UL 9741

STANDARD FOR SAFETY

Electric Vehicle Power Export Equipment (EVPE)

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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First Edition

ULSE Inc.
UL 9741
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Electric Vehicle Power Export Equipment (EVPE)

September 29, 2023

Approved American National Standard

ANSI/UL 9741-2023

Commitment for Amendments

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

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

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This ANSI/UL Standard for Safety consists of the 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.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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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;

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.

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

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.

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.

Figure 2.1

Measuring Instrument Circuit (MIU-RR)

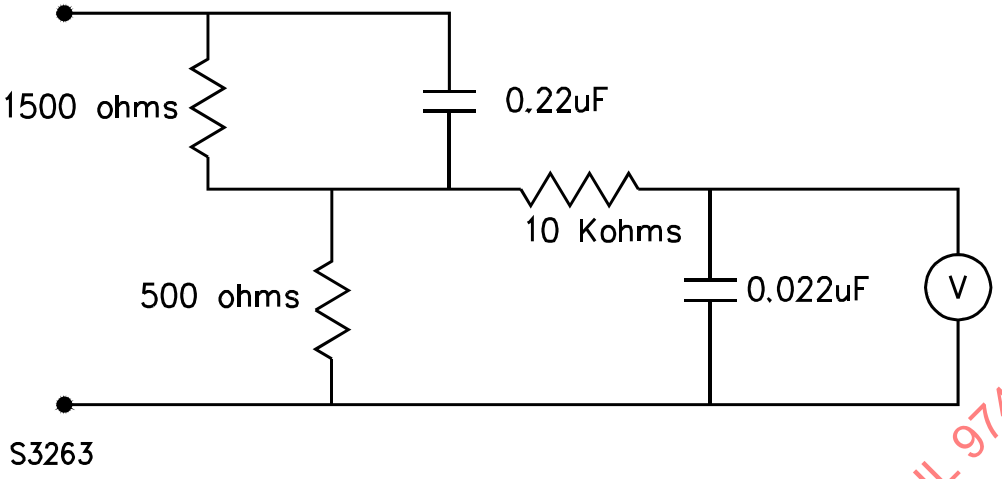

Figure 2.2

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

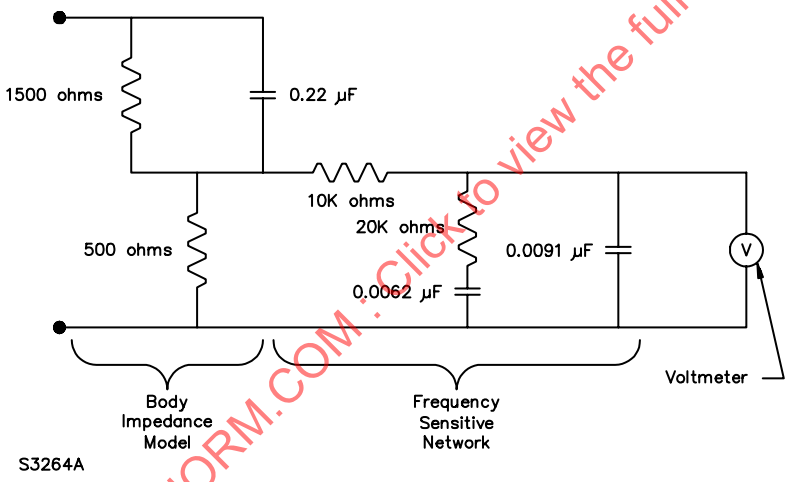

Table 2.1
Measurement Indication Unit

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

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*

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*

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*

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*

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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*

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*

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.

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.

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.

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.

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:

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.

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

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.

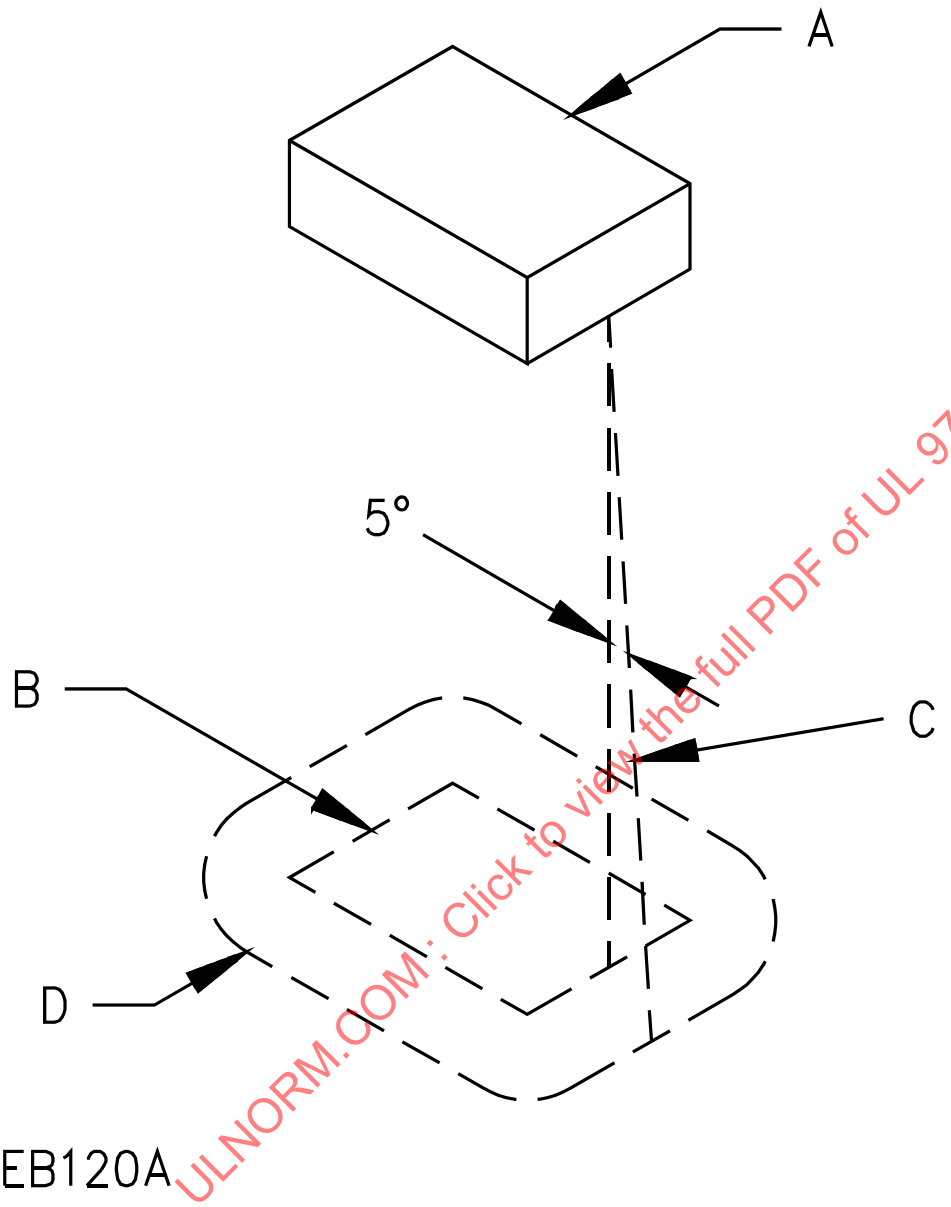
c) The bottom of the enclosure under areas containing only materials classed V-1 or better in accordance with UL 94 or CSA C22.2 No. 0.17, shall have openings no larger than 40 mm^2 (1/16 in^2).

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.

Figure 7.1

Enclosure Bottom



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

B – Projection of outline of component on horizontal plane.

C – Inclined line which traces out minimum area of barrier. When moving, the line is always:

1) tangent to the component;

2) five degrees from the vertical; and

3) so oriented that the area traced out on a horizontal plane is maximum.

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

Figure 7.2

Example of a Bottom-Enclosure Baffle

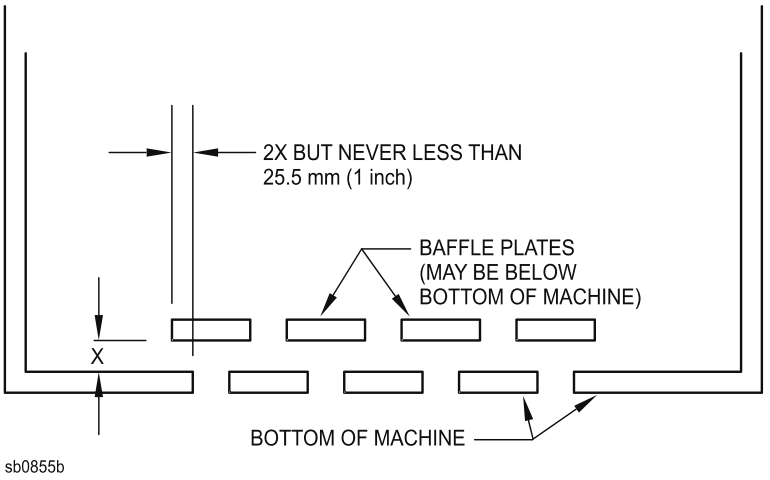


Table 7.5
Perforated Metal Plates for Enclosure Bottom

Minimum thickness		Maximum diameter of holes		Minimum spacings of holes center to center	
mm	(inch)	mm	(inch)	mm	(inch)
0.66	(0.026)	1.14	(0.045)	1.70	(0.067), or 233 holes per 645 mm^2 (1 in^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), or 72 holes per 645 mm^2 (1 in^2)
0.89	(0.035)	1.90	(0.075)	3.18	(0.125)
0.91	(0.036)	1.60	(0.063)	2.77	(0.109)
0.91	(0.036)	1.98	(0.078)	3.18	(0.125)
0.99	(0.039)	1.60	(0.063)	2.77	(0.109)
0.99	(0.039)	2.00	(0.079)	3.00	(0.118)

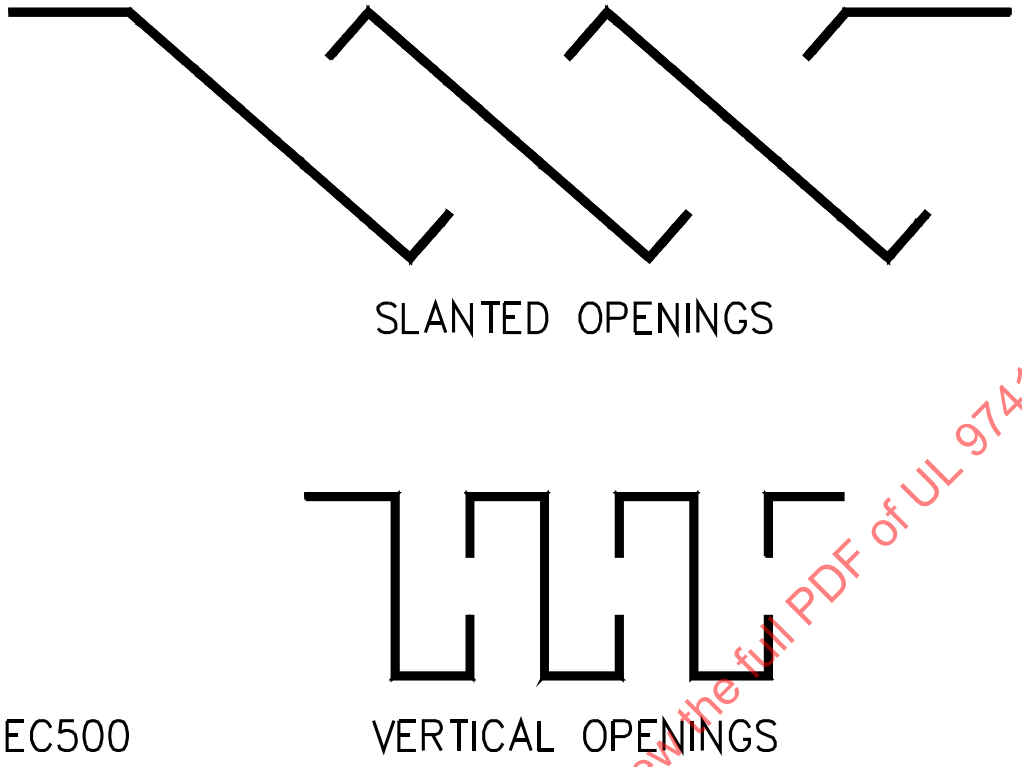
7.10 Enclosure top openings

7.10.1 The minor dimension (see 8.5) of any opening in the top of an enclosure directly over an uninsulated live part involving a risk of electric shock or electrical energy – high current levels – shall not exceed 4.8 mm (3/16 inch) unless the configuration is such that the risk of direct vertical entry of a falling object to uninsulated live parts is reduced by means of a trap or restriction. See Figure 7.3 for examples of top surface openings that reduce the risk of direct entry.

7.10.2 The 4.8 mm (3/16 inch) limitation does not apply for openings located 1.8 m (6 feet) or higher from the floor, when the unit is installed in accordance with the manufacturer's instructions. Such openings shall comply with the accessibility requirements in Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8.

Figure 7.3

Cross Sections of Top-Enclosure Designs



7.11 Expanded metal mesh and screens

7.11.1 The thickness of perforated sheet steel and sheet steel employed for expanded metal mesh used to cover an opening in the enclosure shall comply with Table 7.6 with no restrictions on the size of the opening. The thickness of the sheet steel may be reduced in accordance with Table 7.7 where the indentation of the material does not adversely affect performance or reduce spacings to live parts below the minimum values specified in Spacings, Section 23, or Alternate Spacings – Clearances and Creepage Distances, Section 24, and one of the following is met:

a) The opening has an area of not more than 464.5 cm^2 (72 in^2) and no dimension greater than 304.8 mm (12 inches), or

b) The width of the opening is not greater than 88.9 mm (3-1/2 inches).

Table 7.6
Minimum Thickness of Expanded Metal Mesh

Opening area	Uncoated		Zinc coated	
	mm	(inch)	mm	(inch)
Maximum 323 mm^2 (0.5 in^2) or less	1.07	(0.042)	1.14	(0.045)
More than 323 mm^2 (0.5 in^2)	2.03	(0.080)	2.13	(0.084)

Table 7.7
Minimum Thickness of Expanded Metal Mesh

Uncoated		Zinc coated	
mm	(inch)	mm	(inch)
0.51	(0.020)	0.61	(0.024)

7.11.2 The diameter of the wires of a screen shall not be less than 1.30 mm (0.5 inch) where the screen openings are 323 mm^2 (0.5 in^2) or less in area, and not less than 2.06 mm (0.81 inch) for larger screen openings.

7.12 Outdoor use enclosures

7.12.1 Enclosures for equipment intended to be used outdoors shall be rated a minimum of Type 3R in accordance with CSA C22.2 No. 94.2/UL 50E. Additionally, the enclosure shall comply with the Sprinkler Test in Section 78.

7.12.2 Metallic enclosures for equipment intended to be used outdoors shall comply with Corrosion Protection requirements in Section 11.

8 Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts

8.1 The requirements in this section apply to parts that are accessible to the user. For protection of service personnel requirements, refer to Protection of Service Personnel, Section 37.

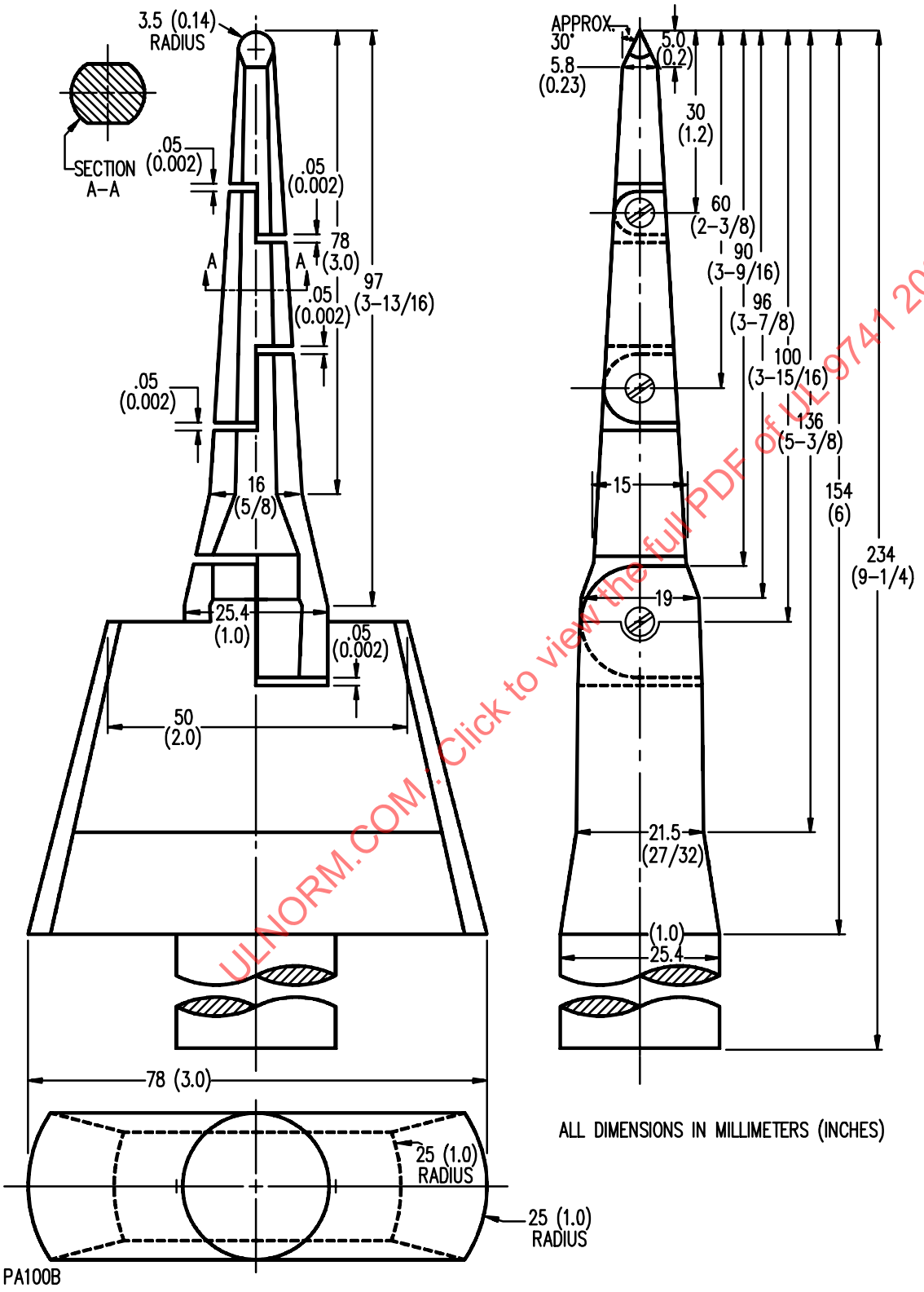
8.2 To reduce the risk of unintentional contact that results in electric shock from an uninsulated live part or film-coated wire, electrical energy – high current levels, or injury to persons from a moving part, an opening in an enclosure shall comply with either one of the following:

a) For an opening that has a minor dimension (see 8.5) less than 25.4 mm (1 inch), such a part or wire shall not be contacted by the probe illustrated in Figure 8.1; or

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

Figure 8.1

Articulate Probe



1 mm = 0.039 inch

Table 8.1
Minimum Required Distance from an Opening to a Part that Involves a Risk of Electric Shock, Electrical Energy-High Current Level, or Injury to Persons

Minor dimension of opening[a,b]		Minimum distance from opening to part[b]	
mm	(inch)	mm	(inch)
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	(2-1/2)	444.0	(17-1/2)
c		762.0	(30)

[a] See 8.5.

[b] Between 25.4 and 54.0 mm, interpolation shall be used to determine a value between values specified in the table.

[c] More than 54.0 mm, and not more than 152.0 mm (5.98 inches).

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

8.4 The probe mentioned in 8.3 shall be used as measuring instruments to judge the accessibility provided by an opening, and not as instruments to judge the strength of a material; they shall be applied with a maximum force of 4.4 N (1 pound).

8.5 With reference to the requirements in 8.2, the minor dimension of an opening is the diameter of the largest cylindrical probe that is capable of being inserted through the opening.

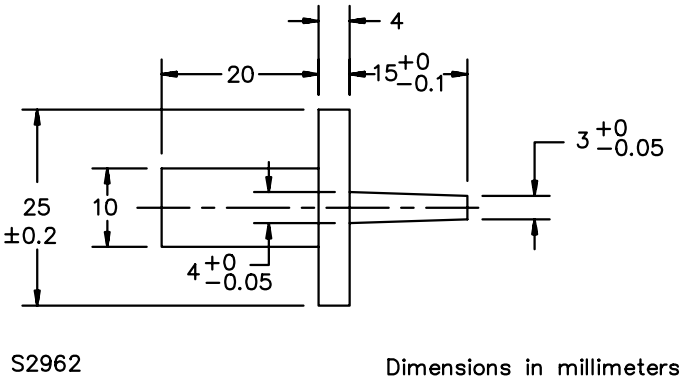
8.6 The test pin illustrated in Figure 8.2, when inserted as specified in 8.3 through an opening in an enclosure, shall not touch any uninsulated live part that involves a risk of electric shock.

8.7 The probe shown in Figure 8.1 and the test pin shown in Figure 8.2 shall be inserted as specified in 8.3 into all openings, including those in the bottom of the unit. The unit shall be moved in whatever way required to make the entire bottom accessible, except for those constructions in 8.8, for insertion of the probe.

8.8 For a floor-standing unit, the probe and test pin shall be inserted into all openings in the bottom that are accessible without tipping, turning over, or otherwise moving the unit from its intended installed position.

Figure 8.2

Test Pin



1 mm = 0.039 inch

8.9 During the examination of a unit to determine whether it complies with the requirements in 8.2, a part of the enclosure that is capable of being opened or removed by the user without using a tool (to attach an accessory, to make an operating adjustment, to give access to a fuse or other overload protective device as described in 7.2, or for other reasons) is to be opened or removed. A fastener, such as a slotted-head thumb screw, that is turned by hand, does not require the use of a tool.

9 Electric Shock

9.1 Voltage

9.1.1 The requirements described in 9.1.2 – 9.2.2 shall be used to determine whether the voltage of an accessible live part involves a risk of electric shock.

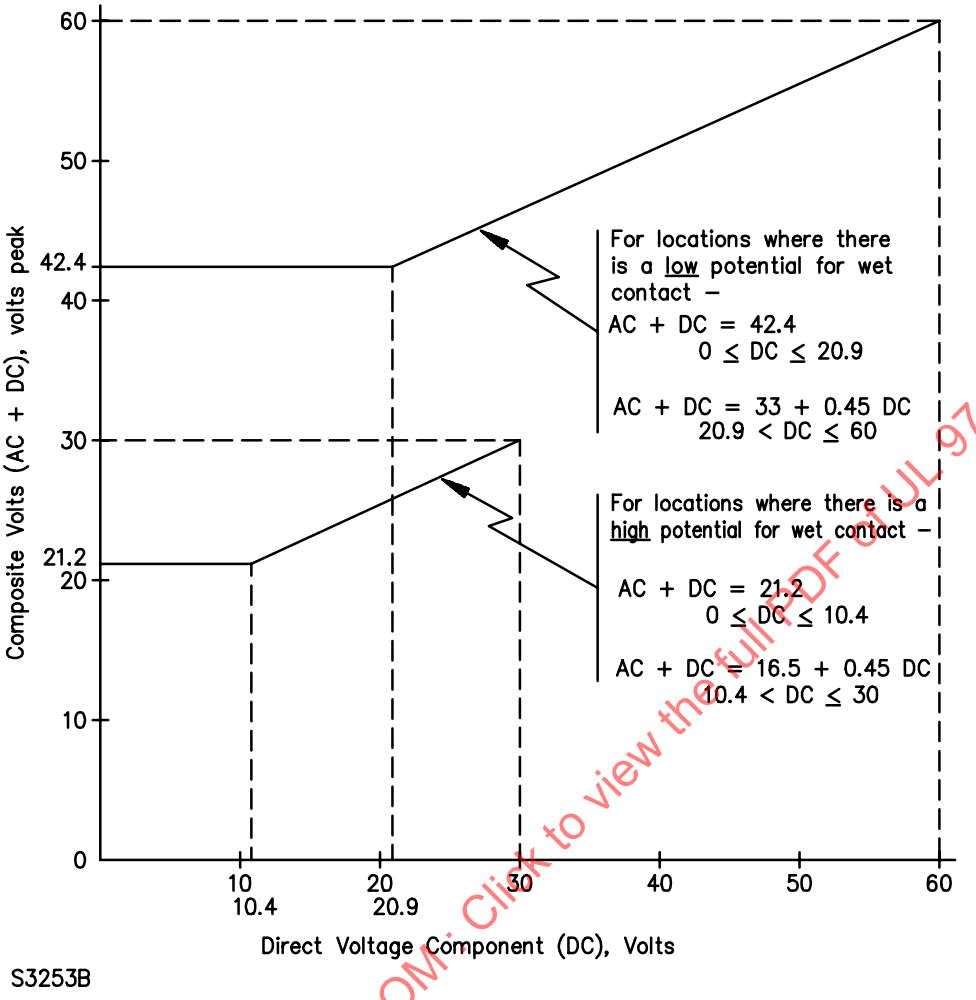
9.1.2 A live part does not involve a risk of electric shock where the voltage of the part does not exceed the values specified in Table 9.1.

Table 9.1
Risk of Electric Shock – Maximum Voltage

Voltage type		Indoor-use units (low potential for wet contact)	Outdoor-use units (high potential for wet contact – immersion not included)
1.	Sinusoidal ac	30 V rms	15 V rms
2.	Nonsinusoidal ac	42.4 V peak	21.2 V peak
3.	Pure dc	60 V	30 V
4.	DC interrupted at a rate of 10 to 200 Hz	24.8 V peak	12.4 V peak
5.	Combinations of dc and sinusoidal ac at frequencies not greater than 100 Hz	See Figure 9.1	See Figure 9.1

Figure 9.1

Maximum Voltage



9.2 Stored energy

9.2.1 The allowable capacitance between capacitor terminals that are accessible as determined by the requirements in Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8, and Protection of Service Personnel, Section 37, shall satisfy the following expressions:

$V < 40{,}000$	where $C < 0.00328$
$V < 729\ C^{-0.7}$	where $0.00328 \leq C < 2.67$
$V < 367$	where $2.67 \leq C < 13.9$
$V < 2314\ C^{-0.7}$	where $13.9\ C \geq 184.5$ in a DRY environment
$V < 60$	where $C \geq 184.5$ in a DRY environment
$V < 2314\ C^{-0.7}$	where $13.9 \leq C < 497$ in a WET environment
$V < 30$	where $C \geq 497$ in a WET environment

in which:

C is the capacitance of the capacitor in microfarads; and

V is the voltage across the capacitor in volts. *V* is to be measured 5 seconds after the capacitor terminals are accessible by the removal or opening of an interlocked cover, or similar device. Typical calculated values appear in Table 9.2, and the equation is shown graphically in Figure 9.2.

9.2.2 With reference to 9.2.1, a part involving a potential of more than 40 kilovolts peak shall be evaluated to determine whether it involves a risk of electric shock.

Table 9.2
Risk of Electric Shock – Stored Energy Current

Environment	Capacitance in microfarads[a]	Maximum allowable voltage across the capacitor, in volts
Wet or Dry	0.00328 or less	40,000
	0.005	29,749
	0.01	18,313
	0.02	11,273
	0.05	5,936
	0.1	3,654
	0.2	2,249
	0.5	1,184
	1.0	729
	2.0	449
	2.0	449
	2.67 to 13.9	367
	20.0	284
	50.0	150
	100.0	92.1

Table 9.2 Continued on Next Page

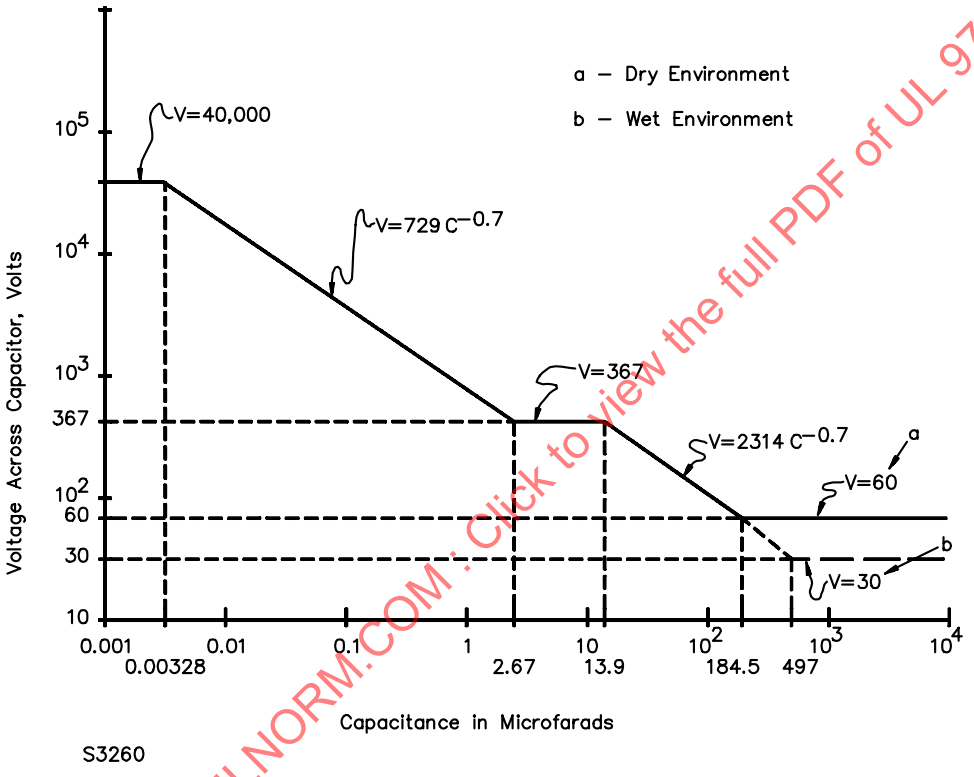
Table 9.2 Continued

Environment	Capacitance in microfarads[a]	Maximum allowable voltage across the capacitor, in volts
	184.5	60.0
Dry only	184.5 or more	60.0
Wet	200	56.7
	497 or more	30.0

[a] See Figure 9.2.

Figure 9.2

Limits for Voltage Across Capacitance



9.3 Personnel protection systems

9.3.1 Bidirectional EVPE shall be provided with a system of protection in accordance with the requirements in UL 2231-1/CSA C22.2 No. 281.1 and UL 2231-2/CSA C22.2 No. 281.2.

9.3.2 UL 2231-1/CSA C22.2 No. 281.1 contains an outline of the features required to provide protection based on voltage and grounding or isolation of the system or part of the system under consideration. UL 2231-2/CSA C22.2 No. 281.2 contains the construction and performance requirements that are applied to a system of protection that is intended to become an integral part of an overall device. Additional guidance in the application of the requirements of UL 2231-1/CSA C22.2 No. 281.1 and UL 2231-2/CSA C22.2 No. 281.2 is contained in Annex B of this document.

10 Mounting

10.1 A unit that is intended to be fastened or fixed in place shall have provision for mounting it securely in position. Bolts, screws, or other parts used for mounting the unit shall be independent of those used to secure components of the unit to the frame, base, or panel.

10.2 Where used, keyhole slots for mounting screws shall be arranged so that wall-mounting screws do not project into a compartment containing electrical parts and reduce spacings to less than those specified in Spacings, Section 23, or in Alternate Spacings – Clearances and Creepage Distances, Section 24.

10.3 A fixed unit shall not be provided with casters unless those casters are only used for transporting the unit and not for support once installed. The use of leveling feet is an example of how casters are not used for support.

11 Corrosion Protection

11.1 Iron and steel parts shall be protected against corrosion by painting, galvanizing, sherardizing, plating, or other equivalent means. This requirement applies to all enclosure parts, whether of sheet steel or cast iron, and to all springs and other parts upon which intended mechanical operation depends. Bearing surfaces shall be of such materials and constructed so that binding due to corrosion is inhibited. See 11.6 – 11.12.

11.2 With reference to 11.1, the parts specified in (a) – (d) are not required to be protected against corrosion:

a) Bearings, or similar parts, where such protection is impracticable;

b) A minor part, such as a washer, screw, bolt, or similar parts, where the failure of such unprotected parts does not result in a risk of fire, electric shock, electrical energy-high current levels, or injury to persons, or the operation of the unit being adversely affected;

c) A decorative grille that is not required to form a part of the enclosure; and

d) A part made of stainless steel.

11.3 Metal shall not be used in combination such as to cause galvanic action that adversely affects an enclosure.

11.4 Hinges and other attachments shall be resistant to corrosion.

11.5 These requirements do not consider corrosion that is sometimes caused by exposure to the earth or other corrosive agents.

11.6 Additional protection against corrosion is not required for aluminum, stainless steel, polymeric materials, copper, bronze, or brass containing at least 80 percent copper.

11.7 An enclosure of cast iron or malleable iron at least 3.2 mm (1/8 inch) thick shall be protected against corrosion by:

a) A 0.0038 mm (0.00015 inch) thick coating of zinc or the equivalent, on the outside surface and a visible coating of such metal on the inside surface; or

b) One coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. Whether the paint meets the intent for which it is required, shall be determined by evaluation of its composition or, where required, by corrosion tests.

11.8 An enclosure of sheet steel having a thickness less than 3.2 mm (0.126 inch) when zinc-coated or 3.12 mm (0.123 inch) thick when uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in 11.10.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G90 in ASTM A653/A653M with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM designation. The weight of zinc coating shall be determined by any applicable method; however, in case of question, the weight of coating shall be established in accordance with ASTM Designation A90/A90M.

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.0155 mm (0.00061 inch) on each surface with a minimum thickness of 0.0137 mm (0.00054 inch). The thickness of the coating shall be established by the metallic-coating thickness test described in UL 50E/CSA C22.2 No. 94.2. An annealed coating shall also comply with 11.12.

c) A zinc coating conforming with 11.9 (a) or (b) with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. Whether the paint meets the intent for which it is required shall be determined by evaluation of its composition or, where required by corrosion tests.

11.9 An enclosure of sheet steel 3.20 mm (0.126 inch) thick or more when zinc-coated or 3.12 mm (0.123 inch) thick or more when uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been shown to provide equivalent protection as described in 11.10.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in ASTM A653/A653M with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM designation. The weight of zinc coating shall be determined by any applicable method; however, in case of question, the weight of coating shall be established in accordance with ASTM Designation A90/A90M. An A60 (alloyed) coating shall also comply with 11.12.

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.0104 mm (0.00041 inch) on each surface with a minimum thickness of 0.0086 mm (0.00034 inch). The thickness of the coating shall be established by the metallic-coating thickness test described in UL 50E/CSA C22.2 No. 94.2. An annealed coating shall also comply with 11.12.

c) Two coats of an organic finish of epoxy or alkyd resin or other outdoor paint on each surface. Whether the paint meets the intent for which it is required shall be determined by evaluation of its composition or, where required, by corrosion tests.

d) Any one of the means specified in 11.8.

11.10 With reference to 11.8 and 11.9, other finishes, including paints, special metallic finishes, and combinations of the two are determined to be equivalent when comparative tests with galvanized sheet steel – without annealing, wiping, or other surface treatment – conforming with 11.8 (a) or 11.9, as applicable, indicate they provide equivalent protection. Among the factors that are considered when judging whether such coating systems meet the intent of the requirement are exposure to salt spray, moist carbon dioxide-sulfur dioxide-air mixtures, moist hydrogen sulfide-air mixtures, ultraviolet light, and water. See UL 1332, for evaluation of component coatings.

11.11 Test specimens of a finish as described in 11.7 or 11.10, 11.8(c), or 11.9(c), when the paint is tested, shall be consistent with the finish that is to be used in production with respect to the base metal,

cleaning or pretreatment method, application method, number of coats, curing method, thickness, and similar factors.

11.12 A hot-dipped mill-galvanized A60 (alloyed) coating or an annealed zinc coating that is bent or similarly formed after annealing and that is not otherwise required to be painted shall be painted in the bent or formed area if the bending or forming process damages the zinc coating, except that such areas on the inside surface of an enclosure that are not exposed to water as determined by the environmental testing of 7.12, are not required to be painted. The zinc coating is evaluated at the outside radius of the bent or formed section visible at 25 power magnification. Simple sheared or cut edges and punched holes are not formed.

12 Mechanical Assembly

12.1 Loosening of parts in a unit as a result of vibration due to handling and operation of the unit shall not result in a risk of fire, electric shock, injury to persons, or electrical energy – high current levels.

12.2 Screws with lock washers applied as intended, screws tightened by means of a power tool, rivets, and staked and upset screws are considered not subject to loosening. See 12.3.

12.3 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 using a center punch applied to the end of a bolt after assembly, mismatching of the nut and bolt threads, or the equivalent.

12.4 A rotating part that, when loosened, results in a risk of fire, electric shock, electrical energy – high current levels, or injury to persons shall be assembled so that the direction of rotation tends to tighten the means that hold the rotating part in place. Alternatively, 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 allowed without concern for rotation direction.

12.5 A switch, fuseholder, lampholder, attachment-plug receptacle, motor-attachment plug, or other component that is handled by the operator shall be mounted securely, not turn, and comply with the requirements specified in 12.6. A switch is allowed to turn when all the following conditions are met:

a) The switch is of a plunger, slide, or other type that does not tend to rotate during intended operation (a toggle switch is considered to be subjected to forces that tend to turn the switch);

b) The means of mounting the switch reduces the risk that operation loosens the switch;

c) Spacings are not reduced below the minimum required value where the switch rotates; and

d) Intended operation of the switch is by mechanical means rather than by direct contact by persons.

12.6 The means of securing components mentioned in 12.5 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.

12.7 A blower or fan motor rated over 5.66 m^3/min (200 ft^3/min), including the blower or fan blade itself, shall be secured by bolts and nuts complying with 12.3, bolts and nuts having holes or slots with cotter pins applied as intended, bolts having a compression type lock nut, rivets, or the equivalent means to reduce the risk of the blower motor or fan blade from vibrating loose and falling from its mounting support.

13 Switches and Controls

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

13.2 A primary-circuit switch that controls an inductive load having a power factor less than 75 percent, such as a transformer or some ballasts and that does not have an inductive rating, shall be either rated not less than twice the maximum load current under normal operating conditions, or be evaluated for the application.

13.3 A switch used to connect a load to various sources or potentials shall be a type that has been evaluated and rated for such use. This includes a switch used for switching a voltmeter, frequency meter, and power factor meter between various phases.

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

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

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

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

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

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

13.8 Solid state switches shall comply with the requirements in this standard. Mechanical and electromechanical switches shall comply with the applicable requirements for switches such as in UL 20, UL 508, CSA C22.2 No. 14, CSA C22.2 No. 178.1, or other applicable standards.

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

14 Supply Connections

14.1 Fixed units

14.1.1 General

14.1.1.1 A fixed unit shall have provision for connection of a wiring system. This provision shall consist of either wiring terminals as specified in 14.1.1.3 – 14.1.2.10 or wiring leads as specified in 14.1.1.3 and 14.1.3.1 – 14.1.3.7 and a means for connection of cable or conduit as specified in 14.2.1. This requirement is not applicable to accessible signal circuits that comply with Section 26.

14.1.1.2 The requirement in 14.1.1.1 applies to the wiring connection means for the alternating current and direct current input and output power circuits of a unit. These connections are intended to be made in the field when the unit is installed.

14.1.1.3 A wiring terminal or lead shall be used for the connection of a conductor having an ampacity based on Table 310-16 of NFPA 70 and Tables 1 to 5 in CSA C22.1 of no less than 125 percent of the maximum current that the circuit carries during rated conditions described in 53.1. For determining the applicable column in Table 310-16, see 87.2(l) and 87.2(m).

14.1.2 Wiring terminals

14.1.2.1 A wiring terminal shall comply with the requirement in 14.1.1.3 for a wire of each metal for which it is marked. See 85.2.8.

14.1.2.2 A wiring terminal shall be provided with a pressure terminal connector of other than the crimping type that is securely fastened in place – for example, firmly bolted or held by a screw. A pressure terminal connector, including a crimping type, may be used when field-installed in accordance with 14.1.2.4. A wire-binding screw may be employed at a wiring terminal intended for connection of a 10 AWG (5.3 mm^2) or smaller conductor where upturned lugs, a cupped washer, or the equivalent is provided to hold the wire in position.

14.1.2.3 A wiring terminal shall be prevented from turning or shifting in position by a means other than friction between surfaces. This shall be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method. A pressure terminal connector of the type that secures the wire by crimping and used in accordance with the requirements in 14.1.2.4 may turn when the least spacing between adjacent terminals and also between terminals and dead metal parts, complies with Spacings, Section 23, for when connectors are oriented in such a position that results in these spacings.

14.1.2.4 In accordance with 14.1.2.2 and 14.1.2.3, a pressure terminal connector is not required to be provided when the conditions in (a) – (e) are complied with:

a) One or more component terminal assemblies shall be available from the unit manufacturer or others, and they shall be specified in the instruction manual. See 87.2 (b) and (c).

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

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

d) Where the pressure terminal connector provided in a terminal assembly requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any required instructions shall be included in the assembly package or with the unit. See 87.2(d).

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

14.1.2.5 An insulating base for support of a pressure terminal connector shall be subjected to the Strength of Terminal Insulating Base and Support Test, Section 63. The test is not required for wire connectors that are part of a component such as a terminal block, circuit breaker, switch, or similar device.

14.1.2.6 A wire-binding screw at a field-wiring terminal shall not be smaller than No. 10 (4.8 mm diameter), except as follows:

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

b) A No. 6 (3.5 mm diameter) screw used for the connection of a 16 or 18 AWG (1.3 or 0.8 2 mm^2) control-circuit conductor is allowed.

14.1.2.7 A wire-binding screw shall thread into metal.

14.1.2.8 A terminal plate tapped for a wire-binding screw shall be of metal not less than 1.27 mm (0.050 inch) thick unless an LVLE circuit or limited energy circuit (see 2.36 and 2.34) is involved and the tapped threads withstand the tightening torque specified in Table 14.1 without stripping.

Table 14.1
Tightening Torque for Wire-Binding Screws

Size of terminal screwnumber	Wire sizes to be tested AWG[a]	Tightening torque	
		Newton meters	Pound-inches
6	16 – 18 (ST)	1.4	12
8	14 (S) and 16 – 18 (ST)	1.8	16
10	10 – 14 (S) and 16 – 18 (ST)	2.3	20

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

14.1.2.9 There shall be two or more full threads in the metal of a terminal plate. When the metal is extruded at the tapped hole, at least two full threads shall be provided. Two full threads are not required for a terminal in a LVLE or limited-energy circuit (see 2.36 and 2.34) when a lesser number of threads results in a secure connection in which the threads do not strip when subjected to the tightening torque specified in Table 14.1.

14.1.2.10 A terminal for connection of a grounded conductor of an alternating current power circuit shall be identified as described in 85.2.11.

14.1.3 Field wiring leads

14.1.3.1 A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is connected and shall not be smaller than 18 AWG (0.82 mm^2). For example, a 10 AWG (5.3 mm^2) or larger field-wiring lead is required for connection to a 6 AWG (14.3 mm^2) field-provided conductor. See also 14.1.3.2. The exposed length of the field-wiring lead shall not be less than 152.4 mm (6 inches) long.

14.1.3.2 A lead may be more than two wire sizes smaller than the field-provided copper conductor to which it is connected, and not smaller than 18 AWG (0.82 mm^2), when more than one factory-provided copper lead is intended for connection to the same field-provided lead, and the construction complies with the conditions in (a) – (c):

a) A wire connector for connection of the field-provided wire is provided as part of the unit or remote-control assembly, and the wire connector is intended for the combination of wires that are spliced;

b) The factory-provided leads are bunched or otherwise arranged so that stress does not result on an individual lead; and

c) Instructions are provided in accordance with 87.2(e).

14.1.3.3 A field-wiring lead shall consist of general premise wire, or other wiring where it has an insulation of:

a) At least 0.8-mm (1/32-inch) thick thermoplastic material;

b) At least 0.4-mm (1/64-inch) thick rubber plus a braid cover for applications of 300 volts or less; and

c) At least 0.8-mm (1/32-inch) thick rubber plus a braid cover for applications between 301 and 600 volts.

14.1.3.4 A field-wiring lead shall be subjected to the test specified in 59.2.3.

14.1.3.5 A field-wiring lead provided for connection to an external line-voltage circuit shall not be connected to a wire-binding screw or pressure terminal connector located in the same compartment as the free end of the wiring lead unless the screw or connector is rendered unusable for field-wiring connection or the lead is insulated at the unconnected end, and a marking is provided on the unit in accordance with 85.2.15.

14.1.3.6 The free end of a field-wiring lead that is not used in every installation, such as a tap for a multivoltage transformer, shall be insulated. For a grounding lead, see 18.8.

14.1.3.7 A field-wiring lead for connection of a grounded conductor shall be identified as described in 85.2.11.

14.1.4 Wiring compartments

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

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

14.2 Openings for conduit or cable connection

14.2.1 For a fixed unit, an opening or knockout complying with the requirements specified in 7.7.1 – 7.7.8 shall be provided for connection of conduit or cable wiring system or the unit shall comply with 7.7.6 and 7.7.7.

14.3 Openings for Class 2 circuit conductors

14.3.1 An opening for the entry of a conductor or conductors of a Class 2 circuit shall be provided with an insulating bushing. The bushing shall be mounted in place in the opening or shall be within the enclosure so that it is mounted as intended when the unit is installed. The bushing is not required when the opening accommodates armored cable or conduit, and the installation instructions indicate that Class 1 wiring methods are to be used as indicated in 87.2(n).

14.3.2 A bushing of rubber or rubber-like material provided in accordance with 14.3.1 shall be at least 3.2 mm (1/8 inch) thick, except that it shall be not less than 1.2 mm (3/64 inch) thick where the metal around the hole is eyeletted or similarly treated to provide smooth edges. A bushing shall be located so that it is not exposed to oil, grease, oily vapors, or other substances having a deleterious effect on the material of the bushing. A hole in which such a bushing is mounted shall be free from sharp edges, burrs, projections, or similar objects that are capable of damaging the bushing.

14.4 Identification

14.4.1 A unit rated as indicated in (a) – (g) shall have the grounded conductor connected to the following items: when provided the screw shell of an Edison-base lampholder and the screw shell of an Edison-base fuseholder. The grounded conductor of a fixed unit shall be connected to the field-wiring terminal intended for the connection of a grounded conductor (see 14.1.2.10) or shall be connected to the field-wiring lead intended for the connection of a grounded conductor (see 14.1.3.7). A single-pole switch or single-pole overcurrent protective device, other than an automatic control without a marked off position shall be connected to the ungrounded conductor. See also 13.8.

a) 120 volts, 2-wire;

b) 120/240 volts, single-phase, 3-wire;

c) 208Y/120 volts, two-phase, 3-wire;

d) 208Y/120 volts, three-phase, 4-wire;

e) 480Y/277 or 600Y/347 volts, three-phase, 4-wire in which the neutral is used as a circuit conductor;

f) 240/120 volts, three-phase, 4-wire in which the midpoint on one phase is used as a circuit conductor; or

g) 240 or 480 volts, three-phase, 3-wire, corner-grounded delta.

15 Wire Bending Space

15.1 A permanently connected unit employing pressure terminal connectors for field connection of circuits described in 14.1.1.2 shall be provided with space within the enclosure as specified in 15.3 – 15.7 for the installation of conductors including grounding conductors that are employed in the installation. In Canada, these products shall comply with the requirements of this section or with CSA C22.2 No. 0.12.

15.2 The conductor size used in judging the wiring space shall be based on the use of a conductor sized in accordance with 14.1.1.3 or as marked on the product wiring diagram.

15.3 Wire bending space for field installed conductors shall be provided opposite any pressure wire connector as specified in 15.4 or 15.5 and opening or knockout for a conduit or wireway in a gutter as specified in 15.9.

15.4 When a conductor is not capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 15.1. A wire can enter or leaving a top, back, bottom, or side surface when there is an opening or knockout for a wireway or conduit.

Table 15.1
Minimum Wire-Bending Space for Conductors Through a Wall Opposite Terminals in mm (inch)

Wire size		Wires per terminal (pole)[a]											
		1			2			3			4 or More		
AWG or kcmil	(mm^2)	mm		(inch)	mm		(inch)	mm		(inch)	mm		(inch)
14 – 10	(2.1 – 5.3)	Not specified			–			–			–		
8	(8.4)	38.1		(1-1/2)	–			–			–		
6	(13.3)	50.8		(2)	–			–			–		
4	(21.1)	76.2		(3)	–			–			–		
3	(26.7)	76.2		(3)	–			–			–		
2	(33.6)	88.9		(3-1/2)	–			–			–		
1	(42.4)	114		(4-1/2)	–			–			–		
0	(53.5)	140		(5-1/2)	140		(5-1/2)	179		(7)	–		
2/0	(67.4)	152		(6)	152		(6)	191		(7-1/2)	–		
3/0	(85.0)	165	[12.7]	(6-1/2)	165	[12.7]	(6-1/2)	203		(8)	–		
4/0	(107)	179	[25.4]	(7)	191	[38.1]	(7-1/2)	216	[12.7]	(8-1/2)	–		
250	(127)	216	[50.8]	(8-1/2)	216	[50.8]	(8-1/2)	229	[25.4]	(9)	254		(10)
300	(152)	254	[76.2]	(10)	254	[50.8]	(10)	279	[25.4]	(11)	305		(12)
350	(177)	305	[76.2]	(12)	305	[76.2]	(12)	330	[76.2]	(13)	355	[50.8]	(14)
400	(203)	330	[76.2]	(13)	330	[76.2]	(13)	355	[76.2]	(14)	381	[76.2]	(15)
500	(253)	355	[76.2]	(14)	355	[76.2]	(14)	381	[76.2]	(15)	406	[76.2]	(16)
600	(304)	381	[76.2]	(15)	406	[76.2]	(16)	457	[76.2]	(18)	483	[76.2]	(19)
700	(355)	40	[76.2]	(16)	457	[76.2]	(18)	508	[76.2]	(20)	559	[76.2]	(22)
750	(380)	432	[76.2]	(17)	483	[76.2]	(19)	559	[76.2]	(22)	610	[76.2]	(24)
800	(405)	457		(18)	508		(20)	559		(22)	610		(24)
900	(456)	483		(19)	559		(22)	610		(24)	610		(24)
1000	(507)	508		(20)	–			–			–		
1250	(633)	559		(22)	–			–			–		
1500	(760)	610		(24)	–			–			–		
1750	(886)	610		(24)	–			–			–		
2000	1013	610		(24)	–			–			–		

NOTE – This table includes only those multiple-conductor combinations that are commonly used. Combinations not specified shall be further evaluated.

[a] Compliance with the following conditions reduces the wire-bending space by the number of mm's shown in brackets:

1) Only removable or lay-in wire connectors receiving one wire each are used (sometimes there is more than one removable wire connector per terminal) and

2) A removable wire connector is able to be removed from its intended location and reinstalled with the conductor in place without disturbing structural or electrical parts other than a cover.

15.5 Where a conductor is not capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 15.2. The wire bending space is in accordance with Table 15.2 when a barrier is provided between the connector and the opening, or drawings are provided specifying that the conductors are not to enter or leave the enclosure directly opposite the wire connector. See Illustrations A, B, and C of Figure 15.1.

Table 15.2
Minimum Width of Gutter and Wire-Bending Space for Conductors through a Wall Not Opposite Terminals in mm (inch)

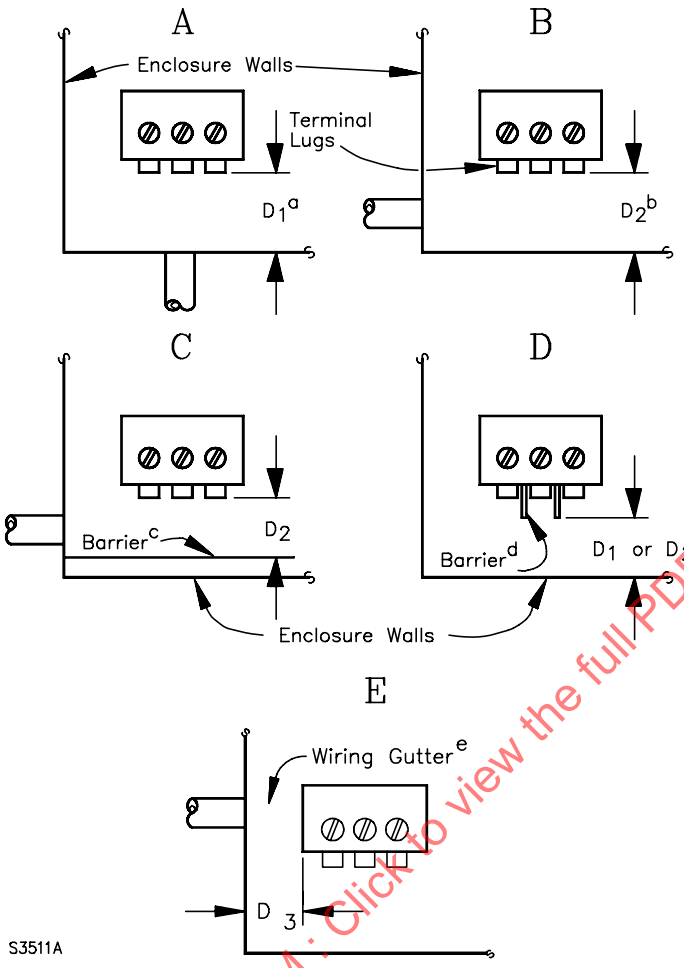
Size of wire		Wires per terminal (pole)									
		1		2		3		4		5	
AWG or kcmil	(mm^2)	mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)
14 – 10	(2.1 – 5.3)	Not specified	–	–		–		–		–	
8 – 6	(8.4 – 13.3)	38.1	(1-1/2)	–		–		–		–	
4 – 3	(21.1 – 26.7)	50.8	(2)	–		–		–		–	
2	(33.6)	63.5	(2-1/2)	–		–		–		–	
1	(42.4)	76.2	(3)	–		–		–		–	
1/0 – 2/0	(53.5 – 7.4)	88.9	(3-1/2)	127	(5)	178	(7)	–		–	
3/0 – 4/0	(85.0 – 107)	102	(4)	152	(6)	203	(8)	–		–	
250	(127)	114	(4-1/2)	152	(6)	203	(8)	254	(10)	–	
300 – 350	(152 – 177)	127	(5)	203	(8)	254	(10)	305	(12)	–	
400 – 500	(203 – 253)	152	(6)	203	(8)	254	(10)	305	(12)	356	(14)
600 – 700	(304 – 355)	203	(8)	254	(10)	305	(12)	356	(14)	406	(16)
750 – 900	(380 – 456)	8	(203)	305	(12)	356	(14)	406	(14)	457	(18)
1000 – 1250	(507 – 633)	254	(10)	–		–		–		–	
1500 – 2000	(760 – 1010)	305	(12)	–				–		–	

NOTE – This table includes only those multiple-conductor combinations that are commonly used. Combinations not specified shall be further evaluated.

15.6 When a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance shall be measured from the end of the barrier. See illustration D of Figure 15.1.

Figure 15.1

Wire Bending Space



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

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

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

[a] A conduit opening or knockout is provided in the wall opposite the terminal lugs. D_1 shall not be less than the minimum wire bending space specified in Table 15.1.

[b] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. The wall opposite the terminal lugs either is not provided with a knockout or conduit opening or a marking is provided indicating that the conduit opening or knockout is not to be used. D_2 shall not be less than the minimum wire bending space specified in Table 15.2.

[c] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. In addition, a conduit opening or knockout is provided in the wall opposite the terminal lugs, however, a barrier preventing the use of the opening is provided. D_2 shall not be less than the minimum wire bending space specified in Table 15.2.

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

[e] A conduit opening or knockout is provided in a wiring gutter. The width of the gutter, D_3, shall not be less than the minimum wire bending space specified in Table 15.2.

15.7 For a unit not provided with a conduit opening or knockout (see 7.7.6) the minimum wiring bending space mentioned in 15.4 – 15.6 shall be based on any enclosure wall capable of being used for installation of the conduit or only specific walls that are to be used as determined by a marking, drawing, or template furnished with the unit.

15.8 The distance mentioned in 15.3 – 15.5 shall be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. See illustrations A – C of Figure 15.1. The wire terminal shall be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it can assume without defeating any means provided to prevent turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or similar part. A barrier, shoulder, or similar part shall be disregarded where the measurement is being made when it does not reduce the radius to which the wire must be bent. Where a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance shall be measured from the wire opening closest to the wall of the enclosure. See also 15.6.

15.9 The width of a wiring gutter in which one or more knockouts are provided shall be large enough to accommodate (with respect to bending) conductors of the maximum size that are used at that knockout. The values of the minimum required width of a wiring gutter, with respect to conductors entering a knockout, are the same as the values of minimum required bending space given in Table 15.2. See illustration E of Figure 15.1. The wiring space is not required to be of this width when knockouts are provided elsewhere that are in compliance with these requirements, the wiring space at such other point or points is of a width that accommodates the conductors in question, and the knockout or knockouts at such other points are used in the intended wiring of the unit.

16 External Connections and Wiring

16.1 An EV receptacle, EV plug, vehicle connector or vehicle inlet shall comply with the requirements in CSA C22.2 No. 282/UL 2251.

16.2 The cable intended for connection to the vehicle shall be:

a) One of the following types, EV, EVJ, EVE, EVJE, EVT, or EVJT, and be attached to or provided with the product, or

b) Any cable that is integral (nondetachable) to the unit and evaluated for the specific use.

The cable and supply conductors shall be of a size and rating intended for the application.

16.3 The overall length of the cable intended for connection to an EV shall be 7.6 m (25 feet) as follows unless it is equipped with a cable management system that is suitable for the purpose.

16.4 External connections of a unit shall be protected by a mechanical interlock or other means so that the connection is not energized from the off board side unless it is coupled to the EV.

16.5 External connections of a unit shall be protected by a means that de-energizes the cable conductors and connector upon exposure to a strain which results in either cable rupture or separation of the cable from the connector and exposure of live parts.

16.6 A fixed unit intended for either indoor charging of electric vehicles or power export from electric vehicles, and rated as requiring ventilation during power transfer, shall be provided with connections for electrically interlocking with the mechanical ventilation system during use. See 85.3.14 for marking requirements.

16.7 The provisions for connection shall consist of:

a) Either wiring terminals as specified in 14.1.1.3 – 14.1.2.10 or wiring leads as specified in 14.1.1.3, 14.1.3.1 – 14.1.3.7; and

b) A means for connection of cable or conduit as specified in 14.2.1.

16.8 A fixed unit which is not intended for either indoor charging of electric vehicles or power export from electric vehicles and rated as requiring ventilation during power transfer shall be marked in accordance with 82.3.17.

17 EV Bonding

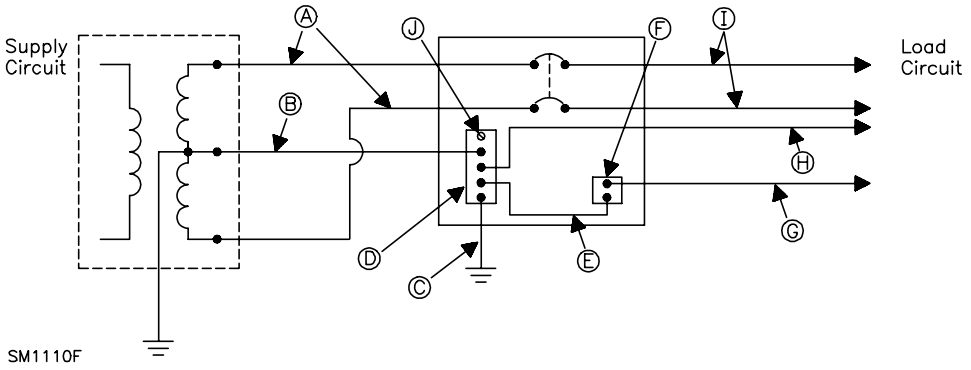
17.1 For a grounded Personnel Protection System, the unit shall provide a means for bonding the EV to the unit when the two are interconnected. The grounded system of protection provided shall be in accordance with the applicable requirements for Personnel Protection Systems in 9.3. The bonding conductor shall not be smaller than the current carrying conductors.

17.2 For an isolated Personnel Protection System, the vehicle shall be isolated from the AC supply source. The isolated system of protection provided shall be in accordance with the applicable requirements for Personnel Protection Systems in 9.3. It shall be permissible to provide bonding conductor that is smaller than the current carrying conductors when needed as a reference by the isolated system of protection.

18 Equipment Bonding/Grounding

18.1 The grounding and bonding terms used in this Standard are in accordance with the UL column in Figure 18.1. The corresponding CSA terms are also provided for information.

Figure 18.1
Grounding/Bonding Terms



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

UL TERMS		CSA TERMS
A –	Ungrounded service conductor	Ungrounded service conductor
B –	Grounded service conductor	Grounded service conductor
C –	Grounding electrode conductor	Grounding conductor
D –	Insulated neutral bus	Neutral bus
E –	Bonding jumper	Bonding jumper
F –	Ground bus	Bonding bus/bonding connector
G –	Equipment grounding conductor	Bonding conductor
H –	Grounded circuit conductor	Identified circuit conductor
I –	Ungrounded circuit conductor	Ungrounded circuit conductor
J –	Screw serving as bonding jumper	Screw serving as bonding jumper

18.2 There shall be provision for grounding all dead metal parts of a unit that are exposed or that possess a risk of being contacted by a person during intended operation or adjustment and that can become energized as a result of electrical malfunction.

18.3 The provisions for equipment bonding/grounding specified in 18.2 shall be provided for the wiring system to be connected to the alternating current input supply. Accessible signal circuits described in Accessible Signal Circuits, Section 26 are not required to have provisions for equipment grounding.

18.4 To determine whether a part can become energized, factors such as construction, the proximity of wiring, and results of a dielectric voltage-withstand test conducted after the appropriate overload, endurance, and abnormal tests shall be evaluated in the US. In Canada, the evaluation shall be in compliance with CSA C22.2 No. 0.4 Clause 4.2.

19 Bonding of Internal Parts

19.1 On a unit having provisions for bonding/grounding (see 18.1) all exposed dead metal parts that can become energized through electrical fault that involves a risk of electric shock or electrical energy – high current levels, shall be conductively connected to the equipment bonding/grounding means.

19.2 In a unit having provisions for bonding/grounding, all uninsulated metal parts of the enclosure, component mounting brackets, capacitors, and other electrical components that involve a risk of electric shock or electrical energy – high current levels shall be bonded for bonding/grounding when they are capable of being contacted by the user or inadvertently contacted by the serviceperson.

19.3 In the US, a metal part as described in (a) – (g) is not required to be bonded for grounding. In Canada, a metal part shall comply with CSA C22.2 No. 0.4.

a) An adhesive-attached metal foil marking, a screw, a handle, or similar device, that is located on the outside of an enclosure or cabinet and isolated from electrical components or wiring by bonded/grounded metal parts so that the risk of them becoming energized is reduced.

b) An isolated metal part, such as a magnet frame and an armature, a small assembly screw, or similar device that is positively separated from wiring and uninsulated live parts.

c) A panel or cover that does not enclose uninsulated live parts when wiring is positively separated from the panel or cover so that the risk of them becoming energized is reduced.

d) A panel or cover that is insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 0.8 mm (1/32 inch) thick and secured in place.

e) An isolated metal part that is mounted on a printed wiring board – such as transformer and choke cores and heat sinks.

f) An isolated metal part that is marked in accordance with 85.3.10.

g) A capacitor sleeved with insulating tubing complying with 23.2.4.

19.4 An internal connection for bonding internal parts to an enclosure for bonding/grounding, and not for a field-installed bonding/grounding conductor, shall not employ a quick-connect terminal unless:

a) The connector is capable of being displaced;

b) The terminal has the dimensions specified in Table 19.1; and

c) The component is limited to use on a circuit having a branch-circuit protective device rated 20 amperes or less.

Table 19.1
Quick-Connect Terminals for Bonding Internal Parts

Nominal size of terminal, mm (inch)					
Width		Length		Thickness	
4.7	(0.187)	6.4	(1/4)	0.5	(0.020)
4.7	(0.187)	6.4	(1/4)	0.8	(0.032)
5.2	(0.205)	6.4	(1/4)	0.8	(0.032)
6.4	(0.250)	8.0	(5/16)	0.8	(0.032)
NOTE: In Canada, CSA C22.2 No. 0.4 shall be consulted for quick-connect.					

19.5 Metal-to-metal piano-type hinges are an example of a means for bonding a door for grounding.

19.6 Where the continuity of the grounding system relies on the dimensional integrity of a nonmetallic material, the material shall be in accordance with the requirements for creep in UL 746A or CSA C22.2 No. 0.17. See also 19.10.

19.7 A separate component bonding conductor shall be of copper, a copper alloy, or an equivalent electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by painting, galvanizing, plating, or equivalent means. A separate bonding conductor or strap shall be protected from mechanical damage or be located within the outer enclosure or frame, not be secured by a removable fastener used for any purpose other than bonding for grounding, unless the bonding conductor is not to be omitted after removal and replacement of the fastener, and not be spliced.

19.8 The bonding shall be by a positive means, such as by clamps, rivets, bolted or screwed connections, or by welding, soldering, or brazing with materials having a softening or melting point greater than 455 °C (850 °F). The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material, other than as indicated in 19.10.

19.9 With reference to 19.8, when penetration of a nonconductive coating is not determined by examination, a Grounding Impedance Test, Section 61, shall be conducted.

19.10 A connection that depends upon the clamping action exerted by rubber or similar material may be used when it complies with the requirements in the Bonding Conductor Test, Section 65, for bonding conductors under any normal degree of compression applied by a variable clamping device and when the results are not significantly changed after exposure to the effects of oil, grease, moisture, and thermal degradation that occur in service. Also, the effect of assembling and disassembling, for maintenance purposes, such a clamping device is to be considered with particular emphasis on reassembling it in its intended position.

19.11 A separate component-bonding conductor shall either be of size intended for the application in accordance with NFPA 70 or CSA C22.1 (see 19.12), not be smaller than the conductor supplying the component, or comply with the requirements in Section 65, Bonding Conductor Test.

NOTE: In Canada, bonding conductors in compliance with CSA C22.2 No. 0.4 are considered to meet these requirements.

19.12 When more than one size branch-circuit overcurrent device is involved, the size of the bonding conductor shall be based on the rating of the overcurrent device intended to provide ground-fault protection for the component bonded by the conductor.

20 Internal Wiring

20.1 Wires

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

20.1.2 With respect to 20.1.1, the effects of vibration, impact, and exposure shall be evaluated for wires smaller than 24 AWG (0.21 mm^2).

20.1.3 All wiring shall be Appliance Wiring Material (AWM) in accordance with CSA C22.2 No. 210 or UL 758 and shall be rated and surface marked "VW-1."

20.1.4 Helical wraps and other continuous forms of harnessing shall be classed V-2 or less flammable when tested in accordance with UL 94 or CSA C22.2 No. 0.17. A harness is not required to be classed V-2 or less flammable when, after tested as an assembly, the assembly is classed V-2 or less flammable. Lacing tape, twine, individual cable clamps, and noncontinuous cable ties are not required to be classed V-2 or less flammable.

20.1.5 Wiring that extends from the enclosure to a hinged door or other part that is subject to movement in use other than installation and servicing shall be stranded and the arrangement shall preclude twisting or stressing of conductors as a result of the movement. The wiring shall be routed or protected to reduce the risk of damage to the insulation. The conductors shall be of a jacketed type, such as Type SJ, SJO, or SJT and provided with strain relief so that stress is not transmitted to terminals or splices. The conductors of a low-voltage, limited-energy circuit described in 2.36 are not required to comply.

20.1.6 A bonding lead used for grounding a door is not required to be jacketed.

20.1.7 Wiring of a type other than those mentioned in 20.1.5, along with any supplementary insulation provided on the wire, that complies with the Flexing Test, Section 60 is acceptable.

20.2 Protection of wiring

20.2.1 Internal wiring shall not be accessible when judged in accordance with Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8, unless it is located and secured within the enclosure such that the risk of it being subjected to stress or mechanical damage is reduced.

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

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

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

20.2.5 A bushing used on other than smooth, rounded surfaces of a hole through which wires pass shall be of material that has mechanical and heat-resistant properties – such as porcelain, phenolic, fiber at least 1.2 mm (3/64 inch) thick, a material complying with the requirements in UL 746C or CSA C22.2 No. 0.17 (see 35.2), or smooth, rounded metal.

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

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

21 Current-Carrying Parts

21.1 General

21.1.1 A current-carrying part shall be of silver, copper, a copper-base alloy, stainless steel, aluminum, or the equivalent except for the materials in 21.1.2.

21.1.2 Using plated steel for secondary-circuit parts and for some primary-circuit parts (such as for capacitor terminals where a glass-to-metal seal is required and for leads or threaded studs of semiconductor devices) is allowed. Blued steel or steel with equivalent corrosion resistance may be used for the current-carrying arms of mechanically operated leaf switches or where the temperature is more than 100 °C (212 °F).

21.1.3 An uninsulated live part and a component that has uninsulated live parts shall be so secured to the base or mounting surface that they do not turn or shift in position where such displacement results in a reduction of spacings below the minimum required values in Spacings, Section 23 or Alternate Spacings – Clearances and Creepage Distances, Section 24.

21.2 Bus bars

21.2.1 Each bus bar shall be plated at each joint with tin, silver, or nickel. A welded or brazed joint, or a copper bus bar with current at the joint of 600 A or less, is not required to be plated. A bus bar provided with an oxide inhibiting compound over the joint surfaces is not required to be plated when the compound is in accordance with 21.3.2.

21.2.2 Other coatings used for aluminum bus bars are allowed when evaluated for the application in accordance with the requirements for current-carrying parts described in Impact Test, Section 73.

21.2.3 The bending of a bus bar shall not result in visible cracks except for roughening or slight surface crazing.

21.2.4 Each riveted joint connection shall have a spring washer at one end and either a spring washer or a flat washer at the other end. See 21.2.6 and 21.2.7. A connection rated 225 amperes or less employing copper bus bars only is not required to comply. Other constructions employing a rivet may be used when they are evaluated in accordance with the applicable requirements in Bus Bar Tests, Section 71.

21.2.5 Each joint connection shall employ a spring washer at one end of a bolt. See 21.2.7. The spring washer may be replaced with a split ring lock washer and flat washer when each bus in the joint is copper or when each aluminum bus in the joint has a tensile yield strength of at least 20,000 psi (138 MPa). A flat washer, a split-ring lock washer, or a bolthead that complies with 21.2.6 may be used in place of a spring washer when the joint does not include any aluminum or when aluminum bolts are used with aluminum

bus bars. Other constructions may be used when they are evaluated in accordance with the applicable requirements in Bus Bar Tests, Section 71.

21.2.6 The flat washer mentioned in 21.2.4 and 21.2.5 shall have a thickness of at least one-sixth that of the diameter of the rivet shank or bolt and shall have an outer diameter at least 150 percent of the rivet shank or bolt and not less than the outer diameter of any adjacent spring washer.

21.2.7 A spring washer as mentioned in 21.2.4 and 21.2.5 is a dished washer of stainless, or hardened and tempered steel, having an outer diameter not less than 150 percent of the bolt diameter, a thickness not less than one-eighth of the bolt diameter, and dished not less than 3-1/2 percent of the bolt diameter.

21.2.8 Unless evaluated for such use, a bolted connection between two bus bars or between a bus bar and another current-carrying part shall not depend on the dimensional integrity of a thermoplastic material.

21.2.9 Insulation over bus bars such as tape or tubing as described in 23.2.4 and 23.2.5 shall not be provided over a bolted joint so that tightening of the joint is accomplished without removal of the insulation.

21.2.10 The current density of a bus bar shall not exceed the values specified in Table 21.1 or Table 21.2 unless:

a) The bus bar has characteristics that do not result in maximum bus bar temperatures exceeding the values specified in Table 54.1.

b) The bus bar contained in a unit has forced air ventilation that does not result in maximum bus bar temperatures exceeding the values specified in Table 54.1.

Table 21.1
Ampacity of Single or Multiple Bus Bars and Clamped Joints

Bus bar material[d]	Current	Current density in amperes per 6.45 cm^2 (in^2)	
		Bus bar cross section	Contact area at clamped joints
Copper	0 – 600 amperes	1000[e]	200
Copper	Over 600	1000[e]	200[a,b]
Aluminum[c]	Any	750[e]	200[a,b]

[a] See 21.1.1, 21.2.11 – 21.2.13.

[b] Joints bolted and plated with silver, tin, or nickel.

[c] Minimum conductivity of 55 percent of International Annealed-Copper Standard.

[d] Multiple bus bars in parallel shall be of the same material.

[e] See also Table 21.2 for 800 ampere maximum single bus bars.

Table 21.2
Rating and Sizes of Single Bus Bars – 800 Amperes Maximum

Current rating in amperes	Copper bus				Aluminum bus[b]			
	Bus size[a, b]		Cross section		Bus size[a]		Cross section	
	mm	(inch)	mm^2	(in^2)	mm	(inch)	mm^2	(in^2)
225	3.2 by 22.2	(0.125 by 0.875)	70.3	(0.109)	6.4 by 22.2	(0.250 by 0.875)	141.3	(0.219)
400	6.4 by 38.1	(0.250 by 1.500)	242.0	(0.375)	6.4 by 50.8	(0.250 by 2.000)	322.6	(0.500)
600	6.4 by 50.8	(0.250 by 2.000)	322.6	(0.500)	See Table 21.1	(See Table 21.1)	518.1	(0.800)
800	6.4 by 76.2	(0.250 by 3.000)	483.9	(0.750)	See Table 21.1	(See Table 21.1)	688.4	(1.067)

NOTES –

1 See 21.2.11 – 21.2.13; for multiple buses in parallel, refer to Table 21.1. The minimum contact area at a clamped joint shall provide not less than 6.5 cm^2 (1 in^2) per 200 amperes.

2 Bolted joints and bus bars plated with silver, tin, or nickel.

[a] A bus bar having other dimensions is not prohibited when it has not less than the cross-sectional area specified in the table and when it has equivalent rigidity.

[b] Minimum conductivity of 55 percent of International Annealed-Copper Standard.

21.2.11 The cross section of a bus as covered in Table 21.1 or 21.2 shall be reduced by not more than 5 percent due to rounding, shaping, or dimensional tolerances.

21.2.12 Removing part of the bus material for slots or holes (whether used or not) is allowed when:

a) The remaining material at any cross section along the length of the bus bar has at least 70 percent of the required ampacity in accordance with Table 21.1 or Table 21.2 and 21.2.11, and

b) The remaining metal in any 152-mm (6-inch) length of bus is at least 93 percent of the metal of a bus having the required ampacity in accordance with Table 21.1 or Table 21.2 and 21.2.11. For example, a 25.4-mm (1-inch) wide bus can have 7.1-mm (9/32-inch) holes on 25.4 mm centers or a 102-mm (4-inch) wide bus can have 10.3-mm (13/32-inch) wide slots 81.3-mm (3.2-inches) long every 152 mm. These limitations do not apply to a bus bar having characteristics that do not result in maximum bus bar temperatures exceeding the values specified in Table 54.1 under the test conditions indicated in Temperature Test, Section 54.

21.2.13 The limitations on current density mentioned in Table 21.1 and Table 21.2 do not apply to a:

a) Connecting strap, bus, or similar device comprising a part of a circuit breaker, switch, or fuseholder employed in the unit.

b) Portion of a strap, bus, jumper, or similar part adjacent and connected to a terminal of a switch, circuit breaker, or fuseholder, and not more than 25.4 mm (1 inch) from the terminal, when a reduced cross section in that portion is required because of the recessing of the terminal or because of barriers adjacent to it.

21.3 Live heat sinks

21.3.1 A current-carrying, aluminum heat sink shall be plated, conductive anodized, iridited or the equivalent at surfaces contacting the solid state component. This requirement does not apply to a live heat sink that is not used to conduct current. A heat sink subjected to the heat cycling tests described in Heat Sink Temperature Cycling Test, Section 68, is considered to comply without further evaluation. This requirement does not apply for leakage current paths.

21.3.2 A heat sink provided with an oxide inhibiting compound over the hear sink surfaces contacting the solid state component is considered to comply with 21.3.1 when the compound is in accordance with 21.3.3.

21.3.3 An oxide inhibiting compound as referenced in 21.3.2 shall be stable at both elevated and low temperatures and the thermal conductivity of the heat sink/solid state component junction shall not be adversely affected by temperature cycling.

22 Electrical Connections

22.1 The requirements described in 22.2 – 22.7 apply to connections of internal wiring that are factory installed in the unit.

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

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

a) Wrapped one full turn around a terminal;

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

c) Twisted with other conductors.

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

22.5 A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch wide quick-connect terminal shall comply with CSA C22.2 No. 153/UL 310. Other sizes of quick-connect terminals shall be evaluated with respect to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rises; all tests shall be conducted in accordance with CSA C22.2 No. 153/UL 310.

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

22.7 A splice shall be provided with insulation equivalent to that of the wires involved unless permanent spacings are maintained between the splice and other metal parts. Insulation over the splice is not prohibited from having:

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

b) Insulating tubing or sleeving used to cover a splice shall be used in accordance with 23.2.4.

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

A splicing device, insulating tubing, sleeving, or tape is not required to be used on splices within coil windings. See 27.2.1 – 27.2.3.

23 Spacings

23.1 General

23.1.1 The spacings for a unit shall not be less than the applicable values as specified in this section or as provided in Alternate Spacings – Clearances and Creepage Distances, Section 24. These spacing requirements do not apply to the internal spacing of a component that complies with the component standard. See Table 23.1.

23.1.2 For printed-wiring boards having a flammability classification of V-0 and constructed from a base material having a minimum Comparative Tracking Index (CTI) rating of 175 volts, spacings (other than spacings to ground, between primary and secondary circuits, and at field wiring terminals) are not specified between traces of different potential connected in the same circuit where:

a) The spacings comply with the requirements in Evaluation of Reduced Spacings on Printed-Wiring Boards, Section 67; or

b) An analysis of the circuit indicates that no more than 12.5 milliamperes of current flows between short-circuited traces having reduced spacings.

23.1.3 For multilayer-printed wiring boards, the minimum spacing between adjacent internal foils of opposite polarity and between an internal foil and a plated-through hole is 0.8 mm (1/32 inch). When these foils are in circuits described in 23.1.15 or 23.1.16, no spacing is specified.

23.1.4 Spacing requirements do not apply between adjacent terminals of a power switching semiconductor device including the connection points of the terminals of the device.

23.1.5 Between adjacent foils on printed wiring boards provided with a conformal coating complying with the requirements in CSA C22.2 No. 0.17 or UL 746C, minimum spacings between adjacent foils are based on voltage transient and dielectric voltage-withstand tests in accordance with CSA C22.2 No. 0.17 or UL 746C. A conformal coating on printed wiring boards shall not be used as insulation in lieu of spacings between a foil on a printed wiring board and uninsulated live metal parts of opposite polarity or to dead metal parts.

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

23.1.7 With reference to 23.1.6, a lock washer applied as intended is a method of rigidly securing a part.

Table 23.1
Spacings

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

[a] For printed wiring boards, see 23.1.2 through 23.1.4.

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

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

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

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

23.1.8 Inherent spacings of the components mentioned in 23.1.1 shall comply with the requirements for the component in question where the spacings are less than the values specified in this standard. Spacings from such components to another component and to the enclosure shall comply with the applicable spacings specified in this standard.

23.1.9 With respect to judging spacings, an uninsulated live part is at opposite polarity to uninsulated live parts in another circuit. Spacings shall be based on the highest of the circuit voltages. See 55.2.1 – 55.2.3.

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

23.1.11 Spacings at field-wiring terminals shall be measured with conductors installed in the terminals. The gauge of these conductors shall be based on the rating of the circuit containing the terminals. See 14.1.1.3.

23.1.12 Spacings between uninsulated live parts of different potential and between such parts and dead metal that are capable of being grounded in service are not specified for parts of LVLE circuits in accordance with 2.41 nor in accessible signal circuits described in Accessible Signal Circuits, Section 26.

23.1.13 Spacings between uninsulated live parts of different potential and between such parts and dead metal that are capable of being grounded in service are not specified for parts of limited-energy circuits in accordance with 2.39. Spacings in these circuits exceeding voltage limits in Section 9, Electric Shock, shall be judged by the applicable test described in Dielectric Voltage-Withstand Test, Section 55. Also see 53.1.

23.1.14 Spacings within the circuits described in (a) and (b) below that are not safety circuits are not specified. The spacings in these circuits shall be judged on the basis of the Dielectric Voltage-Withstand Test, Section 55. Also see 53.1. Spacings between these circuits and the enclosure, grounded dead metal, and other circuits shall comply with the applicable spacing requirements.

a) Secondary circuits supplied by a transformer winding of less than 200 volt-amperes or at a potential of 100 volts or less; and

b) Battery circuits at a potential of 100 volts or less. See 23.1.15.

23.1.15 With reference to 23.1.14(b), spacings within a circuit derived from a battery supply rated over 100 volts are not specified when the voltage within the circuit is limited to 100 volts or less by a regulating network complying with the requirement in 25.11.

23.1.16 The spacings between live and dead metal parts within an instrument shall be determined by conducting the applicable dielectric voltage-withstand test described in Dielectric Voltage-Withstand Test, Section 55. A meter complying with the requirements in UL 1437 or CSA C22.2 No. 29 is not required to be subjected to a dielectric voltage-withstand test.

23.1.17 Epoxy may be used to reduce spacings only when the following conditions are met:

a) Spacings of minimum 0.8 mm (1/32 inch) are maintained prior to application of the epoxy;

b) There are no significant voids in the epoxy;

c) The epoxy is minimum 0.8 mm (1/32 inch) thick;

d) The area of reduced spacing, with epoxy applied, withstands the applicable potential specified in the Dielectric Voltage-Withstand Test, Section 55; and

e) The epoxy temperature during the Temperature Test does not exceed 65 °C (117 °F) rise (based on an assumed operating ambient rating of 25 °C (77 °F) or 90 °C (194 °F) limit (when tested at an ambient rating of greater than 25 °C). When the epoxy has been evaluated and determined to have a higher operating temperature rating, the temperatures indicated above may be exceeded when temperatures do not exceed the material temperature rating.

When the normal operating potential between the parts under evaluation does not exceed 600 V rms, the dielectric test of (d) is not required to be conducted.

23.2 Insulation barriers

23.2.1 An insulating liner or barrier of material such as vulcanized fiber may be employed in lieu of required spacings but not as the sole support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current when it is not less than 0.71 mm (0.028 inch) thick and it is so located that it is not adversely affected by arcing. Other insulating materials used as a barrier or as either direct or indirect support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current shall comply with the requirements in UL 746C or CSA C22.2 No. 0.17.

23.2.2 Vulcanized fiber not less than 0.33 mm (0.013 inch) thick is used only when:

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

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

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

23.2.4 Insulating tubing complying with the requirements in CSA C22.2 No. 198.1/UL 224 is used as insulation of a conductor including bus bars in lieu of the minimum spacings and capacitor case in lieu of bonding the case for grounding, only when the following conditions are met:

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

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

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

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

Tubing complying with CSA C22.2 No. 198.1/UL 224 can also be used over a bolted joint of a bus bar as provided in 21.2.9.

23.2.5 A wrap of thermoplastic tape, complying with the requirements in CSA C22.2 No. 197 or UL 510 is not prohibited when all of the following conditions are met:

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

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

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

d) The tape is not subject to compression;

e) The tape is not wrapped over a sharp edge; and

f) The tape is not wrapped over a bolted bus bar joint. See 21.2.9.

24 Alternate Spacings – Clearances and Creepage Distances

24.1 As an alternative to the spacing requirements of Section 23, Spacings, as applicable the spacing requirements in UL 840 or CSA C22.2 No. 0.2, may be used. The spacing requirements of UL 840 or CSA C22.2 No. 0.2 shall not be used for field wiring terminals and spacings to a dead metal enclosure in applications where the enclosure is likely to be damaged to reduce spacing. In determining the pollution degree and overvoltage category, the end-use application shall be considered and is capable of modifying those characteristics given in 24.2 and 24.3.

24.2 The level of pollution for ventilated indoor use equipment shall be pollution degree 2. For ventilated outdoor use equipment, the level of pollution shall be pollution degree 3. Hermetically sealed or encapsulated enclosures, or coated printing wiring boards in compliance with the Printed Wiring Board Coating Performance Test of UL 840 or CSA C22.2 No. 0.2, are pollution degree 1.

24.3 The equipment shall be rated overvoltage category VI, III, II, and I as defined in UL 840 or CSA C22.2 No. 0.2.

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

25 Control Circuits

25.1 A LVLE circuit as described in 2.36 or a limited-energy circuit as described in 2.34 may be connected to a single-point reference ground.

25.2 Except as indicated in 25.3, a LVLE circuit (see 2.36) is not required to be evaluated. Printed-wiring boards and insulated wire used in such circuits shall be types that are required for the application. See 20.1.1, 20.1.4, and 34.1.

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

25.4 A control circuit, including associated electronic components on printed wiring boards, that does not extend out of the unit is not required to be evaluated when the maximum voltage and current are limited as specified in (a) and (b). Printed wiring boards and insulated wires used in such circuits shall be types that are required for the application. See 20.1.1, 20.1.3, and 34.1.

a) The voltage limits specified in Table 9.2, and

b) 8 amperes for 0 – 42.4 volts peak ac, or 0 – 30 volts dc, or amperes equal to 150 divided by the maximum voltage for 30 – 60 volts dc. See 25.5.

The current values specified in (b) do not apply when the circuit includes an overcurrent protection device as described in 25.8 and 25.9.

25.5 With reference to the current specified in 25.4(b), the maximum current shall be measured under any condition of loading including short circuit using a resistor that is to be continuously readjusted during the 1-minute period to maintain maximum load current, and not exceeding the value indicated in 25.4(b).

25.6 With reference to the voltage limit specified in 25.4(a), measurement shall be made with the unit connected to the voltage specified in 47.1 and with all loading circuits disconnected. Where a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement shall be made from either end of the winding to the tap.

25.7 When the control circuit mentioned in 25.4 is not limited as to available short-circuit current by the construction of a transformer and the circuit includes either one or more resistors, a fuse, a nonadjustable manual-reset protective device, or a regulating network (see 25.11) the circuits in which the current is limited in accordance with 25.8, 25.9, or 25.10 are not required to be evaluated.

25.8 A fuse or circuit-protective device provided in the control circuit used to limit the current in accordance with 25.7 shall be rated or set at not more than the values specified in Table 25.1.

Table 25.1
Rating for Secondary Fuse or Circuit Protector

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

25.9 A fuse or circuit protective device may be connected in the primary of a transformer to limit the current in accordance with 25.7 when the protection is equivalent to that specified in 25.8 as determined by conducting the Overcurrent Protection Calibration Test, Section 62.

25.10 One or more resistors or a regulating network used to limit the current in accordance with 25.10 shall be such that the current under any condition of load including short circuit does not exceed the values indicated in 25.4(b).

25.11 Where a regulating network is used to limit the voltage or current in accordance with 25.4 – 25.10, and the performance is affected by malfunction, either short circuit or open circuit, of any single component – excluding a resistor – the network shall comply with the following:

a) The environmental tests specified in UL 991 or CSA C22.2 No. 0.8; and

b) Critical components shall be derated in accordance with 37.4.

25.12 In a circuit of the type described in 25.7, the secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited shall be evaluated in accordance with the applicable requirements in this standard.

26 Accessible Signal Circuits

26.1 The requirements in 26.2 and 26.3 apply to accessible signal circuits having provision for external connections such as but not limited to RS232, USB, or ethernet, communication ports or similar connections.

26.2 A signal circuit that extends out of a unit shall be isolated from internal circuits having a voltage that involves a risk of electric shock – as determined in accordance with Electric Shock, Section 9 – by any of the following or the equivalent:

a) An optical isolator having an isolation voltage rating of not less than the Dielectric Voltage-Withstand test potential required in 55.3.1 and complying with the requirements in UL 1577;

b) An isolation transformer complying with the requirements in:

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

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

c) An electro-mechanical relay complying with the requirements in UL 508 or CSA C22.2 No. 14; or

d) A voltage regulating network where:

1) The voltage being isolated is not derived from the a-c input circuit; and

2) The network does not show a risk of electric shock to appear at the external signal circuits (as determined in accordance with Electrical Shock, Section 9) as a result of a failure mode and effect analysis in accordance with the method described in UL 991 or CSA C22.2 No. 0.8.

26.3 The maximum voltage and current available from an accessible signal circuit shall comply with the requirements in 26.1 and 26.2.

26.4 The maximum power available from an accessible signal circuit that employs an overcurrent protection device to limit the current as described in 26.4 shall not exceed the values specified in Table 26.1.

Table 26.1
Maximum Power of Accessible Signal Circuits

Circuit voltage volts, rms	Maximum power, volt-amperes
15 or less	350
More than 15 but not greater than 60	250
NOTE – Section 9, Electric Shock, includes additional requirements for accessible circuit voltage limits.	

27 Transformers

27.1 General

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

27.1.2 A thermal cutoff or other device employed to reduce the risk of fire or electric shock due to overheating of a transformer during abnormal operation shall comply with the requirements applicable to such a device in addition to the applicable requirements in this standard. For example, a thermal cutoff shall comply with the applicable requirements in this standard and those in UL 60691 and CSA C22.2 No. 60691.

27.1.3 A transformer used to supply an accessible signal circuit as described in Accessible Signal Circuits, Section 25 shall have its primary winding electrically isolated from its secondary winding and shall be constructed as specified in 27.2.1 – 27.2.6 so that there is no electrical connection – under normal and overload conditions – between the primary and secondary windings, between the primary winding and the core, or between separate adjacent secondary windings, where such connection results in a risk of fire or electric shock.

27.1.4 With reference to the requirement in 27.1.3, a transformer complying with the requirements in any of the following standards complies with this requirement:

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

b) UL 1411; or

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

27.2 Coil insulation

27.2.1 A transformer winding including the start, all taps, finish, and crossover leads up to the point where insulated leads are provided shall be constructed, when used, as specified in Table 27.1.

Table 27.1
Transformer Insulation

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

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

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

c – A material having a thickness less than 0.71 mm (0.028 inch) is used only when it is equivalent to note a or b and the material has a minimum dielectric breakdown strength of 5000 volts for the thickness used as determined by the test described in Tests on Transformer Insulating Materials, Section 70.

d – Using spacings specified in Table 27.2 in place of the specified insulation, is not prohibited.

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

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

g – A material having a thickness less than that specified in notes e and f is not prohibited where it is equivalent to notes e and f and the material has a minimum dielectric breakdown strength of 2500 volts for the thickness used for note e and 5000 volts for the thickness used for note f as determined by the test described in Section 70.

h – Any type and thickness of insulation in addition to the magnet wire coating, or a through air spacing less than that specified in Table 27.2 is not prohibited from being used between a crossover lead and the winding to which it is connected when the construction complies with either of the following:

1. The coil withstands the applicable dielectric withstand potential described in 55.3.1 and 55.3.2. The potential shall be applied between the coil leads with the crossover lead cut at the point where it enters the inner layer.

2. The coil withstands the induced potential described in 55.5.2 and 55.5.5.

Table 27.2
Spacings within a Transformer

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

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

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

27.2.2 Insulating material, such as outer-wrap and crossover-lead insulation, employed to reduce the risk of live parts from becoming accessible through openings in the outer enclosure in accordance with Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8, shall comply with note (a) or (c) of Table 27.1.

27.2.3 A flanged bobbin-wound transformer shall be constructed to maintain physical separation between the primary and secondary windings. Physical separation accomplished by employing a 3-flange

bobbin for winding the primary and secondary windings adjacent to each other is allowed. As an alternative, a telescoping bobbin construction, with each section containing an individual winding, shall be used where the primary winding is wound over the secondary winding or the secondary winding over the primary winding. The bobbin insulation shall comply with note (a), (b), (c), or (d) of Table 27.1.

27.2.4 A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation meets the intent of the requirement in 27.2.3 when in compliance with (a) or (b).

a) The constructions meets the following:

1) The tape insulation complies with note (a) or (c) of Table 27.1;

2) The tape insulation provides a continuous overlap on the bobbin flanges;

3) The transformer complies with the tests described in the Flanged Bobbin Transformer Abnormal Test, Section 58 (see 27.2.6); and

4) The transformer complies with the induced potential tests described in 55.5.1 – 55.5.5.

b) The construction meets the following:

1) The tape insulation complies with note (a) or (c) of Table 27.2;

2) The coils are layer wound; and

3) All windings have end turns that are retained by a positive means and the spacing between end margins of the primary and secondary windings comply with item (d) of Table 27.1.

27.2.5 With reference to the requirement in 27.2.3, a transformer complying with the requirements in any of the following standards complies with this requirement:

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

b) UL 1411; or

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

27.2.6 With reference to 27.2.4(a)(3), the Flanged Bobbin Transformer Abnormal Test, Section 58, is not required when the transformer is supplied from a LVLE circuit in accordance with 2.41, or a limited energy circuit in accordance with 2.39, or complies with the requirements in 25.4 – 25.12.

28 Separation of Circuits

28.1 Factory wiring

28.1.1 Insulated conductors of different circuits (see 28.1.2) within a unit, including wires in a terminal box or compartment, shall be either separated by barriers or segregated and shall be so separated or segregated from uninsulated live parts connected to different circuits. If the insulated conductors of different circuits are all provided with insulation intended for the highest of the circuit voltages, then no barriers or segregation is required.

28.1.2 For the purpose of the requirement in 28.1.1, different circuits include:

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

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

c) Circuits connected to secondary windings of different transformers;

d) Input and output circuits of an optical isolator;

e) AC input power and output AC power circuits;

f) AC input power and DC power circuits; and

g) AC output power and DC power circuits.

Power circuits specified in (e), (f), and (g) that are derived from the taps of an autotransformer or similar device – that does not provide isolation – are not different circuits.

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

28.2 Separation barriers

28.2.1 A barrier used to provide separation between the wiring of different circuits shall be grounded metal or insulating material complying with the requirements for flammability classification of internal materials specified in Printed Wiring Boards, Section 34, and Insulating Materials, Section 35, no less than 0.71 mm (0.028 inch) thick and supported so that it is not capable of being readily deformed so as to defeat its purpose.

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

28.3 Field wiring

28.3.1 The equipment shall be constructed so that a field-installed conductor of a circuit shall be separated as specified in 28.3.3 or separated by barriers as specified in 28.2.1 and 28.2.2 from:

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

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

c) Field-installed conductors connected to any other circuit unless both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3 and both circuits are insulated for the maximum voltage of either circuit unless all conductors are insulated for the maximum voltage of either circuit.

28.3.2 For circuits operating at 150 V or less to ground, field installed conductors are not required to be separated from field installed conductors of another circuit provided the unit is marked (see 85.2.17) indicating one of the following:

a) The Class 2 or Class 3 circuit conductors are to be installed using Class 1 wiring methods; or

b) The Class 2 or Class 3 circuit conductors are to be installed using Type CL3, CL3R or CL3P cable.

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

28.3.4 With reference to 28.3.3, where the number of openings in the enclosure does not exceed the minimum required for the intended wiring of the unit, and where each opening is located opposite a set of terminals, it shall be assumed that a conductor entering an opening is to be connected to the terminal opposite that opening. Where more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than the one opposite the terminal to which it is intended to be connected and the risk of it contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit shall be evaluated.

29 AC receptacles for qualified maintenance personnel or for internal EVPE use

NOTE: These are different from EV receptacles and are not readily accessible to the public.

29.1 AC service receptacles shall be located to prevent public access. Each receptacle intended for general use shall be rated at 15 or 20 amperes, 125 or 250 volts. Each general or special use receptacle shall be of the grounding type and shall comply with the applicable requirements of CSA C22.2 No. 42 and UL 498.

29.2 Overcurrent protection shall be provided as part of the equipment for each receptacle included in the equipment unless:

a) The receptacle is intended to be connected to a power supply separate from that supplying the equipment;

b) The equipment can be connected to a branch circuit rated at not more than 15A or 20A in accordance with CSA C22.1 or NFPA 70; or

c) The receptacle is intended for use only with specific accessories.

29.3 Receptacles connected to the line side of a unit disconnect shall have a separate disconnect.

29.4 When installed on equipment for outdoor use, in addition to complying with the rain

30 Overcurrent Protection

30.1 General

30.1.1 An overcurrent protective device, the intended functioning of which requires renewal, replacement, or resetting, shall be accessible from outside of the enclosure or behind a hinged cover (see 7.2.1). A protective device that is unknown to the user because of its location and omission of reference to the device in the operating instructions provided with the unit is not required to be accessible.

30.1.2 With reference to the requirement in 30.1.1, a control-circuit fuse does not require renewal as an intended function when the fuse and the load are contained within the same enclosure.

30.1.3 The screw shell of a plug-type fuseholder and the contacts including associated live parts that are capable of being contacted by the probe illustrated in Figure 7.1 of an extractor-type fuseholder shall be connected toward the load. See also 30.1.9.

30.1.4 A fuse and a fuseholder shall have voltage and current ratings not less than those for the circuit in which they are connected. A fuseholder shall be of the cartridge, plug, or extractor type. Plug fuses shall not be used in a circuit rated more than 125 volts or 125/250 volts, 3-wire. Fuses intended to be replaced by only service personnel may be bolted in place.

30.1.5 A plug-type fuseholder shall be of the Type S construction.

30.1.6 A circuit breaker connected in the input or the output circuit shall open all ungrounded conductors. Where the unit has provision for connection of a grounded neutral conductor, individual single-pole circuit breakers may be used as the protection for each ungrounded conductor of 3-wire single phase circuits or for each ungrounded conductor of a 4-wire, 3-phase circuit, when no conductor involves a potential to ground in excess of 150 volts. See 85.3.5.

30.1.7 A circuit breaker suitable for branch circuit protection shall be provided to protect each AC receptacle that is provided as an output. The circuit breaker shall be suitably rated for the application.

30.1.8 A unit shall be marked in accordance with 85.3.7 when it is provided with overcurrent protection consisting of an interchangeable fuse and when the fuse is accessible to the user or used to comply with the requirements in this standard.

30.1.9 An overcurrent protective device shall not be connected in the grounded (neutral) side of the line. Additional overcurrent protection provided in the grounded side of the supply circuit is acceptable when the protective device simultaneously disconnects the grounded and ungrounded conductors of the supply circuit.

30.1.10 Temperature or current-sensitive devices such as temperature limiting thermostats, thermal cutoffs, appliance protectors, fuses, circuit breakers, or similar devices that are relied upon to comply with the Abnormal Tests, Section 57, shall comply with the requirements for such devices.

30.1.11 Overcurrent protection employing solid state component circuitry used for protection of control circuits described in 30.2.1 – 30.2.7 shall comply with the requirements in CSA C22.2 No. 5/UL 489. Solid state overcurrent protection is not required to comply with CSA C22.2 No. 5/UL 489 when:

a) its performance is not affected by malfunction, either by short circuit or open circuit of any single component, or

b) it is provided in addition to other overcurrent protection devices such as a fuse or circuit breaker that is intended for the application.

30.1.12 During power export, overcurrent protection shall be located within 1 m (3 ft) of the vehicle inlet, typically at the connector head. Bidirectional circuits shall have protection on both ends of a circuit.

30.2 Control circuits

30.2.1 A control circuit that extends from the unit to a remote-control panel, status panel, or similar device shall be protected in accordance with 30.2.2 – 30.2.7 to reduce the risk of fire and electric shock that is capable of resulting from overload and short circuit conditions.

30.2.2 The overcurrent protective device specified in 30.2.1 shall be a circuit breaker or fuse that is either intended for branch circuit use or a supplementary type. Where the protective device consists of a fuse, the unit shall be marked in accordance with 85.3.7.

30.2.3 A Class 1 power-limited circuit, in accordance with NFPA 70 and CSA C22.1, used to supply an external control circuit shall be supplied from a source having a rated output of no more than 30 volts and

1000 volt-amperes. When the source is other than a transformer, the circuit shall be protected by an overcurrent protection device rated no more than 167 percent of the volt-ampere rating divided by the rated voltage. The overcurrent device shall not be interchangeable with overcurrent devices of higher ratings.

30.2.4 An external control circuit derived from a Class 2 transformer described in 2.8 is not required to be provided with overcurrent protection specified in 30.2.1.

30.2.5 An external control circuit derived from the secondary of a transformer other than that described in 30.2.3 and 30.2.4 shall be provided with overcurrent protection in accordance with 30.2.6 and 30.2.7. For transformers not having a rating, the rated primary or secondary current mentioned in 30.2.6 and 30.2.7 is to consist of the maximum current during normal operation of the unit.

30.2.6 Except as described in 30.2.7, a transformer used to supply a control circuit shall be provided with overcurrent protection in the primary circuit rated as indicated in Table 30.1. Where the rated primary current of the transformer is 9 amperes or more and 125 percent of this current does not correspond to a standard rating of fuse or circuit breaker, the next higher standard rating of protective device may be used. Standard ratings of protective devices are specified in Article 240-6 of NFPA 70.

Table 30.1
Primary Overcurrent Protection for Control Circuit Transformers

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

30.2.7 When a control circuit is derived from the secondary of a transformer that is provided with primary circuit overcurrent protection rated at no more than 250 percent of the rated primary current of the transformer, additional overcurrent protection is not required in the primary circuit when the secondary circuit is protected at no more than 125 percent of the rated secondary current of the transformer. Where the rated secondary current of the transformer is 9 amperes or more and 125 percent of this current does not correspond to a standard rating of fuse or circuit breaker, the next higher standard rating of protective device may be used in the secondary circuit. Standard ratings of protective devices are specified in Article 240-6 of NFPA 70. Where the rated secondary current of the transformer is less than 9 amperes, the overcurrent protection in the secondary circuit shall be rated or set at no more than 167 percent of the rated secondary current.

31 Capacitors

31.1 The materials and construction of a capacitor, its case, or both shall be such that emission of flame from the enclosure of the unit during malfunction of the capacitor does not occur. See 31.3.

31.2 The materials and construction of a capacitor or its case within a unit shall be such that pressures capable of causing injury to persons do not develop in the capacitor in the event of malfunction of the capacitor or the circuit in which it is connected. See 31.3.

31.3 Compliance with the requirements described in 31.1 and 31.2 shall be determined by the abnormal tests specified in 57.8.1 – 57.9.2.

31.4 Under both normal and abnormal conditions of use, including internal shorting of the capacitor, a capacitor containing oil that is more combustible than askarel shall not result in a risk of fire or electric shock and shall be constructed to reduce the risk of expelling dielectric medium from the enclosure of the unit. See 31.5 and 31.6.

31.5 With reference to the requirement in 31.4, a capacitor complying with the requirements for protected oil-filled capacitors in UL 810 or CSA C22.2 No. 60065 shall be constructed to reduce the risk of expelling the dielectric medium.

31.6 With reference to 31.4, a unit having a capacitor other than that described in 31.5 shall be comply with the requirements for bottom openings in 6.9 below the capacitor or the construction shall comply with the capacitor fault test in 57.5.

31.7 A means such as a bleeder resistor shall be provided to drain the charge stored in a capacitor so that it does not provide a risk of electric shock or a risk of electrical energy – high current level. A risk of shock exists when the voltage across the capacitor exceeds the limits specified in 9.1. A risk of electrical energy – high current level – exists when the stored energy exceeds 20 joules as determined by the following equation:

$$J = 5 \times 10^{7} CV^{2}$$

where:

C is in microfarads; and

V is in volts.

31.8 The requirement in 31.7 does not apply when:

a) a tool is required to remove a panel to reach the capacitor and the unit is marked as specified in 85.3.8;

b) when the unit is marked in accordance with 85.3.9; or

c) the capacitor terminals and all parts connected to these terminals are insulated to reduce the risk of contact of these terminals and parts by the serviceman and a cautionary marking per 85.3.15 is provided.

31.9 Capacitors connected across an input ac circuit shall comply with the requirements for across-the-line capacitors in UL 60384-14 or CSA C22.2 No. 8 or UL 1283 or CSA C22.2 No. 8. As an alternative, the capacitor can be subjected to a dielectric voltage withstand test across its terminals in accordance with 55.3.1.

32 Resistors

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

32.2 An assembly employing lock washers complies with the requirement in 32.1.

33 Lampholders

33.1 A lampholder shall be constructed or installed so that uninsulated live parts, other than a screw shell, are capable of unintentionally contacting by persons removing or replacing the lamp during intended service.

33.2 A medium-base screw-shell lampholder shall not be used in a circuit involving a potential of more than 150 volts.

34 Printed Wiring Boards

34.1 A printed wiring board shall comply with the requirements in UL 796 and shall be classed V-0, V-1, or V-2 in accordance with the requirements in UL 94 or CSA C22.2 No. 0.17. A printed wiring board located outside an enclosure, such as in an external control circuit, and located in a LVLE circuit or a limited-energy circuit described in 2.36 and 2.34 respectively shall be classed as either minimum HB.

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

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

35 Insulating Materials

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

35.2 Insulating material shall be judged with respect to the application for which it is to be used. Materials such as mica, some molded compounds, and certain refractory materials are usually used for the sole support of live parts. When an evaluation is required to determine whether a material is capable of being used, such evaluation shall be conducted in accordance with UL 746C or CSA C22.2 No. 0.17. Consideration shall be given to the material's mechanical strength, resistance to hot wire ignition, resistance to high-current-arc ignition, resistance to high-voltage-arc ignition, dielectric strength, insulation resistance, and heat-resistant qualities, in both the aged and unaged conditions; the degree to which the material is enclosed; and any other feature affecting the risk of fire, electric shock, electrical energy-high current levels, or injury to persons. All factors shall be considered with respect to conditions of actual service.

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

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

36 Adhesives

36.1 An adhesive that is relied upon to reduce a risk of fire, electric shock, or injury to persons shall comply with the requirements for adhesives in UL 746C or CSA C22.2 No. 0.17.

36.2 The requirement in 36.1 also applies to an adhesive used to secure a conductive part, including a nameplate, that when loosened or dislodged:

a) Energizes an accessible dead metal part;

b) Makes a live part accessible;

c) Reduces spacings below the minimum usable values; or

d) Short-circuits live parts.

37 Protection of Service Personnel

37.1 The requirements in this section apply only to service personnel who find they must reach over, under, across, or around uninsulated electrical parts or moving parts to make adjustments or measurements while the unit is energized. For requirements covering accessibility of live parts for protection of users, refer to Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8.

37.2 Live parts shall be so arranged and covers so located as to reduce the risk of electric shock or electrical energy – high current levels while covers are being removed and replaced.

37.3 An uninsulated live part involving a risk of electric shock or electrical energy – high current levels and a moving part that involves a risk of injury to persons shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact by service personnel adjusting or resetting controls, or similar action or performing mechanical service functions with the equipment energized, such as adjusting the setting of a control with or without marked dial settings, resetting a trip mechanism, or operating a manual switch.

37.4 Live parts involving a risk of electric shock or electrical energy – high current levels – located on the back side of a door shall be either guarded or insulated to reduce the risk of unintentional contact of the live parts by service personnel.

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

37.6 For an adjustment that is to be made with a screwdriver or similar tool when the unit is energized, 37.5 requires that protection be provided so that the risk of inadvertent contact with adjacent uninsulated live parts involving a risk of electric shock is reduced, considering that misalignment of the tool with the adjustment means is capable of resulting where an adjustment is attempted. This protection shall be provided by locating the adjustment means away from uninsulated live parts or by a guard that reduces the risk of the tool contacting uninsulated live parts.

37.7 A live heat sink for a solid-state component, a live relay frame, or similar device and involving a risk of electrical shock or electrical energy – high current levels, which are capable of being mistaken for dead metal, shall be guarded to reduce the risk of unintentional contact by the serviceperson or be marked in accordance with 85.3.3.

37.8 Moving parts that can cause injury to persons and that are required to be in motion during service operations not involving the moving parts shall be located or protected so that the risk of unintentional contact with the moving parts is reduced.

38 Electronic Protection Circuits

38.1 When circuit analysis or test results indicate that single component failure affects the ability of an electronic or solid-state circuit to perform its back-up, limiting, or other function intended to reduce the risk of fire, electric shock, or injury to persons the circuit shall comply with the requirements in UL 991 or CSA C22.2 No. 0.8, including environmental and stress tests applicable to the intended usage of the end-product. When such circuits employ a microprocessor executing software to perform the safety-related function, the software shall comply with the requirements in UL 1998 or CSA C22.2 No. 0.8.

38.2 When it is determined that environmental tests are required, the protection control shall be subjected to the following tests in accordance with the method described in UL 991 or CSA C22.2 No. 0.8:

a) Transient Overvoltage Test;

b) Ramp Voltage Test;

c) Electromagnetic Susceptibility Tests;

d) Electrostatic Discharge Test;

e) Thermal Cycling Test;

f) Humidity Test; and

g) Effects of Shipping and Storage Test.

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

38.3 The following test parameters shall be used in the evaluation of the control covered by 38.1 for compliance with UL 991 or CSA C22.2 No. 0.8:

a) Electrical supervision of critical components;

b) Audibility as a trouble indicator for an electrical supervision circuit;

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

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

38.4 Critical components identified by the failure mode and effect analysis mentioned in 38.1 shall be derated in accordance with Military Handbook Number 338 (MIL-HDBK-338).

38.5 The following test parameters shall be used in the evaluation of the circuit employing software covered by 38.1 for compliance with UL 1998 or CSA C22.2 No. 0.8:

a) The requirements for Software Class 1 are to be applied; and

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

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

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

PROTECTION OF USERS AGAINST INJURY

39 General

39.1 Where the operation and maintenance of a unit by the user involves a risk of injury to persons, means shall be provided to reduce the risk.

NOTE: When judging a product with respect to the requirement in 39.1, reasonably foreseeable misuse of the unit should be considered.

39.2 For the purpose of the requirements described in 39.3 – 46.1, the words "injury to persons" are in reference to physical harm to persons other than the physiological effects of electric shock.

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

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

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

40 Sharp Edges

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

41 Enclosures and Guards

41.1 A moving part that can cause injury to persons shall be enclosed or provided with other means to reduce the risk of unintentional contact therewith.

41.2 The degree of protection required by 41.1 depends upon the general construction and intended use of a unit.

41.3 A moving part that involves a risk of injury to persons shall comply with the requirements specified in Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8, and shall be evaluated with respect to:

a) The degree of exposure required to perform its intended function;

b) The sharpness of the moving part;

c) The risk of unintentional contact with the moving part;

d) The speed of the moving part; and

e) The risk that a part of the body is endangered or that clothing is capable of being entangled, resulting in a risk of injury to persons.

The above factors shall be evaluated with respect to both intended operation of the unit and reasonably foreseeable misuse.

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

a) Removability without the use of a tool;

b) Removability for servicing;

c) Strength and rigidity;

d) Completeness; and

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

42 Materials

42.1 The material of a part, such as an enclosure, a frame, a guard, or similar part, the breakage of which results in a risk of injury to persons, shall have such properties as to meet the demand of expected use conditions. A component such as a pilot lamp, lens, or control knob is not required to be subjected to the impact test.

42.2 The requirement in 42.1 applies to those portions of a part adjacent to moving parts that involve a risk of injury to persons.

42.3 A part as mentioned in 42.1 shall withstand the Impact Test, Section 73, without being affected to the extent that:

a) The performance of the unit is adversely affected so as to result in a risk of injury; or

b) Parts capable of causing injury to persons are exposed to unintentional contact.

43 Impact of enclosures and guards

43.1 In accordance with 42.3, a part of a unit as described in 42.1 and 42.2 shall be subjected to the Impact Test, Section 73.

44 Drop Test

44.1 Movable units that are provided with a handle, or are intended to be carried, shall be subjected to the Drop Test, Section 74.

45 Stability

45.1 Under all conditions of servicing and intended use after installation, a fully assembled unit shall not become physically unstable to the degree that an injury to operators or service personnel results. A unit intended to be fixed in place complies with this requirement. See Stability Tests, Section 75.

46 Static Load Test

46.1 A mounting means for a fixed power unit shall withstand the Static Load Test, Section 76, without permanent deformation, breakage, or cracking of the mounting supports.

47 Strength of Handles

47.1 A handle used to support or carry a unit shall comply with the Strength of Handles Test, Section 77.

48 Utility Grid Interaction

48.1 General

48.1.1 Units intended for connection and interaction with the EPS / utility grid including grid following (no export), grid support (the ability to export energy to the EPS / electric utility), and more advanced interactive functionality shall comply with the requirements in this section.

48.2 Utility grid interactive inverter

48.2.1 Units rated for connection and operation with an EPS shall be evaluated for the intended purpose as specified in this section. This section requires that the unit operates safely over the manufacturer's specified range of grid interconnection operation. This shall be verified by operating the unit or its subassemblies under operating parameters with the factory default settings enabled.

48.2.2 Within this standard, the term utility grid interactive products refers to complete or modular equipment that are subassemblies of complete utility grid interactive products. These modular products, when connected in accordance with the manufacturer instructions, form a utility grid interactive product or system and shall comply with the requirements in this standard.

48.2.3 Larger EVPE and/or additional grid interactive features or functions will have more requirements and may include connection to interactive products or subassemblies of utility grid interactive products that may be enabled in accordance with local utility interconnection protection requirements, or both.

48.2.4 Units that are rated for and or specify compliance with other specific electric utility interconnection document(s), source requirements document(s) or standard(s) shall be evaluated for compliance with the specified document(s) or standard(s).

48.3 Utility grid interactive anti-islanding products

48.3.1 General

48.3.1.1 Utility grid interactive products, such as inverters and interconnection systems equipment (ISE), shall comply with all applicable portions of UL 1741 or CSA C22.2 No. 107.1 construction requirements defined for utility grid interactive products.

48.3.1.2 Utility grid interactive products may rely upon externally provided equipment to operate in compliance with these requirements. Such external equipment shall be evaluated to UL 1741 or CSA C22.2 No. 107.1 or other applicable component standard for its function and conditions of use.

48.3.1.3 Utility grid interactive products shall be evaluated for compliance with construction requirements or features defined in other specific documents that are referenced in the product ratings.

48.3.2 Performance

48.3.2.1 In the US, Utility grid interactive products shall be tested for compliance with the requirements in UL 1741 as specified for interactive product type and rated functionality. In Canada, refer to Section 82, Utility Grid Interactive Functionality Type Testing.

48.3.3 Abnormal tests

48.3.3.1 A utility grid interactive product shall comply with the abnormal test requirements for utility interactive inverters in accordance with UL 1741 or CSA C22.2 No. 107.1.

48.3.3.2 A utility grid interactive product shall not pose hazards defined in UL 1741 or CSA C22.2 No. 107.1 for Abnormal Tests when performing grid interconnection functions. The utility grid interactive product shall be evaluated at its most extreme rated operational limits.

48.3.4 Utility grid interactive product ratings, markings and instructions

48.3.4.1 Utility grid interactive products shall be marked in accordance with UL 1741 or CSA C22.2 No. 107.1 as defined for the product type and specific grid interconnection functionality it performs.

NOTE: UL 1741 includes the following grid interactive product types: utility interactive, grid support interactive, special purpose interactive, interconnection systems equipment, and interconnection systems equipment that may include EVSE/ISE functionality.

48.3.4.2 Units shall comply with the markings, instructions, and ratings sections of UL 1741 or CSA C22.2 No. 107.1 for the product type and rated functionality.

49 Interaction with On Board Equipment

49.1 In Canada, the requirements of this section are optional.

In the US, the requirements of this section apply.

49.2 Units that are intended to communicate with on board vehicle equipment with AC output shall comply with the applicable sections for communication in SAE J3072.

50 Other Energy Sources

50.1 Equipment rated for connection to other energy sources shall additionally comply with the applicable portions of the following standards as defined below for the source type:

a) Photovoltaic (PV): Either UL 1741/CSA C22.2 No.107.1 or UL 62109/CSA C22.2 No. 62109

b) Wind Energy: UL 1741/CSA C22.2 No. 107.1, UL 6141, or UL 6142

c) Energy storage and batteries: UL 9540 and or UL 1973

NOTE: Renewable energy sources have specific normal and abnormal operating characteristics that need to be addressed via source specific protective functions, ratings, markings and installation instructions. These referenced standards provide critical details applicable for installation code compliance.

50.2 Equipment that include other energy sources as part of the system shall comply with the corresponding standards as defined below:

a) Photovoltaic (PV) modules: UL 1703/ULC 1703 or UL 61730-1/CSA C22.2 No. 61730-1 and UL 61730-2/CSA C22.2 No.61730-2

b) Energy Storage Systems: UL 1973 and UL 9540

c) Wind Turbines: UL 6141 or UL 6142

d) Engine Generator: UL 2200

e) Fuel Cells: UL 2262

PERFORMANCE

51 General

51.1 A representative sample of a unit is to be subjected to the tests described in Sections 49 – 78. The input and output ports of the EVPE unit shall be connected as specified in 51.1 – 51.6 during these tests. Overcurrent protection for those ports shall be connected in accordance with the instructions provided with the unit and in accordance with the markings on the unit.

51.2 Unless otherwise specified, the unit shall be energized from a supply that simulates the current voltage characteristics and time response of the input source. Where the results of a test could be affected by the voltage versus current characteristics and short circuit current capability of the supply, the source shall be adjusted to the maximum rated input voltage of the DUT. The current capability of the test source, measured at the DUT terminals, shall be equal to or greater than the rated maximum input short-circuit current of the DUT. The output of a utility-interactive EVPE device shall be connected to a supply voltage as specified in Table 51.1.

Table 51.1
Values of Test Voltages

Rated voltage, AC	In the US, Test voltage	In Canada, Test voltage
Less than 110	Rated voltage[a]	N/A
110 – 120	120	120 L1-N
121 – 219	Rated voltage[a]	N/A
220 – 240	240	240 L1-N
241 – 253	Rated voltage[a]	N/A
254 – 277	277	N/A
278 – 439	Rated voltage[a]	N/A
440 – 480	480	480 L1-N
481 – 525	Rated voltage[a]	N/A
526 – 600	600	600 L1-N
Greater than 600	Rated voltage[a]	Rated voltage[a]
120/240 split-phase		120 L1/L2-N @ 180°
120/208 2-phase		120 L1/L2-N @ 120°
120/208		120 L1/L2/L3-N
240/416		240 L1/L2/L3-N
277/480		277 L1/L2/L3-N

Table 51.1 Continued on Next Page

Table 51.1 Continued

Rated voltage, AC	In the US, Test voltage	In Canada, Test voltage
347/600		347 L1/L2/L3-N
Greater than 600	Rated voltage[a]	Rated voltage[a]
NOTE – A unit marked as volt-var mode or volt-watt mode shall have Test voltage range from minimum (V_1 or V_{min}) to maximum (V_4 or V_{max} or V_H).		
[a] A unit marked with an operating voltage range shall comply with the requirements in Sections 49 – 75A while connected to a source of voltage adjusted to any value within the specified range.		

51.3 A unit marked with one frequency rating shall be tested at that frequency. For a unit marked with a dual frequency rating such as 50/60 hertz or a frequency range such as 50 – 60 hertz, tests shall be conducted at any frequency covered by the marking. For a unit marked with a dual frequency rating or a frequency range, Power Input (Section 50), Temperature (Section 51), and Transformer Burnout Tests (57.2.1 – 57.2.7) shall be conducted at the lowest frequency.

51.4 When a simulated utility source is required for a test, the impedance of the simulated utility source for a utility-interactive EVPE device shall be less than 5 percent of the EVPE device's output impedance where the EVPE device's output impedance is equal to the EVPE device's rated output voltage divided by the EVPE device's rated output current.

51.5 When a simulated utility source is required for a test, the actual utility is able to be used for the simulated utility.

51.6 The equipment under test provided with, or intended for use with, specific defined input source(s) that cannot provide the input power range described in the test procedure, shall be tested within the limitations of the specified or supplied input source. Under these circumstances, the test may be performed with the actual utility source or a simulated source. Test results shall only be applicable to the combination of the equipment under test and the specified source(s), and this limitation is to be noted in the test results.

52 Dielectric Test Following Humidity Conditioning

52.1 A unit shall comply with the requirements for dielectric strength in Section 55, following exposure to air having a relative humidity of 88 ±2 percent at a temperature of 32 ±2 °C (90 ±4 °F).

52.2 To determine whether a unit complies with the requirement in 52.1, a sample of the unit shall be heated to a temperature just above 34 °C (93 °F) to reduce the risk of condensation of moisture during conditioning. The heated sample shall be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 52.1. Immediately following the conditioning, the sample shall be removed from the humidity chamber and tested unenergized as described in Section 55.

53 Input and Output Power Characteristics

53.1 General

53.1.1 For some unit ports, the test results will not be significantly affected by the input power supply parameters, and for those units, the test may be performed under any convenient rated supply conditions.

53.1.2 For some unit ports the test results will be significantly affected by the input power supply parameters and for those units the test shall be performed under the worst-case rated supply condition(s). Multiple tests may be needed to obtain worst case results.

53.1.3 Input supply voltage shall be evaluated across ±10 percent (90 percent – 110 percent of rated) of a rated input voltage or across a unit's rated range of input voltage.

53.1.4 Rated input supply frequency(s) shall be tested at a worst-case condition. If a worst-case cannot be determined the unit shall be tested at the extremes of a specified frequency range.

53.1.5 A unit shall be tested within its rated range(s) of operation under the least favorable combination of supply and load conditions for each input and output port(s). The conditions shall include worst-case normal rated parameters for voltage, frequency, polarity, earthing, and any other applicable normal conditions that could impact the test results.

53.2 Units that charge batteries

53.2.1 As defined in Section 53.1, the input current to a unit shall be measured with the unit operating while connected to the maximum rated load (see 53.2.2 – 53.2.4). The current input shall not be more than 110 percent of the rated value.

53.2.2 A unit shall be tested with:

a) A resistive-capacitive (rc) load having capacitance of 200,000 microfarads and a parallel resistance adjusted to draw rated output current;

b) A battery supplemented with a resistive load bank;

c) A battery as specified by the manufacturer; or

d) An electronic load configured as a battery simulator.

53.2.3 With reference to 53.3.2(c), when a unit is to be tested using batteries as the load, batteries shall be of the intended size. The batteries shall be charged at the minimum battery voltage rating of the charger, with the AC line potential adjusted to the maximum rated voltage of the charger. The test shall be repeated under battery discharge with the battery voltage at the maximum battery voltage rating of the charger, with the AC line potential adjusted to the minimum rated voltage of the charger.

NOTE: The cutoff voltage / end-of-discharge voltage for various battery chemistries is as follows: Lead acid batteries – 1.70V/cell; nickel-based batteries – 1.00V/cell; and most Li-ion batteries – 3.00V/cell.

53.2.4 Output current measurements of either half-wave or full-wave rectified circuits shall be based on the average current.

53.3 Input rating test

53.3.1 As defined in Section 53.1, the measured continuous input current or power of each input port of a unit shall be within ±10 percent of the units input rating for that specific port.

53.3.2 An input port rated for DC input current shall be made with a measurement device rated for both DC and AC components of the current.

NOTE: Some equipment such as inverters with an AC output can draw an AC current from a DC source which requires appropriate measurement equipment to obtain accurate results.

53.4 Output ratings test

53.4.1 As defined in Section 53.1, the measured continuous output current or power of each output port of a unit shall be within ±10 percent of the units rating for that specific port.

53.5 Standalone (not grid interactive) units that export AC power

53.5.1 Standalone units shall operate as intended when the input is connected to a supply source as specified in Section 53.1. During the test, the unit shall be loaded to its rated load with the minimum and maximum input voltage supplied to the unit. The load for a unit that provides AC output power as a stand-alone inverter or converter shall include both resistance and inductance with a power factor of 0.5.

54 Temperature Test

54.1 Under the conditions specified in 53.1, the unit shall not reach a temperature at any point high enough to cause a risk of fire, damage any material used, cause a protective device to operate, or exceed the temperature limits specified in Table 54.1. During this test, the ambient temperature shall be as specified in 54.11.

a) When the unit is delivering maximum rated output power in an ambient temperature as specified in Table 54.2, and

b) For a unit marked for operation at a higher ambient at reduced output power, the test is to also be performed at the specified higher ambient and the associated reduced output power. Such a unit shall be tested to obtain worst case temperature data including but not limited to maximum ambient before unit derating and the maximum rated ambient including derating. Firmware or Software controlling the temperature limits of a unit shall be disabled for the tests described in 47.2, or evaluated for reliability in accordance with UL 1998 or CSA C22.2 No. 0.8.

54.2 For a fixed unit, the ampacity of the conductors connected to the field wiring terminals or leads shall be in accordance with the value determined by the requirement described in 14.1.1.3.

54.3 With reference to 54.1, a unit having voltage adjustment taps for intended use shall operate within the temperature limits at the setting representing the most severe loading condition as determined by an analysis of the circuit.

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

Table 54.1
Temperature Limits

Materials and Components	Degrees C	Degrees (F)
COMPONENTS		
1. Capacitors:		
a. Electrolytic types	65[b]	(149[b])
b. Other than electrolytic	90[b]	(194[b])
2. Field wiring Terminals	75[c]	(167[c])
3. Vulcanized fiber employed as electric insulation	90	(194)
4. Plated bus bar	90[d]	(194[d])
5. Unplated bus bar and a joint	75[d]	(167[d])
6. Relays, solenoids, and similar devices		

Table 54.1 Continued on Next Page

Table 54.1 Continued

Materials and Components	Degrees C	Degrees (F)
a. Class 105 coil insulation systems:		
Thermocouple method	90[a]	(194[a])
Resistance method	110	(203)
b. Class 130 coil insulation systems:		
Thermocouple method	110[a]	(230[a])
Resistance method	120	(248)
7. Transformer insulation systems:		
a. Class 105:		
Thermocouple method	90[a]	(194[a])
Resistance method	95	(203)
b. Class 130:		
Thermocouple method	110[a]	(230[a])
Resistance method	120	(248)
c. Class 155:		
Thermocouple method	135[a]	(275[a])
Resistance method	140	(284)
d. Class 180:		
Thermocouple method	150[a]	(302[a])
Resistance method	160	(320)
e. Class 200:		
Thermocouple method	165[a]	(329[a])
Resistance method	175	(347)
f. Class 220:		
Thermocouple method	180[a]	(356[a])
Resistance method	190	(374)
8. Phenolic composition employed as electrical insulation or as a part the deterioration of which results in a risk of fire or electric shock	150[e]	(302[e])
9. Wood and other combustible material	90	(194)
10. Rubber- or thermoplastic-insulated wire and cable	60[e,f]	(140[e,f])
11. Other types of insulated wires	g	g
12. A surface upon which a unit is mounted in service, and surfaces that are adjacent to the unit when so mounted	90	(194)
13. Any point on or within a terminal box or compartment of a fixed unit on which field-installed conductors rests	60[c]	(140[c])
14. Thermoplastic sealing compound	h	h
15. Selenium rectifier	75[e,i]	(167)
16. Power semiconductor	j	j
17. Printed-wiring board	k	k

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

Table 54.1 Continued on Next Page

Table 54.1 Continued

Materials and Components	Degrees C	(F)
[b] A capacitor that operates at a temperature of more than 65 °C (149 °F) for electrolytic and more than 90 °C (194 °F) for other types is not prohibited from being judged on the basis of its marked temperature limit.		
[c] The temperature observed on the terminals and at points within a terminal box of a unit shall not attain a temperature higher than the temperature marking required in items p and o of 87.2.		
[d] For a bus bar having a current density in accordance with 21.2.10, it is not required to measure the temperature since it has characteristics which result in temperatures not exceeding the indicated values.		
[e] The temperature limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has heat-resistant properties in accordance with UL 746B.		
[f] A short length of rubber- or thermoplastic-insulated cord or cable inside the unit is exposed to a temperature of more than 60 °C (140 °F) when supplementary insulation on each individual conductor is rated for the measured temperature and has dielectric properties in accordance with UL 746A and UL 746B.		
[g] The temperature shall not exceed the temperature limit of the wire except as noted in note f.		
[h] The sealing compound temperature limit is 15 °C (27 °F) less than the softening point of the compound as determined in accordance with ASTM D1525.		
[i] A temperature limit of 85 °C (185 °F) meets the intent of the requirement when the stack assembly is insulated with phenolic composition or other insulating material rated for a temperature of 150 °C (302 °F).		
[j] For a power-switching semiconductor and similar components the temperature limit on the case is the maximum case temperature specified by the semiconductor manufacturer.		
[k] For a printed wiring board, the temperature limit is the specified limit of the board.		

54.5 A supporting means formed of rubber or neoprene material shall be removed prior to the test. Where the supporting means has a metal insert, such as a screw or rivet, the test shall be conducted with the unit supported by the metal insert. At the request of the manufacturer, it is not prohibited to conduct the test without any means of support.

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

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

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

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

in which:

T is the temperature of the winding in °C;

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

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

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

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

The winding is to be at room temperature at the start of the test.

54.9 All temperature limit values in Table 54.1 are based on an ambient temperature of 40 °C (104 °F) for units intended to be installed outdoors and 25 °C (77 °F) for all other units. However, with correction of temperature measurements, tests conducted in other ambient temperatures as described in Table 54.2 are allowed.

Table 54.2
Temperature Measurement Correction

Ambient temperature rating of unit	Test ambient temperature	Correction of observed temperature
1. 25 °C (77 °F)	Range of 10 – 40 °C (50 – 104 °F)	See note a, item 1
2. Range of 25 – 40 °C (77 – 104 °F)	Range of 20 – 40 °C (68 – 104 °F)	See note a, item 2
3. Above 40 °C (104 °F)	Rated ambient	c
	See note b	

[a] Correction of temperature, as determined by item 1 or 2 below, shall not exceed the temperature limit specified in Table 54.1:

1) When the test ambient temperature is lower than the rated ambient temperature, an observed temperature is to be corrected by addition of the difference between the rated ambient temperature and the test ambient temperature.

2) When the test ambient temperature is higher than the rated ambient temperature, an observed temperature is to be corrected by subtraction of the difference between the rated ambient temperature and the test ambient temperature.

[b] Allowable tolerances are: Minus – not less than 5 °C (9 °F) below rated ambient. Plus – not specified.

[c] When the test ambient temperature equals rated ambient, no correction shall be made, and an observed temperature shall not exceed the temperature limit specified in Table 54.1. When the test ambient temperature is other than rated ambient, correction shall be made as described in item 2 of note a.

54.10 When a unit is rated for an ambient temperature higher than 25 °C (77 °F), the rating shall be indicated in the instruction manual in accordance with 87.2(j).

54.11 Thermocouples shall consist of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ a temperature-indicating instrument with thermocouples consisting of 30 AWG iron and constantan wire. Such equipment shall be used whenever referee temperature measurements by thermocouples are required.

54.12 A temperature is determined to be constant when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 15 minutes, indicate no further increase in temperature.

54.13 During the temperature test, the temperature of a surface that is capable of being contacted by the user shall not be more than the values specified in Table 54.3. When the test is conducted at a room temperature of other than 25 °C (77 °F), the results shall be corrected to that temperature. For units intended for installation outdoors, the results shall be corrected to 40 °C (104 °F).

Table 54.3
Maximum Surface Temperatures

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

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

[b] See 54.14.

54.14 In reference to 54.13, a fixed unit that exceeds the limits in Table 54.3 is acceptable provided it meets all three of the following:

a) The risk of contact is reduced due to the installation of the product;

b) The unit is marked in accordance with 85.3.4; and

c) The unit is provided with instructions in accordance with 87.2(h).

54.15 Localized component heating is able to occur in products that reduce their output power with an increase in temperature. For example, heat generating components, such as Transformers, Inductors, Capacitors, Semiconductors and other similar components, which quickly increase in temperature, independent of the temperature sensing device, are able to attain thermal peaks prior to the first or subsequent power reductions. This is more prevalent in a lower ambient. In such instances, the measured peak temperature results shall be taken as the component operating temperature and shall comply with 43.1, or the results shall be evaluated to the requirements for Temperature Excursions Beyond the Maximum Use Temperature in UL 746C or CSA C22.2 No. 0.17.

55 Dielectric Voltage-Withstand Test

55.1 General

55.1.1 The test potential mentioned in 55.3.1 and 55.4.1 shall be obtained from any convenient source having a capacity of at least 500 volt-amperes. A lower capacity is not prohibited when a meter is located in the output circuit, and the test potential is maintained except in case of breakdown. The voltage of the source shall be continuously adjustable. Starting at zero, the applied potential shall be increased at a rate of 200 volts per second until the required test value is reached.

55.1.2 When a direct-current potential is used for an ac circuit, a test potential of 1.414 times the applicable rms value of alternating-current voltage specified in 55.3.1 and 55.4.1 shall be applied.

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

55.2 Maximum-voltage measurements

55.2.1 The maximum voltage used as a basis for the calculation of the dielectric voltage-withstand test potentials specified in 55.3.1 and 55.4.1 and determination of the minimum spacings specified in Spacings, Section 23, shall be determined in accordance with 55.2.2 and 55.2.3.

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

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

55.3 AC and DC power circuits

55.3.1 The ac and dc power circuits of a unit shall withstand for 1 minute without breakdown the application of a 60 hertz sinusoidal potential with the unit at the maximum operating temperature:

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

1) The primary circuit and dead metal parts,

2) The primary and secondary circuits, and

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

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

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

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

55.3.2 With reference to 55.3.1, the test potential between ac power circuits and dead metal parts shall be based on the phase-to-ground voltage rating. The test potential for other points involving the ac power circuit shall be based on the highest operating voltage of the circuits involved.

55.4 Secondary circuits

55.4.1 Each secondary circuit other than a power circuit covered in 55.3.1 and 55.3.2 shall withstand for 1 minute without breakdown the application of a test potential between primary and secondary circuits, between secondary circuits and grounded metal with grounding connections, where present, disconnected, and between isolated secondary windings of transformers. The unit shall be at operating temperature during the test. The test potential shall be as indicated in Table 54A.1.

Table 54A.1
Magnitude of Test Potential for Secondary Circuits

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

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

[b] Values are rms unless otherwise indicated.

55.5 Induced potential

55.5.1 When an isolating power transformer is tested in accordance with 57.2.1, the test described in 55.5.2 – 55.5.5 shall be conducted.

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

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

55.5.4 Testing a 3-phase transformer with a single phase voltage is not prohibited. The voltage mentioned in 55.5.2 shall be applied successively across each primary winding.

55.5.5 While in the heated condition obtained during the transformer overload test, the test voltage required in 55.5.2 shall be initiated at one-fourth or less of the full value and brought up gradually to the full value in not more than 15 seconds. After being held for the time specified, the voltage shall be reduced slowly, but within 5 seconds, to one-fourth of the maximum value or less, and the circuit opened. The results meet the intent of the requirement when there is no dielectric breakdown.

56 Volt-Ampere Capacity Measurement

56.1 When it is required to determine volt-ampere capacity of a transformer winding for compliance with other requirements in this standard (see 2.36, 23.1.13 and 23.1.14), the capacity shall be measured by replacing the intended load on that winding with a variable resistor that has been set to maximum resistance. A thermal protector or an overcurrent protective device, when provided, shall be shunted. A wattmeter shall be connected to measure power dissipated by the resistor. The assembly shall be energized with the test voltage specified in Table 51.1. The variable resistor shall be continuously adjusted to dissipate maximum power, and the power value shall be measured after 1 minute of operation or just prior to opening the winding, whichever occurs first. This value is the winding capacity. For a multi-secondary winding, one winding shall be loaded and tested at a time, that is, while measuring the output of a particular winding, other windings are to be open circuited.

57 Abnormal Tests

57.1 General

57.1.1 A unit shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons (see 57.1.3), when subjected to the tests specified in 57.1.2 – 57.9.2. Separate samples shall be used for conducting these tests.

57.1.2 Following each test, a dielectric voltage-withstand test specified in Section 55 shall be conducted. The potential shall be applied across the points indicated in 55.3.1. If one sample is to be used for more than one abnormal test based on manufacturer request, then the dielectric voltage withstand test is only required once after all abnormal conditions included are completed.

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

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

b) The insulation breaks down when tested in accordance with 57.1.2 or live parts are made accessible (see Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 8);

c) Cracking, rupturing, or bursting of the battery case or cover, where such damage results in user contact with battery electrolyte; or

d) Explosion of the battery supply where such explosion results in a risk of injury to persons.

57.1.4 During these tests, the unit shall be placed on a softwood surface covered with a white tissue paper, and a single layer of cheesecloth shall be draped loosely over the entire enclosure. The cheesecloth shall be untreated cotton cloth running 26 – 28 m^2/kg (14 – 15 yards per pound), and having, for any 6.5 cm^2 (1 in^2), a count of 32 threads in one direction and 28 in the other direction.

57.1.5 Units not having any bottom openings are not required to be placed on a softwood surface covered with tissue paper. Also, when it is impractical to drape the entire unit, cheesecloth is required to be placed only over all ventilation openings.

57.1.6 For a unit having supporting feet made of rubber or neoprene material, the requirement in 54.5 shall apply.

57.1.7 The supply circuit shall have branch circuit overcurrent protection, the size of which equals 125 percent of the input current rating (20-ampere minimum), except where this value does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating shall be used. The test voltage and frequency shall be adjusted to the values specified in 51.1 and 51.2. When a marking on the product indicates the use of branch circuit protection exceeding 125 percent of the input current, such protection shall be used.

57.1.8 The unit equipment grounding conductor shall be connected to the unit's ground terminal(s) using the minimum rated conductor size and type in accordance with 19.11.

Note: This conductor size should be the same size required in the unit's installation instructions.

57.1.9 Each test shall be continued until further change as a result of the test condition is reduced significantly. When an automatically reset protector functions during a test, the test shall be continued for no less than 7 hours. When a manual reset protector functions during a test, the test shall be continued

until the protector is operated for 10 cycles using the minimum resetting time, and not faster than 10 cycles of operation per minute. The following are examples of test terminations:

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

b) Opening of the intended branch circuit overcurrent protection device described in 57.1.7 (see 57.1.10);

c) Opening of an internal fuse; or

d) As indicated in the individual test requirement.

57.1.10 With reference to 57.1.9(b), when the branch circuit overcurrent protection device terminates the test, the instruction manual shall contain the information specified in 87.2(p).

57.2 Transformer burnout test

57.2.1 An adjustable resistive load shall be connected directly to the secondary winding of each transformer and adjusted to result in the load condition described in (a), (b), or (c) below. Opening of the intended branch circuit overcurrent protection device described in 57.1.7 or an internal overcurrent protection device connected in the primary-winding circuit is an example of when this test is terminated.

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

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

c) For an autotransformer, the conditions specified in (a) shall be used with the supply voltage connected to the outer input legs and the load resistor connected to the outer output legs. See Figure 57.1.

57.2.2 With reference to 57.2.1, a transformer supplied from either an inverter circuit or other means limiting the current to the transformer to less than three times rated current shall be loaded to a condition resulting in maximum obtainable input current without operation of overcurrent protection devices, where any are present.

57.2.3 A transformer employed in a switch-mode inverter or converter circuit shall be subjected to the transformer overload test described in 57.3.5 in lieu of the transformer burnout test.

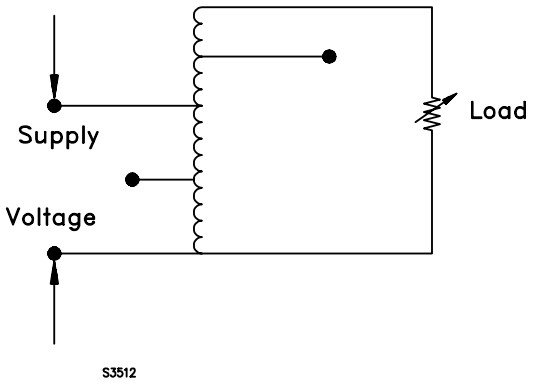
57.2.4 Any transformer, including a control circuit transformer or a power transformer used for the transfer of either the input or output power of the unit, having overcurrent protection described in 30.2.6 is not required to comply with this requirement. A transformer that is protected by the intended branch circuit protection device that is sized in accordance with the requirements in 30.2.6 and is provided in a unit marked in accordance with 87.2(p) is not required to comply with this requirement. A signal or gate-drive transformer that is rated 10 watts or less and having a secondary circuit that does not extend out of the unit is not required to comply with this requirement.

57.2.5 An isolating power transformer used for the transfer of either the input or output power of the unit and complying with CSA C22.2 No. 66.1/UL 5085-1 and CSA C22.2 No. 66.3/UL 5085-3; UL 1561 or CSA

C22.2 No. 47 or UL 1411 are acceptable without test. A transformer subjected to the transformer overload and induced potential tests described in 55.5.1 – 55.5.5 and 57.3.1 – 57.3.4, in lieu of the transformer burnout test need not comply with this requirement.

Figure 57.1

Autotransformer Burnout Test



NOTE: See 57.2.1(c) for description of test.

57.2.6 A ferro-resonant transformer shall be tested in accordance with 57.2.1 with the secondary winding loaded to maximum input current. The transformer shall be operated continuously until ultimate conditions are observed.

57.2.7 During the tests described in 57.2.1 and 57.2.6, secondary circuit protective devices that are external to the transformer shall be bypassed. Primary circuit protective devices shall be left in the circuit.

57.3 Transformer overload test

57.3.1 When an isolating power transformer is to be tested in accordance with 57.2.5, the tests described in 57.3.2 – 57.3.4 shall be conducted. When a transformer employed in a switch-mode inverter or converter circuit is to be tested, the test described in 57.3.5 shall be conducted.

57.3.2 A resistive load shall be connected directly to each transformer secondary winding and adjusted to a value so each secondary winding carries 50 percent of rated load until temperatures of the transformer core become stabilized. The load shall then be increased to 200 percent of the rated value; no further adjustment of the overload current is to be made. The duration of the overload shall be as specified in Table 57.1. The short circuit method as described in IEEE C57.12.91 is one method used to obtain the 200 percent of rated load current. Where the short-circuit test method is used, all secondary windings shall be shorted and the voltage applied to the primary windings shall be adjusted to result in rated current to flow in the secondary windings.

Table 57.1
Overload Test Times

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

57.3.3 With reference to the requirement in 57.3.2, testing of a transformer rated more than 500 kilovolt-amperes is not required when the test has already been performed with results that meet the intent of the requirement on a smaller transformer rated not less than 500 kilovolt-amperes, when the smaller transformer has the same insulation system and same general construction as the larger transformer, and the temperatures recorded during the temperature test are no greater for the larger transformer than those recorded during the temperature test for the smaller transformer.

57.3.4 Within 1 hour following the overload test, the transformer shall perform as intended in a repeated dielectric voltage-withstand test except that the test value shall be at 65 percent of value specified in Dielectric Voltage-Withstand Test, Section 55, and the induced potential test described in 55.5.1 – 55.5.5.

57.3.5 For a unit tested in accordance with 57.2.3, the power circuit supplied by the transformer shall be connected to a resistive load that draws maximum obtainable output power without causing operation of internal overcurrent protection devices or a protection circuit or resulting in opening of a circuit component such as a diode, resistor, sold state device, or similar device.

57.4 Short circuit test

57.4.1 The unit shall be tested as described in 57.4.2. The unit shall comply with the requirement in 57.1.1.

57.4.2 With reference to 57.4.1, fuses and other protective devices provided as part of the unit shall remain in the circuit. The output connections of the unit shall be short-circuited (DC+ to DC-) and the unit connected to a source of supply adjusted to its highest test voltage (see Table 51.1). The test shall be continued in accordance with 57.1.9. When a manually reset protector is provided, the test shall be continued until the protector operates for 50 cycles.

57.5 Capacitor fault test

57.5.1 Where required by 31.6, a unit having a bottom-ventilated enclosure containing oil-filled capacitors shall be subjected to the performance tests specified for protected, oil-filled capacitors in UL 810 or CSA C22.2 No. 190. These tests shall conducted with the capacitors mounted in the unit enclosure as intended, and oil leakage from the capacitors passing through the enclosure, where present shall be extinguished. See 57.1.3(a).

57.6 Forced ventilation test

57.6.1 A unit having forced ventilation shall be operated with the blower motor or fan disabled. For a unit having more than one blower motor or fan, the test shall be conducted with each blower motor or fan disabled, one at a time. If agreeable to all concerned, the test can be performed with more than one blower motor or fan disabled at the same time.

57.6.2 A unit having filters over ventilation openings shall be operated with the openings blocked to represent clogged filters. The test shall be conducted initially with the ventilation openings blocked 50 percent, then to be repeated under fully blocked condition, however, a unit with a single fan with a filter is not required to tested under fully blocked condition.

57.7 Component short- and open-circuit test

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

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

b) For electromagnetic radio frequency interference capacitors subjected to the dielectric voltage-withstand test across their terminals in accordance with 55.3.1, resistors, transformers, inductors, and optical isolators.

57.8 Electrolytic capacitor fault test

57.8.1 For a unit having dc electrolytic storage capacitors operating above 60 vdc, the fault test described in 57.8.2 shall be conducted. This requirement does not apply to a capacitor that meets the requirements below:

a) Complies with the requirements in UL 810; and

b) The capacitor shall have an available fault current rating of 10,000 amperes or a lower value where a circuit analysis indicates that because of a series impedance, the lower value is applicable.

57.8.2 With reference to the requirement in 57.8.1, a fault in one of the capacitors in the storage capacitor bank shall be simulated. This shall be accomplished by connecting the capacitor under test in reverse while the input ac supply to the unit is not energized. The unit shall then be energized and operated as in normal operation.

57.9 Vibration test

57.9.1 A unit intended to be permanently mounted in an EV shall be subjected to a vibration test. After the unit is subjected to the vibration test described in 57.9.2:

a) The unit shall comply with the requirement in 57.1.1;

b) There shall be no loosening of parts; and

c) The unit shall operate normally.

57.9.2 The vibration test shall consist of vibration for 48 hours at a frequency of 22 cycles per second with a displacement of 6.4 mm (1/4 inch) in a vertical plane. The unit shall be mounted as intended during the test. After the vibration exposure is complete, the unit is energized normally and judged for compliance.

58 Flanged Bobbin Transformer Abnormal Test

58.1 A flanged bobbin transformer required to be tested as provided in 27.2.4 (see 27.2.6) shall be subjected to this test. For flanged bobbin transformers used in circuits where isolation is not required or the secondary circuit does not extend outside the unit, this test is not required. The transformer under test

shall operate for 15 days with the secondary winding or windings loaded to the conditions described below in (a) – (c). A risk of fire or electric shock shall not result from:

a) Short-circuiting the secondary winding;

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

c) Loading the secondary winding to maximum normal current.

58.2 The results of the test do not meet the intent of the requirement when the cheesecloth glows, or flames, is charred, or a breakdown occurs when the test described in 58.4 is conducted.

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

a) The transformer shall be mounted either in the unit enclosure as intended under the conditions described in 57.1.4 or on a test bench with the cheesecloth mentioned in 57.1.4 draped over the transformer.

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

58.4 While still in a heated condition from the tests described in 58.1, a transformer shall withstand the dielectric voltage-withstand test applied between the primary winding and the secondary winding. The dielectric voltage-withstand-test potential shall be applied to the transformer 1 minute after completion of the abnormal-operation test.

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

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

58.7 For the sequence of tests described in 58.1, when an abnormal-operation test continues for 15 days without a winding or a protective device opening, the remaining tests are not required to be conducted. For example, when the test described in 58.1(a) continues for 15 days, the tests described in 58.1 (b) and (c) are not required to be conducted.

58.8 To determine whether a transformer complies with the requirement in 58.1, three separate samples shall be subjected to each condition described in 58.1 (a) – (c). For a transformer that employs more than one secondary winding, each of the secondary windings shall be loaded for each condition specified in 58.1 with the other windings loaded to rated current. The test conditions shall be as described in 58.9 – 58.13.

58.9 To determine the short-circuit current value for conducting the tests described in 58.1(b), the transformer shall be at room temperature at the beginning of the measurement, and the short-circuit current shall be measured 1 minute after the voltage is applied to the primary winding. A protective device outside the transformer, where provided by the manufacturer, shall be short-circuited during the measurement of the short-circuit current. When the line fuse or transformer winding opens within 1 minute after the application of the primary voltage, the short-circuit current is that value recorded just before the

line fuse or winding opens. The short-circuit current of any one winding shall be measured with the other secondary windings open-circuited.

58.10 For the loading conditions, a variable resistor is to be connected across the secondary winding. Each test described in 58.1 (a) – (c) is to be continued until a risk of fire develops, the 3-ampere fuse opens, a winding of the transformer or a protective device opens or 15 days have passed. In conducting the tests described in 58.1 (a) – (c), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, where required 1 minute after voltage is applied to the primary winding. For a switch-mode transformer, the load is to be connected to the output of the power supply connected to the transformer.

58.11 When short-circuiting the secondary winding causes one of the windings to open before 15 days, then the next test in the sequence described in 58.1 (b) and (c) that continues for 15 days is to have the variable load resistor reduced to zero impedance at the end of the 15 days to cause the transformer to burn out.

58.12 For a transformer that is provided with a protective device built into the transformer or that is being tested in conjunction with an external protective device, a test described in 58.1 (a) – (c) shall be discontinued when the protective device opens the circuit and the next test in the sequence is to be started. The protective device mentioned above includes automatic recycling type, manual reset type, or a replaceable type.

58.13 When a protective device opens the circuit or a winding on any sample opens during the 15-day abnormal-operation tests while the samples are unattended, the variable resistor load on the other samples shall be increased, by reducing the resistance, until the protective device opens the circuit or the winding opens, so that the samples are subjected to the dielectric voltage-withstand test described in 58.4 while in a heated condition. The next test in the sequence in 58.1 (b) and (c) that continues for 15 days shall be conducted.

59 Strain Relief Tests

59.1 General

59.1.1 The tests in 59.2 and 59.3 apply to the flexible cord or cable connections, field wiring connections, and the EV cable connections.

59.1.2 Both the Strain Relief – Pull Test and the Strain Relief – Push Back Test are required for each cord or cable connection mentioned in 59.1.1. Field wiring connections are only required to be subjected to the Strain Relief – Pull Test.

59.1.3 All of the tests can be performed on one sample, but each test shall be performed individually.

59.1.4 The internal connections shall be disconnected or cut prior to the tests in 59.2 and 59.3.

59.2 Strain relief – Pull test

59.2.1 The strain relief means provided for a flexible cord or EV cable connection, other than output cords of Class 2 Transformers, shall withstand a direct pull of 156 N (35 pounds) applied to the cord or cable for one minute without displacement. The strain relief does not comply when at the point of disconnection of the conductors, there is such movement as to indicate that stress on the connections results.

59.2.2 The strain relief means provided for the output cord of a Class 2 transformer shall be tested as indicated in 59.2.1, except the weight shall be 89 N (20 pounds).

59.2.3 A wiring lead intended for field wiring connection shall be tested as indicated in 59.2.1, except in the case of a lead extending from the enclosure the weight shall be 89 N (20 pounds) and in the case of al lead within a wiring compartment, the weight shall be 44.5 N (10 pounds).

59.2.4 The weight shall be suspended from the cord, cable, or lead and supported by the unit so that the strain relief means is stressed from any angle of the unit.

59.3 Strain relief – Push back test

59.3.1 The cord or cable shall be prevented from being pushed into the product through the entry hole where such displacement is likely to:

a) Subject the cord or cable to mechanical damage or to exposure to a temperature higher than that for which the cord or cable is rated;

b) Reduce spacings below the minimum intended values; or

c) Damage internal connectors or components.

59.3.2 The cord or cable shall be held 25.4 mm (1 inch) from the point where the cord or cable emerges from the unit and shall then be pushed back into the unit. The cord or cable shall be pushed back into the unit in 25.4 mm increments until the cord or cable buckles or the force to push the cord or cable into the unit exceeds 26.7 N (6 pounds force). The cord or cable, within the unit, shall be manipulated to the worst case position during the test to determine compliance with 59.3.1.

60 Flexing Test

60.1 With reference to 20.1.7, after wiring has been subjected to flexing as described in 60.2, the unit shall be subjected to the Dielectric Voltage-Withstand Test in Section 55, and the wiring shall be examined for damage to determine where any conductors are broken or where individual strands have penetrated the insulation.

60.2 Wiring that is subjected to movement at times other than installation and servicing shall be tested by cycling the moving part through the maximum travel intended for the construction. The duration of the test shall be 500 cycles.

61 Grounding Impedance Test

61.1 Equipment shall comply with the Grounding impedance test as follows:

a) In Canada, the Grounding impedance test of CSA C22.2 No. 0.4.

b) In the US, the Grounding impedance test in 61.2 and 61.3.

61.2 In accordance with 19.9 where penetration of nonconductive coatings is not determinable by examination, a measurement of the grounding path resistance shall be made. The impedance at 60 hertz between the point of connection of the equipment-grounding means and the metal part that is required to be bonded to ground shall not be more than 0.1 ohm when measured in accordance with 61.3.

61.3 Compliance with 61.2 shall be determined by passing a current of 25 amperes derived from a 60 hertz source with a no-load voltage not exceeding 6 volts between the following points and measuring the voltage across these points: the equipment grounding connection and the metal part in question.

62 Overcurrent Protection Calibration Test

62.1 A fuse, or circuit protective device, provided in the primary of a transformer for protection of the secondary circuit in accordance with 25.9 shall operate to open the circuit in not more than the time indicated in Table 62.1 when the transformer is delivering the specified secondary current.

Table 62.1
Maximum Time to Open

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

[a] After 15 minutes of operation, the current shall be readjusted to the value shown.

62.2 To determine when a fuse or circuit protective device complies with the requirement in 62.1, the transformer is to deliver the test current to a resistance load with the primary connected to a circuit as described in 51.1. During the 2-minute test, the load shall be adjusted continuously to maintain the required test current. During the 60-minute test, the load shall be adjusted once after 15 minutes of operation, and the test is to be continued without further adjustment.

62.3 When the fuse or circuit protective device is used to protect more than one secondary winding or taps, each winding or partial winding shall be tested as indicated in 62.1 or 62.2 with the remaining windings delivering rated load.

63 Strength of Terminal Insulating Base and Support Test

63.1 In accordance with the requirement in 14.1.2.5, an insulating base or support and the bus or strap upon which pressure wire connectors for field wiring are mounted shall be subjected to the force created when the connectors, securing short lengths of conductors sized as described in 14.1.1.3, are torqued to 125 percent of the value marked on the unit. The results meet the intent of the requirement when the base is not damaged as defined in 63.2.

63.2 With reference to 63.1, damage has occurred when the base insulating material cracks or rotates; bosses, recesses, or other means to prevent turning do not perform their intended function; straps or bus bars bend or twist; or members other than the wire connector move at electrical joints. Minor chipping or flaking of brittle insulating material is not prohibited when the performance is not otherwise impaired. Momentary flexing of metallic members without permanent deformation is not prohibited.

64 Neutral to Ground Potential Measurement Test

64.1 In accordance with 29.3, a unit having an AC receptacle with a ground pin as an output shall be subjected to this test. The unit shall:

a) Operate with no load connected to the output ac terminals; and

b) Deliver maximum rated output alternating current into a load.

The electric energy available between the grounded conductor of the ac output circuit and ground shall not produce a risk of electric shock.

65 Bonding Conductor Test

65.1 A bonding conductor that does not comply with the requirement in 19.11 is not prohibited when, using separate samples for each test, neither the bonding conductor nor the connection opens when:

a) Carrying currents equal to 135 and 200 percent of the rating or setting of the intended branch-circuit overcurrent-protective device for the times specified in Table 65.1; and

b) Three samples are subjected to a limited-short-circuit test using a test current as specified in Table 65.2 while connected in series with a nonrenewable fuse having a rating equal to the intended branch-circuit overcurrent-protective device.

65.2 When a fuse smaller than that indicated in (a) and (b) is employed in the unit for protection of the circuit to which the bonding conductor is connected, the magnitude of the test current and size of fuse used during the test is not prohibited from being based on the rating of the smaller fuse.

Table 65.1
Duration of Overcurrent Test

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

Table 65.2
Circuit Capacity for Bonding Conductor Short-Circuit Test

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

65.3 The test circuit described in 65.1(b) shall have a power factor of 0.9 – 1.0 and a closed-circuit test voltage as specified in 51.1. The open-circuit voltage shall be 100 – 105 percent of the closed-circuit voltage. Each test shall be performed on each of the three samples.

66 Glass Covered Openings Impact Test

66.1 With reference to 7.6.1(b), a glass covered opening shall withstand a 3.38 J (2-1/2 foot-pound) cracking or breaking to the extent that a piece is released or dropped from its normal position.

66.2 The impact specified in 66.1 shall be applied by means of a smooth, solid steel sphere 50.8 mm (2 inches) in diameter and having a mass of 535 g (1.18 pounds). The sphere is to fall freely from rest through a vertical distance of 63.5 cm (25 inches).

67 Evaluation of Reduced Spacings on Printed-Wiring Boards

67.1 General

67.1.1 In accordance with 23.1.2, printed-wiring board traces of different potential having reduced spacings shall be judged by conducting a shorted trace test described in 67.2.1.

67.2 Shorted trace test

67.2.1 Printed-wiring board traces mentioned in 67.1.1 shall be short-circuited, one location at a time, and the test shall be conducted as described in 57.1.1 – 57.1.3, 57.1.6, 57.1.8, and 57.1.9. As a result of this test:

a) The overcurrent protection associated with the branch circuit to the unit shall not open; and

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

When the circuit is interrupted by opening of a component, other than an internal overcurrent protective device, the test shall be repeated twice using new components, as required.

68 Heat Sink Temperature Cycling Test

68.1 When tested in accordance with 21.3.1, a current-carrying aluminum heat sink shall be subjected to the test described in 68.2 and 68.3.

68.2 Three samples of the heat sink/solid state component assemblies shall be subjected to this test. After completion of the 500th cycle described in 68.3, a temperature of the solid state component for each sample shall not be more than 15 °C (27 °F) higher than the temperature during the 24th cycle and neither temperature shall be more than the rating of the solid state component.

68.3 The samples shall be subjected to 500 cycles of current-on and current-off operations. During the current-on time, the samples shall be carrying maximum rated current. The duration of the current-on and current-off times shall be the length of time required to reach stable temperatures. Stable temperatures are obtained when three successive readings taken at not less than 10 minute intervals indicates no more than 2 °C (3.6 °F) variation between any two readings. Forced-air cooling is a way to reduce the current-off time with the concurrence of those concerned.

69 Tests for Permanence of Cord Tag

69.1 General

69.1.1 In accordance with 85.2.2, the tests described in 69.3.1 shall be conducted on a cord tag or cable tag containing markings. Representative samples that have been subjected to these tests shall meet the following requirements:

a) The tag shall resist tearing for longer than 1.6 mm (1/16 inch) at any point;

b) The tag shall not separate from the cord or cable;

c) The tag shall not slip or move along the length of the cord or cable more than 12.7 mm (1/2 inch);

d) There shall be no permanent shrinkage, deformation, cracking, or any other condition that renders the marking on the tag illegible; and

e) Overlamination shall remain in place and not be torn or otherwise damaged. The printing shall remain legible.

69.2 Test conditions

69.2.1 Nine samples of the tag applied to the cord or cable in the intended manner shall be tested. For adhesive applied tags, tests shall be conducted no sooner than 24 hours after application of the tag. The samples shall be conditioned as follows:

a) Three of the samples shall be tested as received.

b) Three samples shall be tested at the end of 30 minutes of conditioning at a room temperature of 23 ±2 °C (73.4 ±3.6 °F) and 50 ±5 percent relative humidity, following conditioning in an air-circulating oven at 60 ±1 °C (140 ±1.8 °F) for 240 hours.

c) The remaining three samples shall be tested within 1 minute after exposure for 72 hours to a humidity of 85 ±5 percent at 32 ±2 °C (89.6 ±3.6 °F).

69.3 Test method

69.3.1 Each sample shall consist of a length of cord or cable to which the tag has been applied. The cord or cable shall be held tautly in a vertical plane. A force of 22.2 N (5 pounds) shall be applied for 1 minute to the uppermost corner of the tag farthest from the cord or cable, within 6.4 mm (1/4 inch) of the vertical edge of the tag. The force shall be applied vertically downward in a direction parallel to the major axis of the cord or cable. In determining compliance with 69.1.1(d), manipulation such as straightening of the tag by hand is used where applicable. To determine compliance with 69.1.1(e), each sample shall be scraped 10 times across printed areas and edges, with a force of 8.9 N (2 pounds), using the edge of a 2.0 mm (5/64 inch) thick steel blade held at a right angle to the test surface.

70 Tests on Transformer Insulating Materials

70.1 Where required by note (c) or (g) of Table 27.1 the transformer insulating material shall be subjected to the test described in 70.2.

70.2 The insulating material shall be placed between two opposing electrodes. The electrodes shall be cylindrical brass or stainless steel rods 6.4 mm (1/4 inch) in diameter with edges rounded to a 0.8 mm (1/32-inch) radius. The upper movable electrode is to weigh 50 ±2 grams (1.76 ±0.07 ounces) to exert sufficient pressure on the specimen to provide good electrical contact. The test potential shall be increased to the test value, and the maximum test potential shall be maintained for 1 second. The result complies when there is no dielectric breakdown.

71 Bus Bar Tests

71.1 An aluminum bus bar employing a coating mentioned in 21.2.2, or a bus bar that has a clamped joint construction covered by 21.2.4 and 21.2.5, shall be subjected to the tests described in 71.2 – 71.4.

71.2 The temperature of the bus bar joint shall be measured during the Temperature Test described in Section 54 and comply with the maximum temperature specified in Table 54.1.

71.3 The temperature rise at the joint during the 500th cycle shall not be more than 15 °C (27 °F) higher than the temperature rise at the end of the 25th cycle.

71.4 The test sample shall consist of an assembly of bus bars connected together to form a series circuit. The bus bars shall be clamped together with the joint construction used in actual production. The number and size of the bus bar shall represent the maximum ampere rating and the maximum current density in which the joint construction is employed. More than one test shall be conducted when required to accomplish this. The length of each bus bar shall be 609 mm (2 feet) unless shorter lengths are agreed to by all concerned. The bus bar shall be connected to a power supply by any means that does not affect the joint temperature. The power supply shall be adjusted to deliver a value of current that results in a temperature of 75 °C (135 °F) above room temperature at the joint. The assembly shall then be subjected to a 500-cycle test. At the end of the 24th cycle, the shall be readjusted to bring the temperature of the joint to 75 °C (135 °F) above room temperature; and this current value shall be maintained for the remainder of the cycling test. At the end of the 25th and 500th cycles, the temperatures shall be recorded. The temperatures shall be measured on both sides of the joint as close as possible to the bolt or rivet. The cycling rate shall be 3 hours on and 1 hour off. The on period during which temperatures are recorded shall be what is required for the joint to attain thermal equilibrium.

72 Charging Harmonic Distortion Test

72.1 A unit rated for a harmonic factor (HF) or total harmonic distortion (THD) of the supply current shall be tested as described in 72.2 and 72.3. With the unit energized at the input voltage and frequency in accordance with 51.1 and 51.2, HF or THD shall not be more than 10 percent over the manufacturer's rating for the unit when controlling the maximum intended battery load.

72.2 The supply for the test shall have a voltage distortion of less 0.5 percent. Since the source (supply) voltage affects the magnitude of the harmonics, for measuring purposes, the supply impedance for cord-connected units rated 240 volts or less shall be 0.08 ohm or less and the supply impedance for other units shall not exceed a value that affects the results of the test. The unit shall be tested at 33 percent, 66 percent and 100 percent of rated current draw.

72.3 The magnitude of the various harmonics of the supply frequency shall be recorded to the thirty-third (33) harmonic. The harmonic distortion factor is the ratio of the harmonic content to the rms value of the fundamental. The harmonic factor (HF) shall be calculated as follows:

$$HF = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots}}{I_{fundamental}}$$

The total harmonic distortion (THD) shall be calculated as follows:

$$THD = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots}}{\sqrt{I_1^2 + I_2^2 + I_3^2 + I_4^2 + \ldots}}$$

where

I_1 = 100 percent at the fundamental frequency,

I_2 = magnitude, in percent of the fundamental, of the second harmonic

I_3 = magnitude, in percent of the fundamental, of the third harmonic

73 Impact Test

73.1 The enclosure of a unit, or any guard, shall be subjected to this test. The unit shall be subjected to an impact of 6.8 J (5 foot-pounds) on any surface that is exposed to a blow during normal use. This impact

is to be produced by dropping a steel sphere, 50.8 mm (2 inches) in diameter and weighing 535 g (1.18 pounds), from a height of 1.29 m (51 inches) to produce the impact. For surfaces other than the top, the steel sphere shall be suspended by a cord and swung as a pendulum, dropping through a vertical distance of 1.29 m to strike the surface.

73.2 A unit shall be subjected to the impact test described in 73.1 with or without any attachment specified by the manufacturer so as to result in the most severe test. One sample of a metallic enclosure shall be tested. Three samples of a nonmetallic enclosure shall be tested in accordance with the conditioning outlined in 73.3 and 73.4.

73.3 When the part under test is made of polymeric material, the impact test shall be first conducted on a sample in the as-received condition. The test shall then be repeated on a different sample that has been cooled to room temperature after being conditioned for 7 hours in an air oven operating at 10 °C (18 °F) higher than the maximum operating temperature of the material, and not less than 70 °C (158 °F). The test shall then be repeated on a different sample that has been conditioned in a cold chamber at minus 30 ±2 °C (minus 22 ±4 °F) for 24 hours. The impact test shall be performed immediately after removing the sample from the cold chamber. Gloves shall be worn when handling the conditioned sample to minimum heat transfer. While being conditioned, either in the oven or the cold chamber, a part shall be supported in the same way it is supported on the unit.

73.4 Upon being removed from the oven mentioned in 73.3 and before being subjected to the impact test, the oven aged sample shall show signs of cracking or other deleterious effects from the oven conditioning, and no sample shall be distorted to result in a risk of injury to persons.

73.5 After the impact test, any openings resulting from the test shall comply with the accessibility requirements described in Protection of Users – Accessibility of Uninsulated Live Parts, Film Coated Wire, and Moving Parts, Section 8. Additionally, there shall be no cracks, holes, or other damage in the enclosure that would compromise environmental integrity. If validation is necessary, the environmental testing of 7.12 shall be repeated.

74 Drop Test

74.1 The test shall be performed on units weighing less than 18 kg (40 lbs) that are intended to be carried.

74.2 With reference to 74.1, each sample shall be dropped three times from a height of 0.9 m (3 feet) to strike a concrete surface in the positions favorable to producing adverse results. One sample of a metallic enclosure shall be tested. Three samples of a nonmetallic enclosure shall be tested in accordance with the conditioning outlined in 74.3.

74.3 When the part under test is made of polymeric material, the drop test shall be first conducted on a sample in the as-received condition. The test shall then be repeated on a different sample that has been cooled to room temperature after being conditioned for 7 hours in an air oven operating at 10 °C (18 °F) higher than the maximum operating temperature of the material, and not less than 70 °C (158 °F). The test shall then be repeated on a different sample that has been conditioned in a cold chamber at minus 30 ±2 °C (minus 22 ±4 °F) for 24 hours. The drop test shall be performed immediately after removing the sample from the cold chamber. Gloves shall be worn when handling the conditioned sample to minimum heat transfer. While being conditioned, either in the oven or the cold chamber, a part shall be supported in the same manner in which it is supported on the unit.

74.4 Immediately following the test, the unit shall be:

a) Subjected to the Dielectric Voltage Withstand Test of Section 55. The potentials shall be applied between the input/output circuits and grounded or dead metal parts;

b) Examined for exposure of live parts of internal wiring;

c) Examined for reduction of spacings below the minimum specified in Spacings, Section 23; and

d) Examined for cracks, holes, and other damage in the enclosure that would compromise environmental integrity. If validation is necessary, the environmental testing of 7.12 shall be repeated.

75 Stability Tests

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

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

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

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

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

75.2 With reference to 75.1(a), where casters are used only to transport the unit and jacks are lowered after installation, then the jacks – not the casters – shall used in the most unfavorable position for the test, consistent with reasonable leveling of the unit.

75.3 In conducting the stability test, the unit shall be:

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

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

75.4 With reference to the requirement in 75.3(b), for a unit that is constructed so that, while being tipped through an angle of 10°, a part or surface of the unit not normally in contact with the horizontal supporting surface touches the supporting surface before the unit has been tipped through an angle of 10°, the tipping shall be continued until the surface or plane of the surface of the unit originally in contact with the horizontal supporting surface is at an angle of 10° from the horizontal supporting surface.

76 Static Load Test

76.1 When mounted as specified by the manufacturer, a power unit shall comply with the test specified in 76.2.

76.2 The supporting means of a power unit shall support a static load of four times the weight of the unit and not less than 9.1 kg (20 pounds):

a) Applied through the center of gravity of the power unit in the downward direction; or

b) Applied evenly over the horizontal plane of the unit.

77 Strength of Handles Test

77.1 A handle used to support or carry a unit shall withstand a load of four times the weight of the unit without damage to the handle, its securing means, or that portion of the enclosure to which the handle is attached.

77.2 To determine whether a unit complies with the requirement in 77.1, the load shall be uniformly applied over a 76 mm (3 inches) width at the center of the handle, without clamping. The load shall be started at zero and gradually increased so that the test value is attained in 5 to 10 seconds; the test value shall be maintained for 1 minute. When a unit has more than one handle and is not capable of being carried by one handle, the load shall be distributed between the handles. The distribution of the load shall be determined by measuring the percentage of the unit weight sustained by each handle with the unit in the normal carrying position. When the unit is furnished with more than one handle and is capable of being carried by only one handle, each handle shall withstand the total load.

78 Sprinkler Tests

78.1 General

78.1.1 Before a sprinkler test is performed, the unit shall be fitted with the intended supply connection means as described in the unit's installation instructions.

78.1.2 A unit intended for multiple mounting orientations shall be tested in all the intended orientations.

78.1.3 The sprinkler tests shall be performed in the operating sequence specified in Table 78.1.

Table 78.1
Operating Sequence for Sprinkler Tests

Duration in hours	Unit	Water
1	On	Off
1/2	Off	On
1	On	On
1/2	Off	On

78.1.4 Except as noted in 78.1.5, as a result of the sprinkler tests, no water shall enter the unit.

78.1.5 When water enters ground-mounted or surface-mounted units and the water does not wet any wiring or other electrical parts that are not inherently waterproof or rated for water exposure, and when the unit is provided with drain holes in accordance with CSA C22.2 No. 94.2/UL 50E the unit is in compliance with the sprinkler tests.

78.2 Sprinkler test

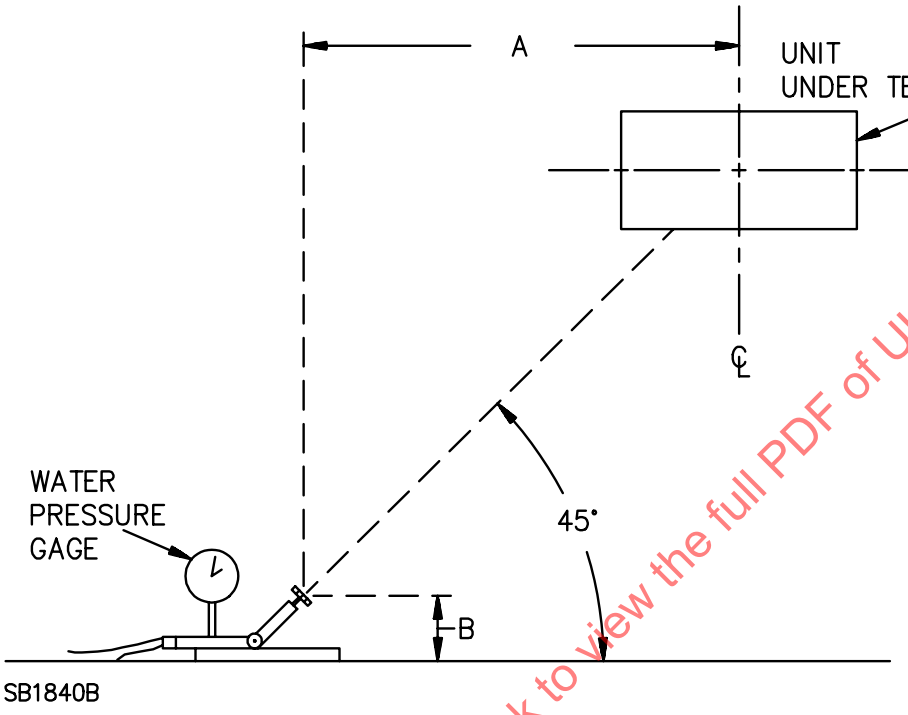
78.2.1 A unit required to be subjected to a sprinkler test shall be tested as described in 78.2.2 and 78.2.3.

78.2.2 An outdoor ground-mounted unit shall be turned about its vertical axis to each of four positions 90° from each other, each for 30 minutes during the 2-hour portion of the test described in 78.1.3, with adjustable parts arranged for maximum vulnerability to the water spray. Wall-mounted units intended for mounting within 914 mm (3 feet) of the ground, shall be similarly tested in the most vulnerable normal mounting position.

78.2.3 The unit shall be positioned as shown in Figure 78.1 in front of a standard water spray head of the type shown in Figure 78.2, to which the water pressure is maintained at a gage pressure of 138 kPa (20 psi).

Figure 78.1

Representative Sprinkler Test Setup



NOTES –

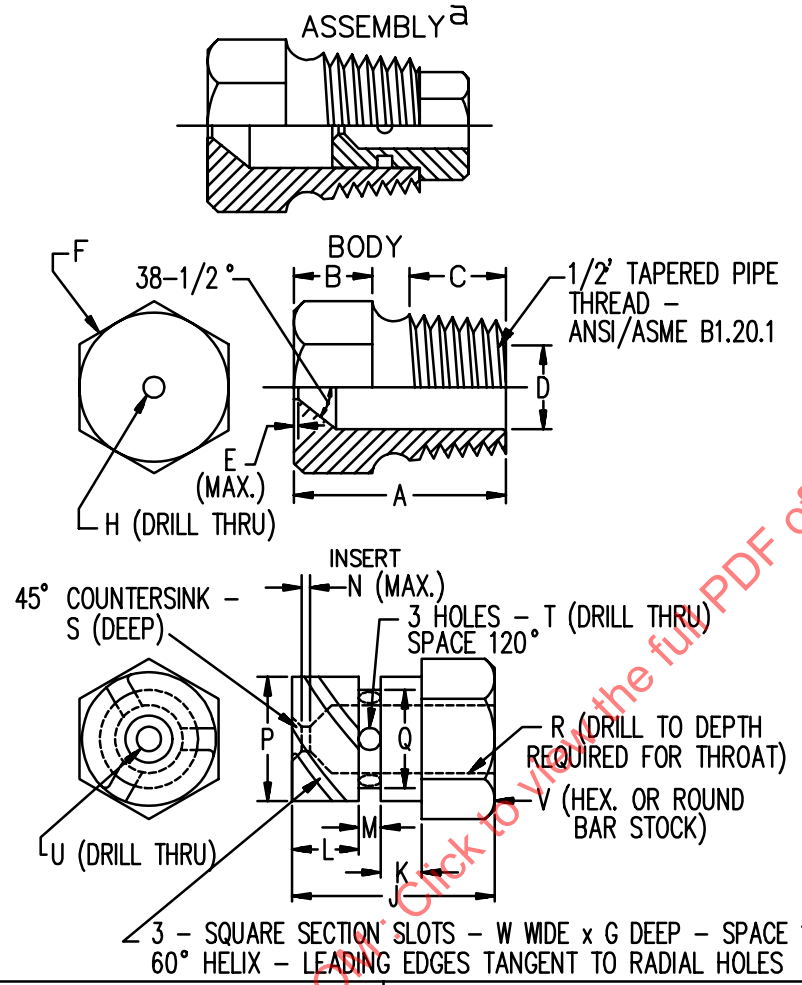
The unit shall be mounted as intended with the dimensional center of the unit on a line projected from the centerline of the nozzle head.

A – 914.4 mm (36 inches)

B – 76.2 – 152.4 mm (3 – 6 inches)

Figure 78.2

Spray Head



Item	inch	mm	Item	inch	mm
A	1–7/32	31.0	N	1/32	0.80
B	7/16	11.0	P	.575	14.61
C	9/16	14.0		.576	14.63
D	.578	14.68	Q	.453	11.51
	.580	14.73		.454	11.53
E	1/64	0.40	R	1/4	6.35
F	c	c	S	1/32	0.80
G	.06	1.52	T	(No. 35)[b]	2.80
H	(No.9)[b]	5.0	U	(No. 40)[b]	2.50
J	23/32	18.3	V	5/8	16.0
K	5/32	3.97	W	0.06	1.52
L	1/4	6.35			
M	3/32	2.38			

[a] Nylon Rain–Test Spray Heads are available from Underwriters Laboratories

[b] ANSI B94.11M Drill Size

[c] Optional – To serve as a wrench grip.

RT100E

MANUFACTURING AND PRODUCTION TESTS

79 Production-Line Dielectric Voltage-Withstand Test

79.1 As a routine production-line test, each unit shall withstand, without electrical breakdown, the application of an alternating-current potential at a frequency within the range of 40 – 70 hertz or a direct-current potential between the primary wiring, including connected components, and accessible dead metal parts that are capable of becoming energized and between primary wiring and accessible low-voltage – 42.4 volts peak, 60 volts, dc or less – metal parts, including terminals and connector contacts.

79.2 The test duration and potential shall be as described in either condition A or B of Table 79.1.

Table 79.1
Production Test Condition

Unit voltage rating, volts	Condition A			Condition B		
	Test potential v ac	Test potential v dc	Time, seconds	Test potential v ac	Test potential v dc	Time, seconds
Rated 250 or less	1000	1400	60	1200	1700	1
Rated more than 250	1000 + 2 V[a]	1400 + 2.8 V[a]	60	1200 + 2.4 V[a]	1700 + 3.4 V[a]	1

[a] Maximum marked voltage.

79.3 The test potential shall be gradually increased to the required value, but the full value shall be applied for 1 second or 1 minute, as required.

79.4 The unit shall be at intended operating temperature, at room temperature, or at any intermediate temperature for the test.

79.5 The test shall be conducted when the unit is fully assembled. It is not intended that the unit be unwired, modified, or disassembled for the test. Parts such as snap covers or friction-fit knobs that interfere with performance of the test are not required to be in place during the test.

79.6 The test shall be performed before final assembly when the test represents that for the completed unit. Any component not included shall not affect the results with respect to determination of possible electric shock from miswiring, defective components, spacings, or similar defect.

79.7 Solid state components that are capable of being damaged by a secondary effect (induced voltage surge, excessive heating, or similar effect) of the test shall be short-circuited by means of a temporary electrical jumper, or the test shall be conducted without the component electrically connected, providing the wiring and terminal spacings are maintained. Additionally, transient voltage suppression devices other than capacitors connected from primary wiring to dead metal shall be disconnected during the test where required.

79.8 The test equipment shall have a means of indicating the test potential, an audible or visual indicator of electrical breakdown and, for automated or station type operations, either a manual-reset device to restore the equipment after electrical breakdown or an automatic-reject feature for any unit that does not comply. When an alternating-current test potential is applied, the test equipment shall include a transformer having a sinusoidal output.

79.9 When the rated output of the test equipment is less than 500 volt-amperes, the equipment shall include a voltmeter in the output circuit to indicate directly the applied test potential.

79.10 When the rated output of the test equipment is 500 volt-amperes or more, the test potential shall be indicated by a voltmeter in the primary circuit or in a tertiary-winding circuit; by a selector switch marked to indicate the test potential; or by a marking in a readily visible location to indicate the test potential in the case of equipment having a single test-potential output. When an indicating voltmeter is not used, the test equipment shall include a visual means (such as an indicator lamp) to indicate that the test voltage is present at the test-equipment output.

79.11 Test equipment other than that described in 79.8 – 79.10 are not prohibited from being used when found to accomplish the intended factory control.

79.12 For the test, either a specified number of control devices shall be closed or separate applications of the test potential shall be made so that all parts of the primary circuit are tested.

80 Production-Line Grounding-Continuity Test

80.1 Each unit that has an input or output cords or cables with a grounding conductor shall be tested, as a routine production-line test, to determine that grounding continuity is provided.

80.2 Only a single test is required when the accessible metal selected is conductively connected to all other accessible metal.

80.3 Any indicating device (an ohmmeter, a battery and buzzer combination, or similar device) shall be used to determine compliance with the grounding continuity requirement.

81 Source Transfer Test

81.1 Installations where there is capability to transfer from EVPE to a grid supply shall also comply with Section 82, Utility Grid Interactive Functionality Type Testing.

82 Utility Grid Interactive Functionality Type Testing (For Canada only)

82.1 Annex C (Type Tests), Annex D (Interoperability Tests) and Annex E (Production Tests) are not required for all EVPE equipment within the Scope of the Standard as found in Clause 1.

82.2 These annexes are required ONLY for EVPE equipment that is electrically connected in parallel with an Area EPS, whether directly or via intermediate Local EPS facilities. Specifically, the annexes are relevant to EVPE that is within the Scope of 1.4 (g) – (m). Under IEEE 1547(2018) all "interconnection equipment"[1] that is part of an "interconnection system"[1] to facilitate an "interconnection: The result of the process of adding DER to an AREA EPS, whether directly or via intermediate Local EPS facilities"[1] are required to meet the Production test, Interconnection test and Type test requirements in IEEE 1547.1(2020).

[1] Page 23 – Clause 3.1 Definitions – IEEE 1547-2018 referenced are in IEEE 1547.-2005

82.3 Under CSA C22.3 No. 9:20 all EVPE equipment that includes an "interactive inverter: An inverter whose AC output is intended for use in parallel with an electric utility or other electricity supply authority network, whether the inverter injects net power into the utility or supply network or not"[2] and EVPE equipment that is part of an "interconnection system"[2] to facilitate an "interconnection – the result of the process of electrically connecting a DER system in parallel to a distribution system"[2] are required to meet the Production test and Type test requirements of CSA C22.3 No. 9:20. There are no Interconnection test requirements within CSA C22.3 No. 9:20.

[2] Pages 14 and 15 – Clause 3 Definitions – CSA C22.3 No. 9:20

[3] Clauses referenced are in IEEE 1547.1 – 2005

83 Utility Grid Interactive Functionality Production Line Testing

83.1 Units with utility grid interactive functionality shall be subjected to the applicable production line tests from UL 1741, CSA C22.2 No. 107.1 or CSA C22.3 No. 9.

RATINGS

84 Details

84.1 A unit shall have the following ratings for charging mode, power-export mode, and other modes as applicable:

a) Input voltage;

b) Number of phases for input and/or output, except for a unit obviously intended for single-phase use only;

c) Input frequency;

d) Input in amperes, volt-amperes, kilovolt-amperes, or watts; and

e) Output voltage;

f) Output amperes, volt-amperes, kilovolt-amperes, or watts;

g) Output frequency; and

h) Short-circuit rating (I_{sc} MAX).

84.2 A unit that performs utility interactive inverter functionality shall be provided with the ratings in accordance with UL 1741 or CSA C22.2 No. 107.1.

MARKINGS

Advisory Note: Markings required by this Standard may have to be provided in other languages to conform with the language requirements of the country or region where the product is to be used. In Canada, there are two official languages, English and French. Annex A provides translations in French of the English safety markings specified in this Standard.

85 Details

85.1 General

85.1.1 Unless otherwise stated, all markings shall be permanent, that is, either by being molded, die-stamped, paint-stenciled; stamped or etched metal that is permanently secured; or indelibly stamped on a pressure-sensitive label secured by adhesive that, upon evaluation, is found to comply with the requirements in UL 969 or CSA C22.2 No. 0.15. A hang tag label shall comply with the requirements in Section 69 or it shall comply with UL 969A.

85.1.2 A unit that performs utility interactive inverter functionality shall be provided with the markings in accordance with UL 1741 or CSA C22.2 No. 107.1.

85.2 Content

85.2.1 A unit shall be plainly and permanently marked where it is readily visible, after installation, with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the equipment is identified. The manufacturer's identification is not prohibited from being in a traceable code when the unit is identified by the brand or trademark owned by a private labeler;

b) A distinctive catalog number or the equivalent;

c) The electrical ratings specified in Details, Section 84; and

d) The date or other dating period of manufacture not exceeding any three consecutive months. The date of manufacturer may be abbreviated, in a nationally accepted conventional code, or in a code affirmed by the manufacturer. If in a code affirmed by the manufacturer, the code cannot repeat in less than 20 years, and cannot require reference to production records to decipher the code.

85.2.2 Markings are not prohibited from being located on a tag that is attached to a cord or cable and complies with the requirements in Tests for Permanence of Cord Tag, Section 69 or the requirements in UL 969A.

85.2.3 With reference to the requirement in 85.2.1(c), the symbols described in (a) and (b) are used for markings:

a) A circuit intended to be connected to an alternating-current supply shall be identified by markings indicating that the supply shall be alternating current. The markings shall include the supply-circuit frequency or supply-circuit frequency-range rating (cycles per second, cycles/second, hertz, c/s, cps, or Hz). The symbol illustrated in Figure 85.1 is an example for this marking. See 85.2.4.

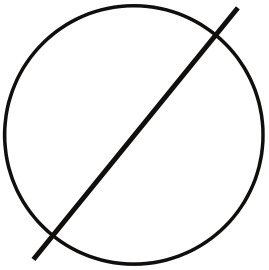
b) The number of phases shall be indicated if the unit is designed for use on a polyphase circuit. The symbol illustrated in Figure 85.2 is an alternative for the word "phase." See 85.2.4.

Figure 85.1

Alternating Current Supply Symbol

Figure 85.2

Phase Symbol



85.2.4 When the symbol referenced in 85.2.3 (a) or (b) is used, the information described in 87.2(g) shall be provided.

85.2.5 When a unit is produced or assembled at more than one factory, each unit shall have a distinctive marking – in code or otherwise – by which it is identified as the product of a particular factory.

85.2.6 The operating positions of a handle, knob, or other means intended for manual operation by the user shall be marked.

85.2.7 Wiring terminals shall be marked to indicate the proper connections for the unit, or a wiring diagram coded to the terminal marking shall be securely attached to the equipment.

85.2.8 Equipment field-wiring terminals shall be marked:

a) "Use Copper Conductors Only" when the terminal is intended only for connections to copper wire.

b) "Use Aluminum Conductors Only" or "Use Aluminum or Copper-Clad Aluminum Conductors Only" when the terminal is intended only for connection to aluminum wire.

c) "Use Copper or Aluminum Conductors" or "Use Copper, Copper-Clad Aluminum, or Aluminum Conductors" when the terminal is intended for connection to either copper or aluminum wire.

85.2.9 In accordance with 18.15, a pressure wire connector intended for connection of an equipment-grounding conductor shall be identified by:

a) Being marked "G," "GR," "GND," "Ground," "Grounding," or similar marking;

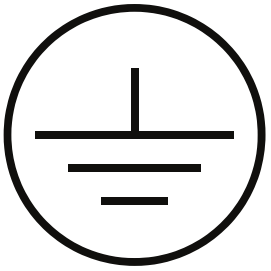
b) A marking on a wiring diagram attached to the unit; or

c) In the US, the symbol illustrated in Figure 85.3 on or adjacent to the connector or on a wiring diagram provided on the unit. See 85.2.10.

In Canada, the symbol of bonding/grounding shall comply with CSA C22.2 No. 0.4.

Figure 85.3

Symbol for Equipment Grounding Conductor



IEC Publication 60417, Symbol 5019

85.2.10 With reference to 85.2.9(c), the following shall apply when the symbol illustrated in Figure 85.3 is used:

a) The information described in 87.2(g) shall be provided in the instruction manual.

b) The symbol shall be used for identifying only the field wiring equipment grounding terminal. However, a symbol as shown in Figure 85.3 except with the circle omitted, is an alternative for identifying various points within the unit that are bonded to ground.

85.2.11 A terminal for the connection of a grounded conductor shall be identified by means of a metallic plated coating white in color, and shall be readily distinguishable from the other terminals; or proper identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as a marking on the unit, an indication on a wiring diagram attached to the unit, or information provided in the instruction manual. Where field wiring leads are provided, the lead intended to be grounded shall have a white or gray color and shall be readily distinguishable from other leads.

85.2.12 A unit employing pressure terminal connectors for field wiring connections shall be provided with a marking making reference to the instruction manual for the tightening torque to be applied to the wiring terminals. See 87.2(f).

85.2.13 A multiple-voltage unit for permanent connection to the branch circuit supply shall be marked to indicate the particular voltage for which it is set when shipped from the factory. The marking shall be in the form of a paper tag or any other nonpermanent material. A unit that may be adjusted for multiple wiring/power systems configurations of branch circuit supply shall be marked to indicate the particular configuration for which it is set when shipped from the factory. The marking shall be in the form of a paper tag or any other nonpermanent material. The manual shall also include corresponding instructions for setting the desired configuration

85.2.14 A clock, timing device, or alarm circuit on or remote from a unit that remains energized during servicing functions shall be marked to indicate that the circuit remains energized while the unit is off.

85.2.15 Where required by 14.1.3.5, a unit containing a field-wiring lead that is connected to a wire binding screw located in the field-wiring compartment shall be marked with information clearly indicating the intended use of the lead.

85.2.16 Low-voltage Class 2 field-wiring leads, color coded in accordance with 18.9.1 shall be identified. The marking shall not require the use of a separate wiring diagram to make proper connections.

85.2.17 Where required by 28.3.2, a marking shall be provided indicating that Class 2 (or Class 3 as applicable) circuit conductors are to be installed using Class 1 wiring methods or Types CL3, CL3R, or CL3P cable.

85.2.18 A unit having a manually operated user accessible test circuit for a ground fault protective device shall be marked with instructions indicating the test circuit shall be operated before each use.

85.2.19 A unit intended for outdoor-use that has been found compliant with CSA C22.2 No. 94.2/UL 50E shall be marked in accordance with CSA C22.2 No. 94.2/UL 50E.

85.3 Cautionary markings

85.3.1 The words "CAUTION," "WARNING," OR "DANGER" in a cautionary marking shall be in letters not less than 3.2 mm (1/8 inch) high. The remaining letters in a cautionary marking shall not be less than 1.6 mm (1/16 inch) high. The words "WARNING" or "DANGER" are alternatives for the word "CAUTION."

85.3.2 A cautionary marking shall be located on a part that impairs the operation of the unit when removed. The marking shall also be visible and legible to the operator during normal operation of the unit. Cautionary markings pertaining to internal parts that are applicable only to service personnel shall be located internally in a location with respect to the parts of concern.

85.3.3 A live heat sink or other part that is capable of being mistaken for dead metal, renders a risk of electric shock or electrical energy – high current levels, and is not guarded as specified in 37.7 shall be marked with the word "CAUTION" and the following or the equivalent: "Risk of electric shock (or fire as applicable) – Plates (or other word describing the type of part) are live. Disconnect unit before servicing." The marking shall be located on or near the live part so as to make the risk of fire or electric shock known before the part is capable of being touched. A single marking for multiple number of parts is allowed.

85.3.4 A fixed unit that exceeds the temperature limits specified in the third item in Table 54.3 (see 54.14) shall be legibly marked externally where readily visible after installation with the word "CAUTION – Risk of injury" and the following or the equivalent "Hot surfaces – To reduce the risk of burns – Do not touch."

85.3.5 A unit provided with single-pole circuit breakers in the input circuit in accordance with 30.1.6 shall be marked internally with the word "CAUTION – Risk of electric shock and fire" and the following or the equivalent: "To reduce the risk of electric shock and fire – Do not connect to a circuit operating at more than 150 volts to ground."

85.3.6 A compartment involving a risk of electric shock and housing no user serviceable parts shall be externally marked with the word "CAUTION – Risk of electric shock" and the following warning or equivalent: "Do not remove cover. No user serviceable parts inside. Refer servicing to qualified service personnel."

85.3.7 There shall be a marking for each fuse that complies with the requirements in this standard, indicating the ampere, voltage, and ac or dc rating of the fuse to be used for replacement. The marking shall be located so that it is obvious as to which fuse or fuseholder the marking applies. A marking that consists of a pictorial identifying the rating of one or more fuses is not prohibited. In addition, the following prominent marking shall be provided – a single marking for a group of fuses is not prohibited – with the word "WARNING – Risk of fire" and the following or the equivalent: "To reduce the risk of fire, replace only with same type and ratings of fuse." Fuses that are secured by solder are not required to comply.

85.3.8 A removable panel covering a capacitor in accordance with 31.8(a) shall be marked "CAUTION – Risk of electric shock" and the following or equivalent wording: "Capacitor stores hazardous energy. Do not remove cover until ___ minutes after disconnecting all sources of supply." The time indicated in the

marking shall be whatever time needed to discharge the capacitor to within the limitations specified in 31.7, and not greater than 5 minutes.

85.3.9 Where required by 31.8(b), a unit shall be marked "CAUTION – Risk of electric shock and/or electric energy-high current levels" and the following or equivalent wording: "Disconnect and discharge (identify capacitor) before removing panel as follows." Instructions shall follow indicating how to disconnect and discharge the capacitor. The procedure indicated shall be limited to functions such as operating a switch, unplugging a connector, or the equivalent.

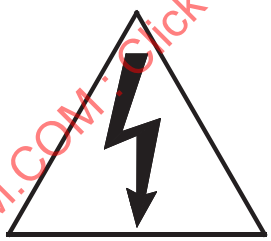
85.3.10 Ungrounded dead metal parts mentioned in 19.3(f) shall be plainly marked with the word "CAUTION – Risk of electric shock" and the following or the equivalent: "(Identify part or parts not earth grounded) (is) (are) not grounded – (it) (they) present(s) risk of electric shock. Test before touching." The marking shall be provided on or adjacent to the ungrounded dead metal parts and shall be visible so that each part or group of parts is positively identified.

85.3.11 Where required by 31.8(c) a marking shall be provided indicating "CAUTION – Risk of electric shock or electric energy-high current levels" and the following or the equivalent: "Dangerous electric charge is sometimes stored in (identify capacitor) and associated circuitry. Test before touching." The marking shall be located internally adjacent to the capacitor.

85.3.12 With reference to the requirements in 85.3.3, 85.3.5, 85.3.6, 85.3.8, and 85.3.10, the symbol illustrated in Figure 85.4 is an alternative for the cautionary statement "Risk of electric shock." The other markings required by the referenced paragraphs shall be provided in addition to the symbol. When the symbol is used, the information described in 87.2(q) shall be provided in the instruction manual.

Figure 85.4

Symbol for "RISK OF ELECTRIC SHOCK" Statement



IEC Publication 60417, Symbol 5036

85.3.13 A unit not provided with external connections for a ventilating means specified in 16.6 shall be marked with the word "WARNING", the words, “Risk of Explosion”, and the following or the equivalent: "This equipment is not intended for indoor charging or discharging of vehicles requiring ventilation during charging." A fixed unit intended to charge only vehicles not requiring ventilation during charging or discharging shall be marked this way or alternatively marked with the word "WARNING" and the following or the equivalent: "This equipment is intended only for charging vehicles not requiring ventilation during charging or discharging." If the unit is only used for discharging the battery during power export, then the word “charging” can be omitted from the marking.

85.3.14 A fixed unit provided with external connections for a ventilating means in accordance with 16.6 shall be marked with the word "WARNING", the words, “Risk of Explosion”, and the following or the equivalent: "Proper Ventilation is required to reduce the Risk of Hazardous or Explosive gas build up during indoor charging or discharging."

85.3.15 A unit that is connected to more than one source of power shall be marked with the word "CAUTION" and the following words "Risk of Electric Shock –" and the following or the equivalent. The marking shall be located on the outside of the unit or shall be prominently visible with any cover or panel opened or removed, "Multiple power sources are terminated inside this equipment. Each circuit must be individually disconnected before servicing".

INSTRUCTIONS

86 Instruction Manual

86.1 A unit shall be provided with an instruction manual as described in 86.2 – 86.4. The instructions shall be legible and shall contrast with the background.

86.2 The important safety instructions shall appear before all other installation, operation, and maintenance instructions.

86.3 The headings for the instruction manual, and the opening statements of the instructions specified in Important Safety Instructions, Section 87 – "IMPORTANT SAFETY INSTRUCTIONS" and "SAVE THESE INSTRUCTIONS" – shall be entirely in upper case letters not less than 4.8 mm (3/16 inch) high or emphasized to distinguish them from the rest of the text. Upper case letters in the instructions shall not be less than 2.0 mm (5/64 inch) high, and lower case letters shall not be less than 1.6 mm (1/16 inch) high.

86.4 There shall be no substitute for the words "CAUTION," "WARNING," or "DANGER" in the text of the instructions, but the words “WARNING” or “DANGER” are alternatives for the word “CAUTION.”

87 Important Safety Instructions

87.1 The important safety instructions shall include information described in 87.2 (a) – (s). The statement "IMPORTANT SAFETY INSTRUCTIONS", and the statement "SAVE THESE INSTRUCTIONS" shall precede the list. The word "CAUTION" shall be entirely in upper case letters.

87.2 The information described in (a) – (s), where applicable, shall be provided for a unit. The information contained in (c) – (s) shall be marked on the unit or provided in the instruction manual.

IMPORTANT SAFETY INSTRUCTIONS

a) SAVE THESE INSTRUCTIONS – This manual contains important instructions for Models _____ (blank space is to be filled in with applicable model numbers if the instructions are different based on model numbers) that shall be followed during installation, operation and maintenance of the unit.

b) In accordance with 14.1.2.4, when pressure terminal connectors or the fastening hardware are not provided on the unit as shipped, the instruction manual shall indicate which pressure terminal connector or component terminal assemblies are for use with the unit.

c) With reference to (b), the terminal assembly packages and the instruction manual shall include information identifying wire size and manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is identified.

d) When a pressure terminal connector provided in the unit [or in a terminal assembly covered in 14.1.2.4(d)] for a field installed conductor requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any required instructions for using the tool shall be included in the instruction manual.

e) A unit provided with a wire connector for field installed wiring as covered in 14.1.3.2 shall be provided with instructions specifying that the connector provided is to be used in making the field connection.

f) A unit employing pressure terminal connectors for field wiring connections shall be provided with instructions specifying a range of values or a nominal value of tightening torque to be applied to the clamping screws of the terminal connectors. The minimum specified tightening torque shall not be less than 90 percent of the value specified in Table 87.1 or Table 87.3 as applicable for the wire size determined by the requirement described in 14.1.1.3 unless a lower value was evaluated in accordance with CSA C22.2 No. 65/UL 486A-486B or UL 486E or CSA C22.2 No. 65.

g) When a symbol is used for compliance with marking requirements mentioned in 85.2.4 or 85.2.5, the instruction manual shall identify the symbol.

h) The instruction manual for a unit that exceeds the temperature limits in the third item of Table 54.3 (see 54.14) shall specify that the unit is to be installed so that the risk of contact by people is reduced.

i) A unit having primary circuit filtering to meet EMC regulations shall include mention of all the following conditions of installation in the instruction manual:

1) An insulated grounding conductor that is identical in size, insulation material, and thickness to the grounded and ungrounded branch-circuit supply conductors except that it is green with or without one or more yellow stripes shall be installed as part of the branch circuit that supplies the unit or system.

2) The grounding conductor described in item 1 shall be grounded to earth at the service equipment or, when supplied by a separately derived system, at the supply transformer.

j) In accordance with 54.12, the instruction manual for a unit having an ambient temperature rating higher than 25 °C (77 °F) shall indicate the maximum ambient temperature rating.

k) For a unit having a single equipment field-wiring terminal that is intended for connection of more than one conductor, the instruction manual shall include information identifying the number of conductors and range of conductor sizes.

l) For a unit provided with field-wiring terminals or leads, the instruction manual shall include the information indicated in Row 1, 2, 3, or 4 of Table 87.4 or with equivalent wording, when it is:

1) Intended for use on a supply circuit rated 110 amperes or less, or

2) Intended for field connection with 1 AWG or smaller conductors.

m) For a unit provided with field-wiring terminals or leads, the instruction manual shall include the information indicated in Row 3 or 4 of Table 87.4, or with equivalent wording, when it is:

1) Intended for use on a supply circuit rated more than 110 amperes, or

2) Intended for field connection with conductors larger than 1 AWG (42.4 mm^2).

n) Where required by 14.3.1, the instruction manual shall include a statement indicating that Class 1 wiring methods are to be used for field wiring connections to terminals of a Class 2 circuit.

o) The instruction manual for a 3-phase unit shall include the electrical ratings for delta or wye phase configuration when the unit is limited to only one configuration. System installation instructions shall include how to configure the system for each voltage it is rated for (see section 51.1).

p) The instruction manual for a unit that, in accordance with 57.1.9, the abnormal test is terminated by operation of the intended branch circuit over current protective device, shall include the word "CAUTION" and the following or equivalent: "To reduce the risk of fire, connect only to a circuit provided with _____ amperes maximum branch circuit overcurrent protection in accordance with the National Electrical Code, NFPA 70 and CSA C22.1." The blank space shall be filled in with the applicable ampere rating of branch circuit overcurrent protection described in 57.1.7.

q) When a symbol is used for compliance with marking requirements mentioned in 85.3.3, 85.3.6, 85.3.8, and 85.3.10, the instruction manual shall illustrate and explain the meaning of the symbol; for example, the lightning flash with arrowhead within a triangle is intended to tell the user that parts inside the product are a risk of shock to persons.

r) The instruction manual for a unit provided with external connections for a ventilating means in accordance with 16.6 shall be provided with the following or the equivalent statements: "This equipment requires the use of an electrically interlocked ventilating means during indoor charging or discharging of vehicles requiring ventilation during charging. When equipment does not energize the connection to the vehicle during indoor charging or discharging of vehicles requiring ventilating during charging, verify that:

1) The ventilating means is properly connected;

2) The ventilating means is operating properly; and

3) The ventilation path is free of obstructions."

When the unit is only capable of power export functions, then word “charging” can be omitted from the instructions.

Table 87.1
Tightening Torque for Pressure Wire Connectors Having Screws

Size of wire that is to be used for connection of the unit		Tightening torque, N·m (pound-inches)							
		Slotted head No. 10 and larger[a]				Hexagonal head – external drive socket wrench			
		Slot width – 1.2 mm (0.047 inch) or less and slot length 6.4 mm (1/4 inch) or less		Slot width – over 1.2 mm (0.047 inch) or slot length-over 6.4 mm (1/4 inch)		Split-bolt connectors		Other Connections	
AWG /kcmil	(mm^2)								
18 – 10	(0.82 – 5.3)	2.3	(20)	4.0	(35)	9.0	(80)	8.5	(75)
8	(8.4)	2.8	(20)	4.5	(40)	9.0	(80)	8.5	(75)
6 – 4	(13.3 – 21.2)	4.0	(35)	5.1	(45)	18.6	(165)	12.4	(110)
3	(26.7)	4.0	(35)	5.6	(50)	31.1	(275)	16.9	(150)
2	(33.6)	4.5	(40)	5.6	(50)	31.1	(275)	16.9	(150)
1	(42.4)	–		5.6	(50)	31.1	(275)	16.9	(150)
1/0 – 2/0	(53.5 – 67.4)	–		5.6	(50)	43.5	(385)	20.3	(180)
3/0 – 4/0	(85.0 – 107.2)	–		5.6	(50)	56.5	(500)	28.2	(250)
250 – 350	(127 – 177)	–		5.6	(50)	73.4	(650)	36.7	(325)

Table 87.1 Continued on Next Page

Table 87.1 Continued

Size of wire that is to be used for connection of the unit		Tightening torque, N·m (pound-inches)					
		Slotted head No. 10 and larger[a]		Hexagonal head – external drive socket wrench			
		Slot width – 1.2 mm (0.047 inch) or less and slot length 6.4 mm (1/4 inch) or less	Slot width – over 1.2 mm (0.047 inch) or slot length-over 6.4 mm (1/4 inch)	Split-bolt connectors		Other Connections	
AWG /kcmil	(mm^2)						
400	(203)	–	5.6 (50)	93.2	(825)	36.7	(325)
500	(253)	–	5.6 (50)	93.2	(825)	42.4	(375)
600 – 750	(304 – 380)	–	5.6 (50)	113.0	(1000)	42.4	(375)
800 – 1000	(406 – 508)	–	5.6 (50)	124.3	(1100)	56.5	(500)
1250 – 2000	(635 – 1016)	–	–	124.3	(1100)	67.8	(600)

NOTE – Connectors having clamping screw with multiple tightening means (for example, a slotted, hexagonal head screw) shall be tested using both values of torque.

[a] For values of slot width or length not corresponding to those specified, select the largest torque value associated with the conductor size. Slot width is the nominal design value. Slot length shall be measured at the bottom of the slot.

Table 87.2
SI Equivalents

N·m	Pound-inches	N·m	Pound-inches	N·m	Pound-inches
1.7	(15)	12.4	(110)	42.4	(375)
2.3	(20)	14.1	(125)	43.5	(385)
2.8	(25)	15.3	(135)	45.2	(400)
3.4	(30)	16.9	(150)	56.5	(500)
4.0	(35)	18.6	(165)	62.1	(550)
4.5	(40)	20.3	(180)	67.8	(600)
5.1	(45)	22.6	(200)	73.4	(650)
5.6	(50)	25.4	(225)	76.3	(675)
6.8	(60)	28.2	(250)	90.4	(800)
7.3	(65)	31.1	(275)	93.2	(825)
8.5	(75)	33.9	(300)	111.7	(900)
9.0	(80)	35.6	(315)	113.0	(1000)
10.2	(90)	36.7	(325)	124.3	(1100)

Table 87.3
Tightening Torque for Pressure Wire Connectors Having Internal Drive Socket Head Screws

Socket size across flats		Tightening torque	
mm	(inch)[a]	N·m	(pound-inches)
3.2	(1/8)	5.1	(45)
4.0	(5/32)	11.40	(100)
4.8	(3/16)	13.8	(120)
5.6	(7/32)	17.0	(150)

Table 87.3 Continued on Next Page

Table 87.3 Continued

Socket size across flats		Tightening torque	
mm	(inch)[a]	N·m	(pound-inches)
6.4	(1/4)	22.6	(200)
7.9	(5/16)	31.1	(275)
9.5	(3/8)	42.4	(375)
12.7	(1/2)	56.5	(500)
14.3	(9/16)	67.8	(600)

[a] See NOTE in Table 87.1 for screws with multiple tightening means.

Table 87.4
Termination Markings

Temperature rating of wire that is intended to be used for connection of the unit	Copper conductors only	Aluminum conductors or copper-clad conductors[a]
60 or 75 °C	"Use either (b) AWG, 60 °C or (c) AWG, 75 °C copper wire"	"Use 60 °C wire, either (b) AWG copper or (b) AWG aluminum; or 75 °C wire, either (c) AWG copper or (c) AWG aluminum"
60 °C	"Use (b) AWG, 60 °C copper wire"	"Use 60 °C wire, either (b) AWG copper or (b) AWG aluminum"
75 °C	"Use (c) AWG, 75 °C copper wire"	"Use 75 °C wire, either (c) AWG copper or (c) AWG aluminum"
90 °C	"Use (c) AWG, 90 °C copper wire"	"Use 90 °C wire, either (c) AWG copper or (c) AWG aluminum"

[a] Reference to copper wire is included when wiring terminals are applicable for only the conductors specified in 85.2.8(b).

[b] The wire size for 60 °C wire is not required to be included in the marking; however, when it is included, it shall be based on the ampacities given in Table 310-16 of NFPA 70 and CSA C22.1, for 60 °C wire and the derating factor described in 14.1.1.3.

[c] The conductor size shall be no smaller than the larger of the following:

1) The conductor size used for the temperature test (see 54.2); or

2) The 75 °C wire size based on the ampacities given in Table 310-16 of NFPA 70 and CSA C22.1, and the derating factor described in 14.1.1.3.

87.3 The instructions for a unit shall include below information as applicable to the particular unit.

GROUNDING INSTRUCTIONS – This unit is to be connected to a grounded, metal, permanent wiring system; or an equipment-grounding conductor is to be run with circuit conductors and connected to equipment-grounding terminal or lead on the unit. Connections to the unit shall comply with all local codes and ordinances.

88 Assembly Instructions

88.1 The assembly instructions, where applicable, shall contain all information required for proper assembly of parts, such as wheels and handles and shall be preceded by the heading "ASSEMBLY INSTRUCTIONS," or the equivalent.

88.2 With reference to 7.1.6, a fixed unit shall be provided with instructions indicating that the 6.1 m (20 feet) of an outdoor motor fuel dispensing device.

89 Operating Instructions

89.1 The operating instructions shall contain all information required to operate the unit properly and shall be preceded by the heading "OPERATING INSTRUCTIONS," or the equivalent.

89.2 The operating instructions shall:

a) Warn that the unit is to be properly assembled in accordance with the assembly instructions before it is used.

b) Explain and describe the location, function, and operation of each control of the unit, including all user-operated devices intended to reduce the risk of fire, electric shock, or injury to persons; and warn against tampering with such devices.

c) Explain any automatic features when the marking on the unit includes the word "Automatic" such as "Automatic Power Export Equipment" or "Automatic Circuit Protector."

90 Maintenance Instructions

90.1 The instructions for user maintenance shall include explicit instructions for all cleaning and minor servicing – lubrication, external adjustments, and similar functions – that are to be performed by the user; and shall warn the user that all other servicing is to be performed by qualified service personnel. User maintenance instructions shall be preceded by the heading "MAINTENANCE INSTRUCTIONS," or the equivalent.

90.2 The user maintenance instructions, as described in 90.1, shall not include operations that require disassembly of the unit to accomplish.

91 Moving and Storage Instructions

91.1 When moving or storage of a unit results in damage to the unit that creates risk of fire, electric shock, or injury to persons during subsequent use, the instruction manual shall include explicit instructions for proper moving and storage. Such instructions shall be preceded by the heading "MOVING AND STORAGE INSTRUCTIONS," or the equivalent.

Annex A (Normative for Canada and Informative for the US) – French Translations

Clause	English	French
85.3.3	"CAUTION" and the following or the equivalent: "Risk of electric shock (or fire as applicable) – Plates (or other word describing the type of part) are live. Disconnect unit before servicing."	« ATTENTION » suivi du libellé suivant ou l'équivalent : « Risque de choc électrique (ou d'incendie selon le cas) – Les plaques (ou tout autre mot décrivant le type de pièce) sont sous tension. Débrancher l'unité avant l'entretien. »
85.3.4	"CAUTION – Risk of injury" and the following or the equivalent "Hot surfaces - To reduce the risk of burns – Do not touch."	« ATTENTION – Risque de blessure » suivi du libellé suivant ou l'équivalent « Surfaces chaudes – Pour réduire le risque de brûlures – Ne pas toucher ».
85.3.5	"CAUTION – Risk of electric shock and fire" and the following or the equivalent: "To reduce the risk of electric shock and fire – Do not connect to a circuit operating at more than 150 volts to ground."	« ATTENTION – Risque de choc électrique et d'incendie » suivi du libellé suivant ou l'équivalent : « Pour réduire le risque de choc électrique et d'incendie – Ne pas raccorder à un circuit fonctionnant à plus de 150 volts à la terre. »
85.3.6	"CAUTION – Risk of electric shock" and the following warning or equivalent: "Risk of electric shock, do not remove cover. No user serviceable parts inside. Refer servicing to qualified service personnel."	« ATTENTION – Risque de choc électrique » suivi de l'avertissement suivant ou l'équivalent : « Risque de choc électrique, ne pas enlever le couvercle. Aucune pièce pouvant être réparée par l'utilisateur ne se trouve à l'intérieur. Confier l'entretien à du personnel d'entretien qualifié. »
85.3.7	"WARNING – Risk of fire" and the following or the equivalent: "To reduce the risk of fire, replace only with same type and ratings of fuse."	« AVERTISSEMENT – Risque d'incendie » suivi du libellé suivant ou l'équivalent : « Pour réduire le risque d'incendie, remplacer uniquement par des fusibles de même type et de même courant nominal. »
85.3.8	"CAUTION – Risk of electric shock" and the following or equivalent wording: "Capacitor stores hazardous energy. Do not remove cover until ___ minutes after disconnecting all sources of supply."	« ATTENTION – Risque de choc électrique » suivi du libellé suivant ou l'équivalent : « Le condensateur emmagasine de l'énergie dangereuse. Ne pas retirer le couvercle avant ___ minutes après avoir débranché toutes les sources d'alimentation. »
85.3.9	"CAUTION – Risk of electric shock and/or electric energy-high current levels" and the following or equivalent wording: "Disconnect and discharge (identify capacitor) before removing panel as follows."	« ATTENTION – Risque de choc électrique et/ou de niveaux élevés de courant d'énergie électrique » suivi du libellé suivant ou l'équivalent : « Débrancher et décharger (identifier le condensateur) avant de retirer le panneau de la façon suivante. »
85.3.10	"CAUTION – Risk of electric shock" and the following or the equivalent: "(Identify part or parts not earth grounded) (is) (are) not grounded – (it) (they) present(s) risk of electric shock. Test before touching."	« ATTENTION – Risque de choc électrique » suivi du libellé suivant ou l'équivalent : (identifier la ou les pièces qui ne sont pas mises à la terre) – si elles présentent un risque de choc électrique. Faire un essai avant d'y toucher. »
85.3.11	"CAUTION – Risk of electric shock or electric energy-high current levels" and the following or the equivalent: "Dangerous electric charge is sometimes stored in (identify capacitor) and associated circuitry. Test before touching."	« ATTENTION – Risque de choc électrique ou de niveaux élevés de courant d'énergie électrique » suivi du libellé suivant ou l'équivalent : « Une charge électrique dangereuse est parfois emmagasinée dans (identifier le condensateur) et dans les circuits connexes. Faire un essai avant d'y toucher. »
85.3.13	"WARNING" and the following or the equivalent: "This equipment is not intended for indoor charging or discharging of vehicles requiring ventilation during charging." "WARNING" and the following or the equivalent: "This equipment is intended only for charging vehicles not requiring ventilation during charging or discharging."	« AVERTISSEMENT » suivi du libellé suivant ou l'équivalent : « Cet équipement n'est pas destiné à uneutilisation intérieure dede recharge ou de décharge de véhicules nécessitant une ventilation pendant la recharge. » « AVERTISSEMENT » suivi du libellé suivant ou l'équivalent : « Cet équipement est destiné uniquement à la recharge de véhicules qui ne nécessitent pas de ventilation pendant la recharge ou la décharge. »
85.3.14	"WARNING" and the following or the equivalent: "Proper Ventilation is required to reduce the Risk of Hazardous or Explosive gas build up during indoor charging or discharging."	« AVERTISSEMENT » suivi du libellé suivant ou l'équivalent : « Une ventilation adéquate est exigée pour réduire le risque d'accumulation de gaz dangereux ou explosifs pendant la recharge ou la décharge à l'intérieur. »

Clause	English	French
85.3.15	"CAUTION" and the following words "Risk Of Electric Shock –" and the following or the equivalent: "Multiple power sources are terminated inside this equipment. Each circuit must be individually disconnected before servicing".	« ATTENTION » et les mots suivants « Risque de choc électrique – » suivi du libellé suivant ou l'équivalent : « Plusieurs sources d'alimentation ont leur terminaison à l'intérieur de cet équipement. Il est impératif que chaque circuit soit débranché individuellement avant l'entretien. »
87.2(p)	"CAUTION" and the following or equivalent: "To reduce the risk of fire, connect only to a circuit provided with _____ amperes maximum branch circuit overcurrent protection in accordance with the National Electrical Code, NFPA 70 and CSA C22.1."	« ATTENTION » suivi du libellé suivant ou l'équivalent : « Pour réduire le risque d'incendie, brancher uniquement à un circuit doté d'une protection maximale de _____ ampères contre les surintensités de la dérivation, conformément au National Electrical Code, ANSI/NFPA 70 et à CSA C22.1. »