac power.

2.28 I_{sc} MAX – Absolute maximum prospective short circuit current (AC or DC) that an input or output of the equipment is rated to have connected to it.

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2.29 ISOLATED CIRCUIT – A circuit that has no intentional connection to ground including, but not limited to source circuit connections to ground. This does not include filter component impedance connections to ground provided the corresponding leakage current does not exceed the 100 ohms/volt.

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

2.31 LEAKAGE CURRENT – Electric current which flows through a person upon contact, between accessible parts of a unit and:

a) Ground, or

b) Other accessible parts of the unit.

2.32 LIMITED-ENERGY CIRCUIT – An ac or dc circuit having a voltage not exceeding 1000 volts and the energy limited to 100 volt-amperes by either a secondary winding of a transformer, one or more resistors complying with 25.10, or a regulating network complying with 25.11.

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

2.34 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 an overcurrent 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 a marking in accordance with 85.3.7 is provided; or

b) A combination of an isolated transformer secondary winding and one or more resistors or a regulating network complying with 25.11 that complies with all the performance requirements for an inherently limited Class 2 transformer or power source.

2.35 MEASUREMENT INDICATION UNIT (MIU) – The output voltage from either of the instruments in Figure 2.1 or Figure 2.2, in millivolts or millivolts peak, divided by 500 ohms. Suffixes are used to signify the instrument and meter type associated with the MIU value, as described in Table 2.1. MIUs are related to physiological effects when electric current flows through the human body. At low frequency, the number of MIUs that is obtained by dividing the output voltage, in millivolts, by 500 ohms, equals the current, in milliamperes, through the measuring instrument. At high frequency, the meter indication of MIUs is less than the number of milliamperes through the measuring instrument. For example, at 100 KHz, 0.5 MIU-RR occurs when the actual current through the measuring instrument, shown in Figure 2.1, is 70 mA. At any frequency, the acceptability of the leakage current may be determined by comparing the number of MIU's to the MIU limit.

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Figure 2.1

Measuring Instrument Circuit (MIU-RR)

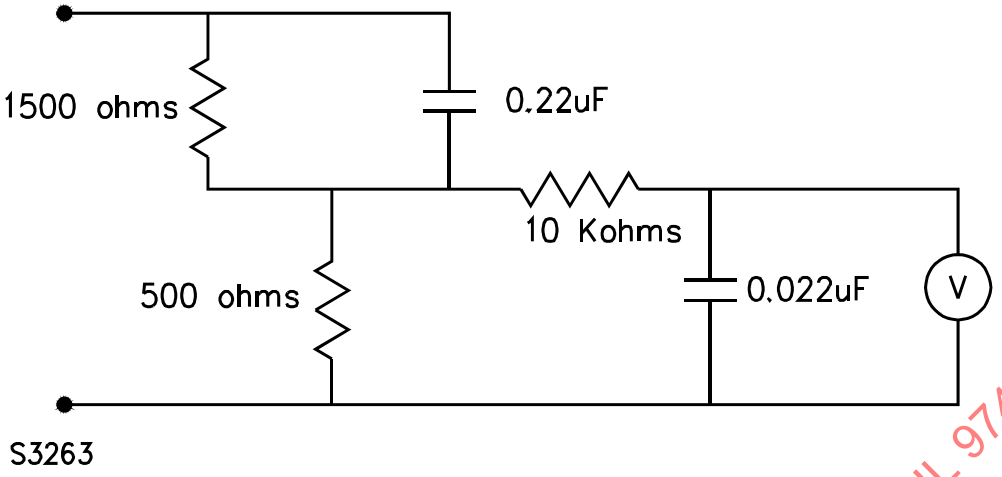

Figure 2.2

Measuring Instrument Circuit (MIU-LR or MIU-LP Peak)

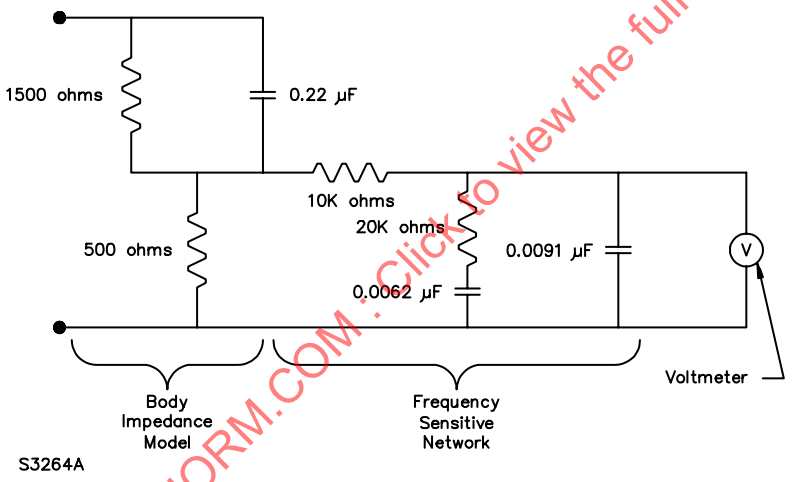

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Table 2.1
Measurement Indication Unit

Measurement instrument	Voltmeter type	MIU with suffix[a]
Figure 2.1 (Reaction)	RMS Responding and Indicating	MIU-RR
Figure 2.2 (Let-go)	RMS Responding and Indicating	MIU-LR
Figure 2.2 (Let-go)	Peak Responding and Indicating	MIU-LP peak

[a] For the MIU suffixes, the first letter refers to the measurement network (See Figure 2.1 and Figure 2.2) where R refers to the reaction network, Figure 2.1, and L refers to the let-go network, Figure 2.2. The second letter refers to the measurement indication where R is rms and P is peak.

2.36 PERSONNEL PROTECTION SYSTEM (SYSTEM OF PROTECTION) – A system of devices and constructional features that when used together provide protection of personnel against electric shock. These systems may either be of a grounded or isolated type.

2.37 POWER CONTROL SYSTEMS (PCS) – Systems or devices which electronically limit or control the steady state AC currents, or DC currents, to a programmable limit or level.

2.38 PRESSURE TERMINAL CONNECTOR – A field wiring terminal that accomplishes the connection of one or more conductors by means of pressure without the use of solder. Examples of pressure terminal connectors are barrel and setscrew type, crimp-type barrel, and clamping plate and screw type.

2.39 PRIMARY CIRCUIT – Wiring and components that are conductively connected to a branch circuit.

2.40 RISK OF ELECTRICAL ENERGY – HIGH CURRENT LEVELS – The capability for damage to property or injury to persons, other than by electric shock, from available electrical energy exists when between a live part and an adjacent dead metal part or between live parts of different polarity, there exists a potential of 2 volts or more and either an available continuous power level of 240 volt-amperes or more, or a reactive energy level of 20 joules or more. For example, a tool, or other metal short-circuiting a component causes a risk of a burn or a fire when enough energy is available at the component to vaporize, melt, or more than warm the metal.

2.41 RISK OF ELECTRIC SHOCK – As defined in CSA C22.2 No. 281.1/UL 2231-1.

2.42 RISK OF FIRE – A risk of fire is determined to exist at any component unless an evaluation of the supply delivering power to that component complies with the criteria in 25.4 – 25.12.

2.43 SAFETY CIRCUIT – Any primary or secondary circuit that is used to reduce the risk of fire, electric shock, injury to persons, or electrical energy – high current levels. For example, in some applications, an interlock circuit is considered to be a safety circuit.

2.44 SECONDARY CIRCUIT – A circuit supplied from a secondary winding of an isolating transformer. See 27.1.3.

2.45 SERVICE PERSONNEL – Trained persons having familiarity with the construction and operation of the equipment and the risks involved.

2.46 SUPPLEMENTARY INSULATION – An independent insulation provided in addition to the basic insulation to protect against electric shock hazard in the event that functional insulation fails.

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

2.48 TRIP – Automatic interruption by the CCID, GM/I, or IM/I of the electric circuit to the load.

2.49 UTILITY-INTERACTIVE INVERTER – An inverter intended for use in parallel with an electric utility to supply common loads and sometimes deliver power to the utility.

NOTE: This term is traditionally associated with products compliant with IEEE 1547-2003 and IEEE 1547.1-2005.

3 Components

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

a) Comply with the requirements for that component as specified in this Standard. A component shall comply with the CSA or UL standards as appropriate for the country where the product is to be used;

b) Be used in accordance with its rating(s) established for the intended conditions of use; and

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c) Be used within its established use limitations or conditions of acceptability.

3.2 A component of a product covered by this Standard is not required to comply with a specific component requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product;

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.

3.3 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.

3.4 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 standard(s) that cover devices that provide those functions.

4 Units of Measurement

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

5 Normative References

5.1 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. For dated references to Standards, such reference shall be considered to refer to the dated edition and all revisions published to that edition up to the time the Standard was approved.

5.2 Products covered by this Standard shall comply with the reference installation codes and Standards noted in the standard 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.

5.3 Devices, units, assemblies, and subassemblies that perform multiple specific functionalities shall comply with the applicable standard or standards that cover devices that provide those functions.

5.4 General requirements in Canada applicable to this Standard are given in CSA-C22.2 No. 0, General Requirements – Canadian Electrical Code, Part II.

5.5 The following standards are referenced in this Standard.

ANSI Z97.1, *Safety Glazing Materials Used in Buildings – Safety Performance Specifications and Methods of Test*

ASTM A90/A90M, *Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM Designation*

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ASTM A653/A653M, *Specification for Steel Sheet, Zinc-Coated (Galvannealed), or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*

ASTM D1525, *Test Method for Vicat Softening Temperature of Plastics*

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

ASTM E230/E230M, *Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples*

CSA C22.1, *Canadian Electrical Code, Part I*

CSA-C22.2 No. 0, *General Requirements – Canadian Electrical Code, Part II*

CSA C22.2 No. 0.2, *Insulation coordination*

CSA C22.2 No. 0.4, *Bonding of Electrical Equipment*

CSA C22.2 No. 0.8, *Safety functions incorporating electronic technology*

CSA C22.2 No. 0.12, *Wiring space and wire bending space in enclosures*

CSA C22.2 No. 5, *Molded-case circuit breakers, molded case switches, and circuit-breaker enclosures*

CSA C22.2 No. 8, *Electromagnetic Interference (EMI) Filters*

CSA C22.3 No. 9, *Interconnection of distributed energy resources and electricity supply systems*

CSA C22.2 No. 0.17, *Evaluation of Properties of Polymeric Materials*

CSA C22.2 No. 14, *Industrial control equipment*

CSA C22.2 No. 29, *Panelboards and enclosed panelboards*

CSA C22.2 No. 42, *General use receptacles, attachment plugs, and similar wiring devices*

CSA C22.2 No. 66.1, *Low voltage transformers – Part 1: General requirements*

CSA C22.2 No. 66.3, *Low voltage transformers – Part 3: Class 2 and Class 3 transformers*

CSA C22.2 No. 94.1, *Enclosures for electrical equipment, non-environmental considerations*

CSA C22.2 No. 94.2, *Enclosures for electrical equipment, environmental considerations*

CSA C22.2 No. 107.1, *Power conversion equipment*

CSA C22.2 No. 107.2, *Battery Chargers*

CSA C22.2 No. 153, *Electrical Quick-Connect Terminals*

CSA C22.2 No. 178.1, *Transfer switch equipment*

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CSA C22.2 No. 190, *Capacitors for power factor correction*

CSA C22.2 No. 197, *PVC Insulating Tape*

CSA C22.2 No. 198.1, *Extruded insulating tubing*

CSA C22.2 No. 223, *Power supplies with extra-low-voltage Class 2 outputs*

CSA C22.2 No. 280, *Electric vehicle supply equipment*

CSA C22.2 No. 281.1, *Safety for personnel protection systems for electric vehicle (EV) supply circuits: General requirements*

CSA C22.2 No. 281.2, *Safety for personnel protection systems for electric vehicle (EV) supply circuits: Particular requirements for protection devices for use in charging systems*

CSA C22.2 No. 282, *Standard for Plugs, Receptacles, and Couplers for Electric Vehicles*

CSA C22.2 No. 61730-1, *Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction*

CSA C22.2 No. 61730-2, *Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements for Testing*

CSA C22.2 No. 62109-1, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

CSA C22.2 No. 62109-2, *Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters*

CSA C22.2 No. 60691, *Thermal-Links – Requirements and Application Guide*

CSA C22.2 No. 60065, *Audio, video and similar electronic apparatus – Safety requirements*

IEEE C57.12.91, *Test Code for Dry Type Distribution and Power Transformers*

IEEE 1547, *Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*

IEEE 1547.1, *Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces*

IEEE 1815, *Electric Power Systems Communications-Distributed Network Protocol (DNP3)*

IEEE 2030.5, *Smart Energy Profile Application Protocol*

MIL-HDBK-338, *Military Handbook Number 338, Electronic Reliability Design Handbook*

NFPA 70, *National Electrical Code*

SAE J3072, *Interconnection Requirements for Onboard, Utility-Interactive Inverter Systems*

UL 20, *General-Use Snap Switches*

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UL 50, *Enclosures for Electrical Equipment, Non-Environmental Considerations*

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

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

UL 224, *Extruded Insulating Tubing*

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 498, *Attachment Plugs and Receptacles*

UL 508, *Industrial Control Equipment*

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

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

UL 723, *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 758, *Appliance Wiring Material*

UL 796, *Printed Wiring Boards*

UL 810, *Capacitors*

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

UL 969, *Marking and Labeling*

UL 969A, *Marking and Labeling – Flag Labels, Flag Tags, Wrap-Around Labels and Related Products*

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

UL 1236, *Battery Chargers for Charging Engine-Starter Batteries*

UL 1283, *Electromagnetic Interference Filters*

UL 1310, *Class 2 Power Units*

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UL 1332, *Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment,*

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

UL 1437, *Electrical Analog Instruments – Panel Board Types*

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

UL 1564, *Industrial Battery Chargers*

UL 1577, *Optical Isolators*

UL 1703, *Flat-Plate Photovoltaic Modules and Panels*

UL 1741, *Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources*

UL 1973, *Batteries for Use in Stationary and Motive Auxiliary Power Applications*

UL 1998, *Software in Programmable Components*

UL 2200, *Stationary Engine Generator Assemblies*

UL 2202, *DC Charging Equipment for Electric Vehicles*

UL 2231-1, *Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements*

UL 2231-2, *Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protection Devices for Use in Charging Systems*

UL 2251, *Plugs, Receptacles, and Couplers for Electric Vehicles*

UL 2262, *Outline for Fuel Cell Modules for Use in Portable and Stationary Equipment*

UL 2594, *Electric Vehicle Supply Equipment*

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 6141, *Wind Turbines Permitting Entry of Personnel*

UL 6142, *Small Wind Turbine Systems*

UL 9540, *Energy Storage Systems and Equipment*

UL 60384-14, *Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains*

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

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UL 61730-1, *Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements For Construction*

UL 61730-2, *Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements For Testing*

UL 62109, *Power Converters for use in Photovoltaic Power Systems – Part 1: General Requirements*

CONSTRUCTION

6 General

6.1 The requirements in this standard apply to all product types covered under the scope unless otherwise noted. When noted, the requirements will indicate the product type or specific constructional feature that is affected.

6.2 For some features or functions, the requirements are contained in other standards. Where applicable the standard will be noted. Any pertinent instructions or markings associated with those referenced requirements would be applicable to the product covered by this Standard.

6.3 Products under this Standard are intended for outdoor use and shall comply with the given requirements in this standard at a default ambient range of -30 °C to 40 °C (minus 22 °F to 104 °F). A manufacturer may specify an upper or lower ambient temperature outside of this range, but the default range represents the minimum requirement.

6.4 Electric Vehicle Power Export (EVPE) equipment may also charge the EVs where input and output ports may be AC or DC. Some ports can function as inputs and outputs at different times. Some EVPE may have multiple input and output ports. The requirements in this Standard will specify input and output based on the intended direction of the current flow. As such, input and output ports can reverse when the current flow is reversed. These designations will be used throughout this document.

6.5 Equipment covered by this standard may communicate with other equipment and systems via standardized communications protocols such as but not limited to IEEE 2030.5 and IEEE 1815, Sunspec Modbus.

6.6 Connections to the EVPE may include but are not limited to: EV, EPS and alternative energy sources including but not limited to photovoltaic, wind turbine, fuel cell, and energy storage.

7 Frame and Enclosure

7.1 General

7.1.1 A unit shall be provided with one or more enclosures that house all live parts that present a risk of electric shock or a risk of electrical energy – high current levels. The enclosure shall protect the various parts of the unit against mechanical damage from forces external to the unit. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, injury to persons, and electrical energy – high current levels shall comply with the applicable enclosure requirements specified in this standard.

7.1.2 The frame or chassis of a unit shall not be used to carry current during intended operation.

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.

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7.1.4 When an electrical instrument, such as a meter, forms part of the enclosure, the face or the back of the instrument housing, or both together, shall comply with the requirements for an enclosure.

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, the functioning of which requires renewal or resetting, or where it is required to open the cover in connection with intended operation of the unit. A means shall be provided to hold the cover positively closed.

7.2.2 A hinged cover is not required when the only overload-protective device enclosed is:

a) Connected in a control circuit, where the protective device and the circuit loads are within the same enclosure;

b) Rated 2 amperes or less for loads not exceeding 100 volt-amperes;

c) An extractor fuse having an integral enclosure; or

d) Connected in a low-voltage, limited-energy circuit.

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

7.3 Cast metal enclosures

7.3.1 The thickness of cast metal for an enclosure shall be as specified in Table 7.1. As an alternative, die-cast metal and cast metal of a lesser thickness can be used when upon evaluation, considering the shape, size and function of the enclosure, it is found to have equivalent mechanical strength 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 in^2) or less and having no dimension greater than 152 mm (6 inches)	1.6	(1/16[a])	3.2	(1/8)
Area greater than 154.8 cm^2 (24 in^2) 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.

7.4 Sheet metal enclosures

7.4.1 The thickness of a sheet-metal enclosure shall not be less than that specified in Table 7.2 and Table 7.3. Uncoated steel shall not be less than 0.81 mm (0.032 inch) thick, zinc-coated steel shall not be less than 0.86 mm (0.034 inch) thick, and nonferrous metal shall not be less than 1.14 mm (0.045 inch) thick for surfaces of an enclosure at which a wiring system is to be connected.

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7.4.2 With reference to 7.4.1, sheet metal of a lesser thickness than shown in Table 7.2 and Table 7.3 is possible where the end-product enclosure complies with the Comparative deflection test (enclosure) in CSA C22.2 No. 94.1/UL 50.

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[c]					
cm	(inch)	cm	(inch)	cm	(inch)	cm	(inch)	Uncoated		Coated	
10.2	(4.0)	Not limited		15.9	(6.25)	Not limited		0.51[d]	(0.020)	0.58[d]	(0.023)
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[d]	(0.026)	0.74[d]	(0.029)
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	(38.00	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 7.4.4 and 7.4.5.

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. In some cases, adjacent surfaces of an enclosure have supports in common and are made of a single sheet.

[c] "Not limited" applies only where 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 for coated metal and not less than 0.81 mm (0.032 inch) thick for uncoated metal.

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Table 7.3
Thickness of Aluminum, Copper, or Brass Enclosures

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]			
cm	(inch)	cm	(inch)	cm	(inch)	cm	(inch)	mm	(inch)
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)		
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)	63.5	(25.0)	114.3	(45.0)	139.7	(55.0)		
63.5	(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	(0.152)
152.4	(60.0)	188.0	(74.0)	330.2	(130.0)	406.4	(160.0)		

[a] See 7.4.4 and 7.4.5.

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. In some cases, adjacent surfaces of an enclosure have supports in common and are made of a single sheet.

[c] "Not limited" applies only where 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.

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7.4.3 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.

7.4.4 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.

7.4.5 With reference to 7.4.4 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.

7.5 Nonmetallic enclosures

7.5.1 A polymeric enclosure or polymeric part of an enclosure shall comply with the requirements in UL 746C or CSA C22.2 No. 0.17. See 7.5.2. Additionally, the material shall be rated for water and UV exposure in accordance with UL 746C or CSA C22.2 No. 0.17.

7.5.2 A nonmetallic part that forms part of the enclosure is not required to comply with 7.5.1 under any one of the following conditions:

a) The part covers an opening that has no dimension greater than 25.4 mm (1 inch) and the part is made of a material classed as V-0, V-1, V-2, or HB;

b) The part is made of a material classed V-0, V-1, V-2, or HB and covers an opening which does not allow access to live parts involving a risk of fire, electric shock, or electric energy – high current levels – or moving parts to the user when the part is removed;

c) The part covers an opening that has no dimension greater than 102 mm (4 inches) and the part is made of a material classed as V-0, V-1, V-2, or HB, and there is no source of a risk of fire closer than 102 mm from the surface of the enclosure; or

d) The part is made of a material classed V-0, V-1, V-2, or HB and there is a barrier or a device that forms a barrier made of a material classed V-0 between the part and a source of a risk of fire.

7.5.3 A polymeric material enclosure having in any single unbroken section, a projected surface area greater than 0.93 m^2 (10 ft^2) 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 the:

a) UL 723; or

b) Radiant-panel furnace method in ASTM E162.

7.5.4 A material with a flame-spread rating higher than specified in 7.5.3 is a usable alternative for the exterior finish or covering on any portion of the enclosure when the flame-spread rating of the combination of the base material and finish or covering complies with 7.5.3.

7.5.5 A conductive coating applied to a nonmetallic surface (such as the inside surface of a cover or an enclosure) shall comply with the appropriate requirements in UL 746C or CSA C22.2 No. 0.17, unless the coating is not deemed to be a safety risk such as when peeling or flaking does not result in a risk of fire or electric shock, reduction of spacings, bridging of live parts, and the like.

7.5.6 A nonmetallic enclosure intended for connection to a rigid conduit system shall comply with the Polymeric Enclosure Rigid Metallic Conduit Connection Tests in CSA C22.2 No. 94.1/UL 50.

7.6 Glass covered openings

7.6.1 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.

7.6.2 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 in^2) 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 thick and shall:

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a) Be of a nonshattering or tempered type that, when broken, complies with ANSI Z97.1; or

b) Be subjected to the test described in Section 66, Glass Covered Openings Impact Test.

7.7 Openings for wiring

7.7.1 The requirements described in 7.7.2 – 7.7.9 apply to fixed units.

7.7.2 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.

7.7.3 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 514B.

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

7.7.5 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 23.

7.7.6 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as mentioned in 7.7.5, it is to be assumed that a bushing having the dimensions specified in Table 7.4 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

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Table 7.4
Knockout or Hole Sizes and Dimensions of Bushings

Trade size of conduit		Knockout or hole diameter[a]		Bushing dimensions			
				Overall diameter		Height	
mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)
12.7	(1/2)	22.2	(7/8)	25.4	(1)	9.5	(3/8)
19.05	(3/4)	27.8	(1-3/32)	31.4	(1-15/64)	10.7	(27/64)
25.4	(1)	34.5	(1-23/64)	40.5	(1-19/32)	13.1	(33/64)
31.75	(1-1/4)	43.7	(1-23/32)	49.2	(1-15/16)	14.3	(9/16)
38.1	(1-1/2)	50.0	(1-31/32)	56.0	(2-13/64)	15.1	(19/32)
50.8	(2)	62.7	(2-15/32)	68.7	(2-45/64)	15.9	(5/8)
63.5	(2-1/2)	76.2	(3)	81.8	(3-7/32)	19.1	(3/4)
76.2	(3)	92.1	(3-5/8)	98.4	(3-7/8)	20.6	(13/16)
88.9	(3-1/2)	104.8	(4-1/8)	112.7	(4-7/16)	23.8	(15/16)

Table 7.4 Continued on Next Page

Table 7.4 Continued

Trade size of conduit		Knockout or hole diameter[a]		Bushing dimensions			
				Overall diameter		Height	
mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)
101.6	(4)	117.5	(4-5/8)	126.2	(4-31/32)	25.4	(1)
114.3	(4-1/2)	130.2	(5-1/8)	140.9	(5-35/64)	27.0	(1-1/16)
127	(5)	142.9	(5-5/8)	158.0	(6-7/32)	30.2	(1-3/16)
152.4	(6)	171.5	(6-3/4)	183.4	(7-7/32)	31.8	(1-1/4)

[a] The knockout or hole diameters noted in this table are nominal values. For tolerance information, refer to UL 50/CSA C22.2 No. 94.1, Annex D, Table D1.

7.7.7 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum specified in Spacings, Section 23 shall be provided between uninsulated live parts and a conduit bushing installed at any location that is to be used during installation. Permanent marking on the enclosure, a template, or a drawing furnished with the unit 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.

7.7.8 With respect to the requirement in 7.7.7, 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 using a removable, bolted plate.

7.7.9 A plate or plug for an unused conduit opening or other hole in the enclosure shall have a thickness not less than:

a) 0.36 mm (0.014 inch) for steel or 0.48 mm (0.019 inch) for nonferrous metal for a hole having a 6.4 mm (1/4 inch) maximum dimension, and

b) 0.69 mm (0.02 inch) for steel or 0.81 mm (0.032 inch) for nonferrous metal for a hole having a 34.9 mm (1-3/8 inch) maximum dimension.

A closure for a larger hole shall have a thickness equal to that required for the enclosure of the unit or a standard knockout seal shall be used. Such plates or plugs shall be securely mounted.

7.7.10 An opening in an environmental rated enclosure shall be closed with components having the applicable environmental ratings for that enclosure rating or higher.

7.8 Openings in an enclosure

7.8.1 The enclosure of a unit shall be designed and constructed to reduce the risk of emission of flame, molten metal, flaming or glowing particles, or flaming drops from exiting the enclosure and falling on combustible materials outside of the enclosure.

7.9 Enclosure bottom openings

7.9.1 The requirement in 7.8.1 requires a complete noncombustible bottom or a construction employing individual noncombustible barriers under components, groups of components, or assemblies, as specified in Figure 7.1. Other constructions are allowed when they meet the following:

a) An enclosure may be provided with ventilating openings in the bottom panel when noncombustible baffle plates are provided to reduce the risk of materials from falling directly from

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the interior of the unit onto the supporting surface or any other location under the unit. An example of such a baffle is illustrated in Figure 7.2.

b) An enclosure may be provided with ventilation openings in the bottom of an enclosure when the openings incorporate a perforated metal plate as described in Table 7.5, or where a galvanized or stainless steel screen having a 14- by 14-mesh per 25.4 mm (1 inch) constructed of wire with a diameter of 0.4 mm (0.018 inch) minimum is used.

c) The bottom of the enclosure under areas containing only materials classed V-1 or better in accordance with UL 94 or CSA C22.2 No. 0.17, shall have openings no larger than 40 mm^2 (1/16 in^2).

d) An enclosure may be provided with ventilating openings without limitation on their size and number and complying with 8.7 in the bottom panel in areas that contain only wires, cable, plugs, receptacles, transformers, and in areas that contain only capacitors that are described in Section 31.

e) Ventilation openings provided in the bottom of an enclosure meet the intent of the requirement where the openings incorporate an expanded metal mesh as described in 7.11.

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