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JOINT CANADA-UNITED STATES
NATIONAL STANDARD

ANSI/CAN/UL/ULC 2200:2020

STANDARD FOR SAFETY

Stationary Engine Generator Assemblies

Approved American National Standard
ANSI
ANSI/UL 2200-2020

Standards Council of Canada
Conseil canadien des normes

SCC FOREWORD

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UL Standard for Safety for Stationary Engine Generator Assemblies, ANSI/CAN/UL/ULC 2200

Third Edition, Dated September 29, 2020

Summary of Topics

This New Edition of ANSI/CAN/UL/ULC 2200 includes several substantive changes and new requirements to address current technology.

The requirements are substantially in accordance with Proposal(s) on this subject dated September 20, 2019 and May 1, 2020.

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ANSI/UL 2200-2020

ANSI/CAN/UL/ULC 2200:2020

Standard for Stationary Engine Generator Assemblies

First Edition – October, 2011
Second Edition – December, 2013

Third Edition

September 29, 2020

This ANSI/CAN/UL/ULC Safety Standard consists of the Third Edition.

The most recent designation of ANSI/UL 2200 as an American National Standard (ANSI) occurred on September 29, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on September 29, 2020.

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Preface

This is the Third Edition of ANSI/CAN/UL/ULC 2200, Standard for Safety for Stationary Engine Generator Assemblies.

UL is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO). ULC Standards is accredited by the Standards Council of Canada (SCC) as a Standards Development Organization (SDO).

This Standard has been developed in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization.

This ANSI/CAN/UL/ULC 2200 Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

Annex A is identified as Normative, as such, form mandatory parts of this Standard.

Annex B, identified as Informative, is for information purposes only.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

This joint American National Standard and National Standard of Canada is based on, and now supersedes, the Second Edition of UL 2200.

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

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

This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Stationary Engine Generator Assemblies, STP 2200.

This list represents the STP 2200 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

STP 2200 Membership

Name	Representing	Interest Category	Region
Mathher Abbassi	NYC Dept of Buildings	AHJ	USA
Blake Allen	Marex Canada Limited	AHJ	Alberta, Canada
Phillip Brehe	Solar Turbines	Producer	USA
Donald Cook	Shelby County	AHJ	USA
Bret Dalton	GE – Gas Power and Power Services	Producer	USA
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This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

CETTE NORME NATIONALE DU CANADA EST DISPONIBLE EN VERSIONS FRANÇAISE ET ANGLAISE

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INTRODUCTION

1 Scope

1.1 These requirements cover stationary engine generator assemblies that are intended for installation and use in ordinary locations in accordance with the following:

a) The National Electrical Code, NFPA 70;

b) The Canadian Electrical Code, Part I, CSA C22.1;

c) The Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines, NFPA 37;

d) Natural Gas and Propane Installation Code, CSA B149.1;

e) The Code for Digester Gas, Landfill Gas, Biogas Generation and Utilization, ANSI/CSA B149.6;

f) The Installation Code for Oil-Burning Equipment, CSA B139;

g) The Standard for Health Care Facilities, NFPA 99;

h) The Code for Canadian Health Care Facilities, CSA Z8000;

i) The Standard for Emergency, Standby Power Systems, NFPA 110; and

j) Emergency Electrical Power Supply for Building, CSA C282.

1.2 Units that incorporate a pressure vessel shall comply with the following:

a) ASME Boiler and Pressure Vessel Code;

b) Boiler, Pressure Vessel, and Pressure Piping Code, CSA B51;

c) Process Piping, ASME B31.3; and

d) Gas-Fired Low Pressure Steam and Hot Water Boilers, ANSI Z21.13 / CSA 4.9

1.3 Hazards addressed by this Standard include electrical (energy, shock, explosion, and fire), mechanical (enclosures and moving parts), fuel related (containment and flow control for liquid and gaseous fuels including purge / dilution functions), and prime mover related hazards.

1.4 These requirements do not cover engine generator assemblies for use in hazardous (Classified) locations.

1.5 These requirements do not cover engine generator assemblies for shipboard marine applications.

2 Components

2.1 Except as indicated in 2.2, a component or auxiliary equipment used as a part of a unit covered by this Standard shall comply with the requirements for that component. A component shall comply with both the applicable United States and Canadian Standards.

2.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

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

2.4 Components that are incomplete in construction features or restricted in performance capabilities shall be used only under the specific conditions for which they have been evaluated.

3 Units of Measurement

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

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

4 Glossary

4.1 In the text of this Standard, the term "unit" refers to any product covered by this Standard.

4.2 For the purpose of this Standard, the following definitions apply.

4.3 AC CONVENIENCE RECEPTACLE – A receptacle that is intended for general use.

4.4 AMBIENT AIR TEMPERATURE – The temperature, determined under prescribed conditions, of the air surrounding the complete engine generator assembly, switching device or fuse. [IEC 60050-441: IEV ref 441-11-13, modified]

NOTE: For engine generator assemblies, switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

4.5 AUTOMATIC SAFETY SHUTOFF VALVE (ASSV) – A device consisting of a valve and operator that controls the fuel supply to the engine. The operator may be actuated by the application of fuel pressure on a flexible diaphragm, by electrical means, by mechanical means, or some other means. The valve serves as a safety device that closes upon command from the automatic engine shutdown sensor or programmable control.

4.6 AUTOMATIC VALVE – A valve which controls the flow of fuel to the engine during normal operation, and will automatically shut off the flow of fuel to the engine in case the engine stops for any cause. Automatic valves include zero governor type regulating valves, safety shutoff valves, and combination metering safety shutoff valves. Also see 4.5.

4.7 AUTOMATIC SAFETY VENT VALVE (ASVV) – A valve that is automatically opens by the safety control system or by an emergency device.

4.8 BARRIER – A means of isolating that reduces the risk of access to a part that involves a risk of fire, electric shock, injury to persons, or electrical energy – high current levels. See 4.64 and 4.65.

4.9 BATTERY CASE/COVER – The container that directly encloses and confines the electrolyte of a battery or cell.

4.10 BATTERY, VALVE-REGULATED – A battery in which the venting of the products of electrolysis is controlled by a reclosing pressure-sensitive valve.

4.11 BATTERY, VENTED – A battery in which the products of electrolysis and evaporation escape freely to the atmosphere. These batteries have commonly been referred to as "flooded" or "wet."

4.12 BUS BAR – A conductor or an assembly of conductors for collecting electric currents and distributing them to outgoing feeders.

4.13 CAST INSULATED or CAST INSULATION – A polymeric insulating material applied to conductors, components or equipment such as transformers, windings, bus bars or coils. Cast insulated components are typically potted or fully impregnated with an epoxy resin.

4.14 CELL – The main components are two electrodes of dissimilar material separated from one another by a common ionically conductive electrolyte, that are intended to convert chemical energy directly into electrical energy.

4.15 CLASS 1 POWER LIMITED CIRCUIT – A circuit which is supplied from a source having a rated output of not more than 30 V and 1000 VA. This is often wiring between the protective overcurrent device and connected load equipment.

4.16 CLASS 2 CIRCUIT – A circuit which is supplied from a Class 2 transformer.

4.17 CLASS 2 TRANSFORMER – A step-down transformer complying with the applicable requirements in CSA C22.2 No. 66-1 / UL 5085-1 and CSA C22.2 No. 66.3 / UL 5085-3.

4.18 CLASS 3 CIRCUIT – In the US, a circuit which is supplied from a Class 3 Transformer.

In Canada, Class 3 circuits are not recognized in the Canadian Electrical Code, Part I.

4.19 CLEARANCE – The shortest distance through air spacing between two conductive parts.

4.20 COMPONENT – Refers to subassemblies used in the construction of the generating assembly.

4.21 CONDUCTIVE PART – A part which is capable of conducting current, although it is not necessarily used for carrying current. [IEC 60050-441: IEV ref 441-11-09, modified]

4.22 CONTROL CIRCUIT – A circuit used for monitoring and or control of an engine generator assembly.

4.23 CONTROL POWER TRANSFORMER (CPT) – A transformer utilized to supply voltage for control circuits and auxiliary devices.

4.24 COVER – An unhinged portion of an enclosure that covers an opening.

4.25 CREEPAGE DISTANCE – The shortest distance along the surface of an insulating material between two conductive parts.

4.26 DEDICATED PURPOSE GENERATOR OUTLET / RECEPTACLE – A receptacle used to supply power to specific purpose generator components or accessories such as block heaters, oil heaters, and battery chargers.

4.27 DEGREE OF PROTECTION – The extent of protection provided by an enclosure or guard to prevent access to moving parts.

4.28 DOOR – A hinged portion of an enclosure that covers an opening.

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

4.30 ELECTRONIC FORMAT – Any electronic media content (other than computer programs or system files) provided on commonly available physical media or internet link, which is intended to be used in either an electronic form (such as a text file or PDF) or as printed output derived from the electronic document.

4.31 ENCLOSURE – That portion of a unit that:

a) Reduces the accessibility of a part that involves a risk of fire, electric shock or injury to persons; or

b) Reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

4.32 ENGINE – A prime mover machine that converts energy into motion that may consume fuel in the process.

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

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

4.35 GENERATOR ASSEMBLY – Refers to the assembly, consisting of the engine and generator/alternator.

4.36 GROUND – The earth.

4.37 GROUNDING KIT – A grounding terminal means intended to be field-connected or factory-installed, consisting of connectors (lugs) and hardware, such as bolts, studs, or screws, and suitable for connecting a conductor 14 AWG (2.08 mm^2) or larger to equipment required to be grounded, which is in addition to the means for securing conduit or cable armor. It is not intended that a grounding kit consist merely of screws for direct attachment of grounding conductors.

In Canada, a grounding kit can also be referred to as a bonding kit.

4.38 HEAT SINK – A piece of thermally conductive metal attached to a semiconductor or other electronic device and designed to prevent it from overheating by conducting heat away from it and radiating it to the environment.

4.39 IMPULSE WITHSTAND VOLTAGE – The specified peak value of impulse voltages, of prescribed form and polarity, that does not cause breakdown under specified conditions of test.

4.40 INSULATION CLASS – The classification of insulation materials for the purpose of establishing temperature limits for the use of the material.

4.41 INTERLOCK – A means relied upon to reduce the accessibility to an area that results in risk of electric shock, electrical energy – high current levels, or injury to persons until the risk has been removed, or to automatically remove the risk when access is gained.

4.42 ISOLATING MEANS (isolating switch or disconnector) – A mechanical switching device that provides, in the open position, isolating distance in the main circuit from the source of power. [IEC 60050-441: IEV ref 441-14-05, modified]

4.43 LIMITED-ENERGY CIRCUIT – An ac or dc circuit having a voltage not exceeding 1000 volts and the energy limited to 100 volt-amperes by any of the following:

a) Secondary winding of a transformer;

b) One or more resistors complying with 26.10; or

c) A regulating network complying with 26.11.

4.44 LINEAR LOAD – A load that does not rectify the current or otherwise alter the current wave shape, resulting in a load current that is proportional to the instantaneous voltage.

4.45 LIVE PART – Denotes metal or a conductive part within the unit that during intended use involves a risk of electric shock.

4.46 LOW-VOLTAGE – For this Standard, ac voltage in the range of 50 to 1,000 Vac and 1,500 Vdc (in Canada, 30 to 750 V). The applicable installation codes refer to voltages above 1,000 Vrms (750 Vrms in Canada) as “high voltage”.

4.47 LOW-VOLTAGE, LIMITED-ENERGY (LVLE) CIRCUIT – A circuit involving an alternating current voltage of not more than 30 Vrms (15 Vrms wet), 42.4 V peak (24.2 V peak wet) or a direct current voltage of not more than 42.4 V (30 V wet) and supplied by:

a) An inherently limited Class 2 transformer or a not inherently limited Class 2 transformer 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 provided with a marking in accordance with 94.7.

b) A combination of an isolated transformer secondary winding and one or more resistors or a regulating network complying with 26.11 that complies with all the performance requirements for an inherently limited Class 2 transformer or power source; or

c) A battery that is isolated from the primary circuit or a combination of a battery, including the battery charging circuit of a unit that is isolated from the primary circuit, and one or more resistors or a regulating network complying with 26.11.

The DC dry voltage limit is 60 V in the US and 42.4 V in Canada, and this Standard includes the lower value for consistency.

4.48 MECHANICAL GUARD (or partition) – A part, barrier, or enclosure that reduces the risk of access to or separating a component from another or prevents the splashing, dripping or spraying of coolant, oil, or fuel that has the potential of causing an electrical fire, fuel fire hazard, or injury to persons.

4.49 MEDIUM-VOLTAGE – For this Standard, a voltage over 1,000 Vac or 1,500 Vdc (in Canada, over 750 V), up to 46 kV. The applicable installation codes refer to voltages above 1,000 Vrms (750 Vrms in Canada) as “high voltage”.

4.50 MEDIUM-VOLTAGE COMPARTMENT – A compartment containing one or more medium-voltage components.

4.51 MEDIUM-VOLTAGE FUSE – A current-limiting fuse intended for use in medium-voltage circuits, capable of interrupting all currents from the rated maximum interrupting current down to the rated minimum interrupting current (where applicable).

NOTE: See IEEE C37.40, which categorizes different types of current-limiting fuses based on their minimum interrupting current capability:

a) BACKUP CURRENT-LIMITING FUSE – a current-limiting fuse capable of interrupting all currents from its rated maximum interrupting current down to its rated minimum interrupting current.

b) FULL-RANGE CURRENT-LIMITING FUSE – a current-limiting fuse capable of interrupting, under specified conditions, all currents from its rated maximum interrupting current down to the minimum continuous current that can cause the fusible element to melt.

c) GENERAL-PURPOSE CURRENT-LIMITING FUSE – a current-limiting fuse capable of interrupting all currents from its rated interrupting current down to the current that causes melting of the fusible element(s) in one hour or more.

4.52 MODULE – A packaged functional assembly component of the generator assembly, such as engine module or generator module.

4.53 OPERATING VOLTAGE – The voltage across two points occurring due to normal operation of the product when controls are set in any position.

4.54 OUTPUT RECEPTACLE – A receptacle that is intended to carry the output power of the generator.

4.55 OVERCURRENT – A current exceeding the rated continuous current. Overcurrents can result from motor starting, overload, short-circuit, or ground faults.

4.56 OVERLOAD – Equipment operating condition exceeding normal rated current or power.

4.57 OVERVOLTAGE CATEGORY – Grouping of products based on typical installed location with respect to overvoltage protection and available energy.

4.58 POLLUTION – Any addition of contaminants, solid, liquid, or gaseous (ionized gases), and moisture that may produce a reduction of dielectric strength or surface resistivity.

4.59 POLLUTION DEGREE – The level of pollution present at the location on or in a product where the clearance and creepage distance measurement is made and can be controlled by design of the product. For example, enclosures can be used to achieve pollution degree 3, heaters within non-ventilated enclosures can help achieve pollution degree 2, and encapsulation can be used to achieve pollution degree 1.

4.60 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 a pressure terminal connector are the:

a) Barrel and setscrew type;

b) Crimp-type barrel; or

c) Clamping plate and screw type.

4.61 PRIMARY CIRCUIT – Wiring and components that are conductively connected to a power output and or branch circuit.

4.62 RESTRICTED ACCESS AREA – A location for equipment where the following apply:

a) Access is only gained by service personnel who have been instructed of the reasons for the restrictions applied to the location and about any precautions that must be taken; and

b) Access is through the use of a special tool or other means of security and is controlled by the authority responsible for the rotating equipment or live component location.

4.63 RISK – Combination of the probability of occurrence of harm (i.e. physical injury or damage to health) and the severity of harm. [ISO 12100, 3.12, modified]

4.64 RISK OF ELECTRIC SHOCK – As defined in Electric Shock, Section 9.

4.65 RISK OF ELECTRICAL ENERGY – HIGH CURRENT LEVELS – The risk for damage to property or injury to persons, other than by electric shock, from available electrical energy is determined to exist, when between a live part and an adjacent dead metal part or between live parts of different polarity, there exists a potential of 2 V or more and either:

a) An available continuous power level of 240 VA or more; or

b) A reactive energy level of 20 J or more.

For example, a tool, or other metal short-circuiting a component is capable of causing a burn or a fire when enough energy is available at the component to vaporize, melt, or more than warm the metal.

4.66 RISK OF FIRE – A risk of fire exists at any component unless an investigation of the supply delivering power to that component complies with the criteria in 26.4 – 26.12.

4.67 SAFETY CIRCUIT – Any primary or secondary circuit that is relied upon 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 a safety circuit.

4.68 SAFETY FUNCTION – Function of a machine whose failure can result in an immediate increase of risk(s). [ISO 12100, 3.30]

4.69 SECONDARY CIRCUIT – A circuit supplied from a secondary winding of an isolating transformer. See Section 31, Transformers.

4.70 SERVICE DISCONNECTING MEANS or SERVICE DISCONNECT – Isolating means that disconnects all conductors into a building or other structure from the service entrance conductors.

4.71 SERVICE PERSONNEL – Persons having technical training and experience required to be aware of the risks encountered when performing a task and the measures to be taken to minimize the risks to themselves and other persons. Service personnel tasks include periodic engine maintenance like changing oil and filters.

4.72 SKIN-TIGHT ENCLOSURE – An enclosure where required clearances are provided through the exterior to the enclosure with maintenance access to parts of the engine generator set from the outside of the enclosure with no accessibility to uninsulated live electrical components.

4.73 STATIONARY – A unit that is intended to be hard wired and/or permanently installed.

4.74 SWITCH, LOCKOUT – An indicating type switch that provides a means to disconnect all ungrounded conductors and is also provided with a positive lockout in the "off" position.

4.75 SWITCH, TRANSFER – A device for transferring one or more load conductor connections from one power source to another.

4.76 SYNCHRONIZATION – The matching of the voltage amplitude, phase angle, and frequency of the output of a generator with the amplitude, phase angle, and frequency of other generators, the electric power system or electric utility.

4.77 TOOL – A screwdriver, wrench, or any other special object that is a service access tool that is used to operate a screw, latch, or similar fastening means.

4.78 USER – Any person other than service personnel. Sometimes referred to as operator.

4.79 USER ACCESS AREA – An area to which, under normal operating conditions, one of the following applies:

a) Access is gained without the use of a tool;

b) The means of access is deliberately provided to the user; or

c) The user is instructed to enter regardless of whether or not tools are required to gain access. This includes control panels, behind locked doors, and inside of access covers with guarding or barriers in place to prevent the user from accessing rotating machinery or live components.

4.80 UTILITY-INTERACTIVE – A generator intended for use in parallel with an electric utility or electric power system to supply common local area / micro grid system loads and sometimes deliver power to the utility.

4.81 WALK-IN ENCLOSURE – An enclosure that allows an operator or service person to enter inside the generator enclosure.

4.82 WEATHER ENCLOSURE – An enclosure for outdoor use that is integral to the engine generator and protects the engine generator assembly from the wetting of live parts in an outdoor environment while the unit is operating or is in standby.

4.83 WRITTEN FORMAT – A printed document, label, or molded text provided in a physical form as part of or with the product.

4.84 ZERO GOVERNOR REGULATOR (vacuum demand regulator) – A fuel regulating device that allows fuel flow when a partial vacuum is applied to the regulator output port. The regulator stops fuel flow when vacuum demand on the output port is discontinued.

5 Referenced Publications

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.

5.2 Throughout this Standard, the CSA and ULC standard references apply to products intended for use in Canada, while the UL standard references apply to products intended for use in the United States. Combined references are separated by a slash (“ / ”) to denote the difference between the applicable requirements specified for use in Canada and the United States.

5.3 The following publications are referenced in this Standard:

Canada	United States
ANSI Z21.13 / CSA 4.9, Gas-Fired Low Pressure Steam and Hot Water Boilers	ANSI Z21.13 / CSA 4.9, Gas-Fired Low Pressure Steam and Hot Water Boilers
ANSI Z21.18 / CSA 6.3, Gas Appliance Pressure Regulators	ANSI Z21.18 / CSA 6.3, Gas Appliance Pressure Regulators
ANSI Z21.21 / CSA 6.5, Automatic Valves for Gas Appliances	ANSI Z21.21 / CSA 6.5, Automatic Valves for Gas Appliances
ANSI Z21.80 / CSA 6.22, Line Pressure Regulators	ANSI Z21.80 / CSA 6.22, Line Pressure Regulators
ASME B1.20.1, Pipe Threads, General Purpose (Inch)	ASME B1.20.1, Pipe Threads, General Purpose (Inch)
ASME B31.3, Process Piping	ASME B31.3, Process Piping
ASME B31.11, Slurry Transportation Piping Systems	ASME B31.11, Slurry Transportation Piping Systems
ASME B36.10M, Welded and Seamless Wrought Steel Pipe	ASME B36.10M, Welded and Seamless Wrought Steel Pipe
ASME B36.19M, Stainless Steel Pipe	ASME B36.19M, Stainless Steel Pipe
ASTM A90, Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings	ASTM A90, Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
ASTM B117, Standard Practice for Operating Salt Spray (Fog) Apparatus	ASTM B117, Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM A179 / A179M, Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes	ASTM A179 / A179M, Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
ASTM E230/E230M, Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples	ASTM E230/E230M, Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
ASTM D412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers Tension	ASTM D412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers Tension
ASTM D471, Standard test method for rubber property – Effect of liquids, ASTM F152, Standard Test Methods for Tension Testing of Nonmetallic Gasket Materials	UL 157, Gaskets and Seals
ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process	ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM F1120, Standard Specification for Circular Metallic Bellows Type Expansion Joints for Piping Applications	ASTM F1120, Standard Specification for Circular Metallic Bellows Type Expansion Joints for Piping Applications
ASTM D1525, Standard Test Method for Vicat Softening Temperature of Plastics	ASTM D1525, Standard Test Method for Vicat Softening Temperature of Plastics
CAN/CGSB 12.1-M90, Tempered or Laminated Safety Glass	ANSI Z97.1, Safety glazing Materials Used in Buildings – Safety Performance Specifications and Methods of Test
CSA C22.2 No. 0.2, Insulation Coordination	UL 840, Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment
CSA C22.2 No. 0.15, Adhesive Labels	UL 969, Marking and Labeling Systems
CSA C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials	UL 746C, Polymeric Materials – Use in Electrical Equipment Evaluations
CSA C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials	UL 796, Printed-Wiring Boards

Canada	United States
CSA C22.2 No. 0.19, Requirements for Service Entrance Equipment	UL 869A, Reference Standard for Service Equipment
CSA C22.2 No. 0.22, Evaluation Methods for Arc Resistance Ratings of Enclosed Electrical Equipment	IEEE C37.20.7, Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults
CSA C22.2 No. 0.8, Safety functions incorporating electronic technology	UL 1998, Software in Programmable Components
CSA C22.2 No. 5, Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures	UL 489, Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
CSA C22.2 No. 8, Electromagnetic Interference (EMI) Filters	UL 1283, Electromagnetic Interference Filters
CSA C22.2 No. 9.0, General Requirements for Luminaires	UL 2108, Low Voltage Lighting Systems
CSA 8.3, Thermoplastic Hose And Hose Couplings For Conducting Propane And Natural Gas	UL 21, LP-Gas Hose UL 569, Pigtails and Flexible Hose Connectors for LP Gas
CGA-8.1, Elastomeric Composite Hose and Hose Couplings for Conducting Propane and Natural Gas	
CSA C22.2 No. 13, Transformers for Luminous-Tube Signs, Oil- or Gas-Burner Ignition Equipment, Cold-Cathode Interior Lighting	UL 506, Specialty Transformers
CSA C22.2 No. 14, Industrial Control Equipment	UL 508, Industrial Control Equipment
CSA C22.2 No. 18.1, Metallic Outlet Boxes	UL 514A, Metallic Outlet Boxes
CSA C22.2 No. 18.2, Nonmetallic Outlet Boxes	UL 514C, Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers
CSA C22.2 No. 42.1, Cover Plates for Flush-Mounted Wiring Device	UL 514D, Cover Plates for Flush-Mounted Wiring Devices
CSA C22.2 No. 18.3, Conduit, Tubing, and Cable Fittings	UL 514B, Conduit, Tubing, and Cable Fittings
CSA C22.2 No. 26, Construction and Test of Wireways, Auxiliary Gutters, and Associated Fittings	UL 870, Wireways, Auxiliary Gutters, and Associated Fittings
CSA C22.2 No. 29, Panelboards and Enclosed Panelboards	UL 67, Panelboards
CSA C22.2 No. 31, Switchgear Assemblies	IEEE 1247, IEEE Standard for Interrupter Switches for Alternating Current Rated Above 1000 Volts IEEE C37.20.2, IEEE Standard for Metal-Clad Switchgear IEEE C37.20.3, Metal-Enclosed Interrupter Switchgear (1 kV – 38 kV) IEEE C37.20.4, Indoor AC Switches (1 kV to 38 kV) for Use in Metal-Enclosed Switchgear NEMA C37.54, For Indoor Alternating Current High-Voltage Circuit Breakers Applied as Removable Elements in Metal-Enclosed Switchgear – Conformance Test Procedures NEMA C37.57, For Switchgear – Metal-Enclosed Interrupter Switchgear Assemblies – Conformance Testing NEMA C37.58, For Switchgear – Indoor AC Medium-Voltage Switches for Use in Metal-Enclosed Switchgear – Conformance Test Procedures
	NEMA CC1, Electric Power Connection for Substations
CSA C22.2 No. 42.1, Nonmetallic Outlet Boxes	UL 514C, Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers
CSA C22.2 No. 46, Electric Air Heaters	UL 499, Electric Heating Appliances
CSA C22.2 No. 47, Air-Cooled Transformers (Dry Type)	UL 1561, Dry-Type General Purpose and Power Transformers
CSA B51, Boiler, pressure vessel, and pressure piping code	ASME B31.3, Process Piping
CSA B51, Boiler, Pressure Vessel, and Pressure Piping Code	ASME Boiler and pressure vessel Code VIII Rules for Construction of Pressure Vessels, Division 1
CSA C22.2 No. 65, Wire Connectors	UL 486A-486B, Wire Connectors
CSA C22.2 No. 65, Wire Connectors	UL 486E, Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors

Canada	United States
CSA C22.2 No. 66.1, Low Voltage Transformers – Part 1: General Requirements	UL 5085-1, Low Voltage Transformers – Part 1: General Requirements
CSA C22.2 No. 66.2, Low Voltage Transformers – Part 2: General Purpose Transformers	UL 5085-2, Low Voltage Transformers – Part 2: General Purpose Transformers
CSA C22.2 No. 66.3, Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers	UL 5085-3, Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers
CSA C22.2 No. 75, Thermoplastic-Insulated Wires and Cables	UL 83, Thermoplastic-Insulated Wires and Cables
CSA C22.2 No. 94.1, Enclosures for Electrical Equipment, Non-Environmental Considerations	UL 50, Enclosures for Electrical Equipment, Non-Environmental Considerations
CSA C22.2 No. 94.2, Enclosures for Electrical Equipment, Environmental Considerations	UL 50E, Enclosures for Electrical Equipment, Environmental Considerations
CSA C22.2 No. 107.1, Power Conversion Equipment	UL 1012, Power Units Other Than Class 2
CSA C22.2 No. 107.1, Power Conversion Equipment	UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
CSA C22.2 No. 107.2, Battery Chargers	UL 1236, Battery Chargers for Charging Engine-Starter Batteries
CSA C22.2 No. 107.3, Uninterruptible Power Systems	UL 1778, Uninterruptible Power Systems
CSA C22.2 No. 100, Motors and Generators	UL 1004-4, Electric Generators
CSA C22.2 No. 111, General-Use Snap Switches	UL 20, General-Use Snap Switches
CSA C22.2 No. 139, Electrically Operated Valves	UL 429, Electrically Operated Valves UL 428A, Electrically Operated Valves for Gasoline and Gasoline/Ethanol Blends with Nominal Ethanol Concentrations Up to 85 Percent (E0 – E85) UL 428B, Electrically Operated Valves for Diesel Fuel, Biodiesel Fuel, Diesel/Biodiesel Blends with Nominal Biodiesel Concentrations Up to 20 Percent (B20), Kerosene, and Fuel Oil
CSA C22.2 No. 141, Emergency Lighting Equipment	UL 924, Emergency Lighting and Power Equipment
CSA C22.2 No. 144, Ground Fault Circuit Interrupters	UL 943C, Outline for Special Purpose Ground-Fault Circuit-Interrupters
CSA C22.2 No. 144.1, Ground-Fault Circuit-Interrupters	UL 943, Ground-Fault Circuit-Interrupters
CSA B149.1, Natural Gas and Propane Installation Code	UL 181, Factory-Made Air Ducts and Air Connectors
CSA B149.6, Code for digester gas, landfill gas, and biogas generation and utilization	ANSI/CSA B149.6, Code for digester gas, landfill gas, and biogas generation and utilization
CSA C22.2 No. 153, Electrical Quick-Connect Terminals	UL 310, Electrical Quick-Connect Terminals
CSA C22.2 No. 165, Electric Boilers	UL 834, Heating, Water Supply, and Power Boilers – Electric
CSA C22.2 No. 178.1, Transfer Switch Equipment	UL 1008, Transfer Switch Equipment
CSA C22.2 No. 190, Capacitors for Power Factor Correction	UL 810, Capacitors
CSA C22.2 No. 197, PVC Insulating Tape	UL 510, Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape
CSA C22.2 No. 198.1, Extruded Insulating Tubing	UL 224, Extruded Insulating Tubing
CSA C22.2 No. 223, Power Supplies with Extra-Low-Voltage Class 2 Outputs	UL 1310, Class 2 Power Units
CSA C22.2 No. 236, Heating and Cooling Equipment	UL 1995, Heating and Cooling Equipment
CSA C22.2 No. 250.0, Luminaires	UL 1598, Luminaires
CSA C22.2 No. 250.0, Luminaires	UL 2108, Low Voltage Lighting Systems
CSA C22.2 No. 253, Medium-Voltage AC Contactors, Controllers, and Control Centres	UL 347, Medium-Voltage AC Contactors, Controllers, and Control Centers
CSA C22.2 No. 268, Power circuit breakers up to 1000 Vac/1500 Vdc	UL 1066, Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures
CSA C282, Emergency Electrical Power Supply for Buildings	NFPA 110, Emergency and Standby Power Systems

Canada	United States
CSA C22.2 No. 295, Neutral Grounding Devices	IEEE C57.32, Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
CSA C22.2 No. 301, Industrial Electrical Machinery	NFPA 79, Electrical Standard for Industrial Machinery
CSA E60384-14, Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains	UL 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
CSA C22.2 No. 60529, Degrees of Protection Provided by Enclosures (IP Code)	IEC 60529, Degrees of Protection Provided by Enclosures (IP Code)
CSA-E60730-1, Automatic Electrical controls – Part 1: General Requirements	UL 60730-1, Automatic Electrical Controls – Part 1: General Requirements
CSA C22.2 No. 60950-1, Information Technology Equipment – Safety – Part 1: General Requirements	UL 1989, Standby Batteries
CSA C22.2 No. 61010-2-030, Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-030: Particular Requirements for Testing and Measuring Circuits	UL 61010-2-030, Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-030: Particular Requirements for Testing and Measuring Circuits
CSA C61869-1, Instrument Transformers – Part 1: General Requirements and CSA C61869-5, Instrument transformers – Part 5: Additional requirements for capacitor voltage transformers, which is an adoption, with Canadian deviations, of the identically titled IEC (International Electrotechnical Commission) Standard 61869-5 (first edition, 2011-07)	IEEE C57.13, Requirements for Instrument Transformers, and IEEE C57.13.5, Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 kV and Above
CSA C61869-1, Instrument Transformers – Part 1: General Requirements, CSA C61869-2, Instrument Transformers – Part 2: Additional Requirements for Current Transformers, CSA C61869-3, Instrument Transformers – Part 3: Additional Requirements for Inductive Voltage Transformers	IEEE C57.13, Requirements for Instrument Transformers, and IEEE C57.13.2, Conformance Test Procedure for Instrument Transformers
	UL 795, Commercial-Industrial Gas Heating Equipment
CSA Component Acceptance Service Notice No. 5, Component Acceptance Service for Optocouplers and Related Devices	UL 1577, Optical Isolators
IEC 60417 Database, Graphical Symbols for Use on Equipment	IEC 60417 Database, Graphical Symbols for Use on Equipment
IEC 60695-2-13, Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials	IEC 60695-2-13, Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials
IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems	IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 61508-2, Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems	IEC 61508-2, Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems
IEC 61508-3, Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 3: Software requirements	IEC 61508-3, Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 3: Software requirements
IEC 62061, Safety of Machinery – Functional Safety of Safety-Related Electrical, Electronic and Programmable Electronic Control Systems	IEC 62061, Safety of Machinery – Functional Safety of Safety-Related Electrical, Electronic and Programmable Electronic Control Systems
IEEE 4, High-Voltage Testing Techniques	IEEE 4, High-Voltage Testing Techniques
	IEEE C37.09, Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
	IEEE C37.40, Service Conditions and Definitions for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories

Canada	United States
ISO 10380, Pipework – Corrugated metal hoses and hose assemblies	ISO 10380, Pipework – Corrugated metal hoses and hose assemblies
ISO 13849-1, Safety Of Machinery – Safety-Related Parts Of Control Systems – Part 1: General Principles For Design	ISO 13849-1, Safety Of Machinery – Safety-Related Parts Of Control Systems – Part 1: General Principles For Design
ISO 7000, Graphical symbols for use on equipment – Registered symbols	ISO 7000, Graphical symbols for use on equipment – Registered symbols
ISO 7010, Graphical symbols – Safety colours and safety signs – Registered safety signs	ISO 7010, Graphical symbols – Safety colours and safety signs – Registered safety signs
ISO 12100, Safety of machinery – General principles for design – Risk assessment and risk reduction	ISO 12100, Safety of machinery – General principles for design – Risk assessment and risk reduction
ISO 19372, Microturbines applications – Safety	ISO 19372, Microturbines applications – Safety
National Building Code of Canada – Emergency Lighting	NFPA 101, Life Safety Code
NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines	NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
NFPA 54/ANSI Z223.1, National Fuel Gas Code	NFPA 54/ANSI Z223.1, National Fuel Gas Code
	UL 94, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
ULC-C252, Guide for the Investigation of Gas Pressure Regulators	UL 252, Compressed Gas Regulators
	UL 723, Test for Surface Burning Characteristics of Building Materials
	UL 746A, Polymeric Materials – Short Term Property Evaluations
	UL 746B, Polymeric Materials – Long Term Property Evaluations
	UL 810A, Electrochemical Capacitors
	UL 991, Tests for Safety-Related Controls Employing Solid-State Devices
ANSI/AGA NGV3.1/CGA NGV 12.3, Fuel System Components for Natural Gas Powered Vehicles	UL 1337, LP-Gas, Natural Gas, and Manufactured Gas Devices for Engine Fuel Systems
	UL 1439, Tests for Sharpness of Edges on Equipment
	UL 1446, Systems of Insulating Materials – General
	UL 1973, Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications
ANSI/CAN/UL/ULC 6200, Controllers for Use in Power Production	ANSI/CAN/UL/ULC 6200, Controllers for Use in Power Production
ANSI/CAN/UL 9540, Energy Storage Systems and Equipment	ANSI/CAN/UL 9540, Energy Storage Systems and Equipment
ANSI/CAN/UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	ANSI/CAN/UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
ULC-S111, Standard Method of Fire Tests for Air Filter Units	UL 900, Air Filter Units
ULC-S601, Shop Fabricated Steel Aboveground Tanks For Flammable And Combustible Liquids	UL 142A, Special Purpose Aboveground Tanks for Specific Flammable or Combustible Liquids
ULC/ORD-C536, Flexible Metallic Hose	UL 536, Flexible Metallic Hose
ULC/ORD-C558, Guide for the Investigation of Internal Combustion Engine-Powered Industrial Trucks	UL 558, Industrial Trucks, Internal Combustion Engine-Powered
ULC-S629, 650 Degrees C Factory-Built Chimneys	UL 103, Factory-Built Chimneys for Residential Type and Building Heating Appliances
ULC/ORD-C959, 540 Degrees C and 760 Degrees C Industrial Chimneys	UL 2561, 1400 Degree Fahrenheit Factory-Built Chimneys

CONSTRUCTION

6 Materials

6.1 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.

6.2 The requirement in 6.1 applies to those portions of a part adjacent to moving parts that involve a risk of injury to persons.

6.3 A part as specified in 6.1 shall withstand the impact test described in 80.3, without being affected to the extent that:

a) The performance 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.

Exception: A component such as a pilot lamp, lens, or control knob is not required to be subjected to the impact test.

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. 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. Terminals that do not present a risk of electric shock but do present a risk of electrical high energy levels such as battery terminals, starter relay/contactor terminals, and terminals on engine-mounted battery-charging alternators within the engine compartment shall be insulated and secured in a manner where the terminal is not able to be removed except for servicing of the part and protected from contact by:

a) An insulator that complies with the requirements in Section 38, Insulating Materials; or

b) An insulating boot/barrier made from polyvinyl-chloride, neoprene, silicone rubber or a rubber compound or material.

Exception: Live parts, including terminals, which do not present a risk of electric shock or a risk of electrical energy – high current levels, are not required to be enclosed.

7.1.2 The frame or chassis of a unit shall not be used to carry current during intended operation (see 20.11).

Exception: Engines and their components may be used to carry current for normal engine operation but the resulting voltage from the current passing through an engine part shall not exceed the voltage levels in Table 9.1.

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.

Exception: This requirement does not apply to a meter complying with the requirements in CSA C22.2 No. 61010-2-030 / UL 61010-2-030.

7.2 Enclosures and guards

7.2.1 The generator shall be evaluated for risk of injury to persons from electrical hazards, mechanical hazards and burn hazards. This shall include consideration of the results of breakdown or malfunction of any component; not more than one component at a time, unless one event contributes to another. When the investigation shows that breakdown, leak, or malfunction of a particular component can result in a hazard to service personnel or user, that component shall be investigated for reliability. Guards and protective devices shall be suitable for the intended use and hazards involved and shall not be easily defeated. Whether a mechanical guard, a release, an interlock, or similar device is required and whether such a device is applicable shall be determined from an investigation of the complete unit, its operating characteristics, and the risk of injury to persons resulting from a cause other than gross negligence.

7.2.2 The rotor of a motor, a pulley, a fan blade, a belt, a gear, or other moving part that is capable of causing injury to persons shall be enclosed or provided with other guarding means to reduce the risk of unintentional contact with the hazard.

7.2.3 The degree of protection required by 7.2.2 depends upon the general construction and intended use of a guarding means. Protection for service personnel shall be provided such that the risk of unintentional contact with hazardous moving parts is greatly reduced during servicing operations involving other parts of the equipment.

Exception: This requirement does not apply to major repairs that expose trained and qualified repair personnel to hazards that are not able to be addressed by common barriers because of the nature and location of the repair. These repairs often include but are not limited to significant generator disassembly or removal of guards and will require specific specialized documented repair procedures as required by 96.4(s) to provide guidance on how to perform the major repair work and to alert the repair persons to hazard exposure while performing the specialized major repair work.

7.2.4 A moving part that involves a risk of injury to persons shall comply with the requirements specified in Section 8, Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing, taking into account:

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 the risk that clothing is capable of being entangled, resulting in a risk of injury to persons.

These factors are to be considered with respect to both intended operation and foreseeable misuse.

7.2.5 Mechanical guarding shall be used where necessary on hot surfaces, radiant heat sources, fluid system piping unions, flanges, and fittings in the event of a leak to reduce or contain splashing, dripping or spraying of coolant, oil or fuel to reduce the potential risk of causing an electrical fire, fuel fire hazard or injury to persons.

7.2.6 Enclosures for medium voltage generators shall be metallic and built to the requirements of UL 50 / CSA C22.2 No. 94.1. External parts of the enclosure may be of insulating material, provided that medium-voltage parts are completely enclosed by grounded metallic partitions. These metallic partitions shall meet the thickness requirements of UL 50 / CSA C22.2 No. 94.1.

Exception: These requirements do not apply to inspection windows complying with the requirements for Inspection Windows, 5.102.205, of UL 347 / CSA C22.2 No. 253.

7.2.7 Generators containing both low and medium voltage components and circuit wiring shall be provided with an enclosure surrounding all medium voltage parts in accordance with 7.2.6. Low voltage parts may be located in a separate enclosure that complies with the enclosure requirements of this standard other than 7.2.6.

7.3 Access doors and covers

7.3.1 A door shall be provided to allow access to a fuse or other overload-protective device, if the functioning requires renewal or resetting, or where it is required to open the door in connection with intended operation of the unit. A means shall be provided to hold the door closed. When the door encloses medium voltage components or wiring, it shall also comply with 7.3.4 and 7.3.5.

Exception No. 1: A door is not required when the only overload-protective device enclosed is:

> *a) Connected in a control circuit, provided the protective device and the circuit loads are within the same enclosure;*
>
> *b) Rated 2 A or less for loads not exceeding 100 VA;*
>
> *c) An extractor fuse having an integral enclosure; or*
>
> *d) Connected in a low-voltage, limited-energy circuit.*

Exception No. 2: A door is not required for an enclosure for low voltage equipment that:

> *a) Contains no user-serviceable or -operable parts; and*
>
> *b) Is marked in accordance with 94.6.*

7.3.2 Doors and covers that provide user or service access, including the function specified in 7.3.1, shall be constructed such that they open to no less than 90 degrees from the closed position.

Exception: A wind strap, chain, or similar attachment that may be detached without the use of tools to open the door or cover to no less than 90 degrees meets the intent of this requirement.

7.3.3 A door or cover that provides access to a fuse or other overload-protective device shall be tight-fitting or self-latching.

7.3.4 Doors giving access to medium-voltage compartments shall be provided with one of the following interlock systems:

> a) An interlock that is solely mechanical, such that the door cannot be opened unless all medium voltage components or wiring in the compartment are de-energized. The interlock shall also prevent energizing any medium voltage components or wiring in the compartment until the door is closed. Electrical or electro-mechanical interlocks may be provided in addition to the required mechanical interlock, but shall not replace the requirement for a solely mechanical interlock. (The use of a captive key interlocking system is one method to provide mechanical interlocking.); or

b) An electromechanical interlock system that combines electrical and mechanical interlock protection that complies with all the following:

1) The interlock system shall prevent an enclosure door from being opened unless all medium voltage components or wiring in the compartment are de-energized. The interlock shall also prevent energizing any medium voltage components or wiring in the compartment until the door is closed.

NOTE: UL/ULC 6200 includes requirements for disabling generator starting which is one means to energize a medium voltage circuit.

2) The interlock system shall have at least two different protection means:

i) With different actuation methodologies; and

ii) Requires use of a tool to disable the protection.

3) The interlock system shall comply with the functional safety requirements in Table 7.1.

Table 7.1
Functional safety standards

Interlocks using electronic devices	Standard for Safety for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. Critical components evaluated using the Computational Investigation method shall have predicted failure rates equivalent or better than IEC 61508 SIL 2 or ISO 13849-1 PL d.
Interlocks using firmware/software	Standard for Software in programmable components and or equipment, UL 1998. UL 1998 shall be used in conjunction with Functional Safety standards, such as UL 991, to also evaluate discrete component hardware and non-programmable IC's.
Alternate standards may be used in place of UL 1998 and UL 991 for evaluating the unit's functional safety. If other standards are used, the environmental stress testing as described in UL 991 shall be applied in addition to the requirements of the other standards. If tests in the other standards are similar to those prescribed in UL 991, the more severe criteria of both standards shall be applied.	
	Automatic Electrical Controls – Part 1: General requirements, UL 60730-1. A unit shall comply with Control Class B as a minimum. • Functional Safety of Electrical/Electronic/Programmable Electronic Safety Related Systems, IEC 61508. A unit shall comply with a minimum of SIL 2. • Safety of Machinery – Functional Safety of Safety-Related Electrical, Electronic and Programmable Electronic Control Systems, IEC 62061. A unit evaluated to this standard shall comply with a minimum of SIL CL 2. • Safety of Machinery – Safety-Related Parts of Control Systems – Part 1: General Principles for Design, ISO 13849-1. A unit shall comply with a minimum of PL d.

7.3.5 Covers giving access to medium-voltage compartments shall comply with all the following conditions:

a) The cover shall be bolted on all sides with a minimum of two bolts per side;

b) No bolts are operable by hand, without the use of a tool;

c) All bolts are captive fasteners;

d) The cover does not provide access to fuses; and

e) The cover shall be marked in accordance with 95.1 for the unit's operating voltage.

7.4 Cast metal enclosures

7.4.1 The thickness of cast metal for an enclosure shall be as specified in Table 7.2.

Exception: Cast metal of a lesser thickness is not prohibited when upon investigation (consideration being given to the shape, size, and function of the enclosure), it is found to be mechanically equivalent for the intended use.

Table 7.2
Thickness of cast-metal enclosures

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

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

7.5 Sheet metal enclosures

7.5.1 Sheet metal enclosures shall comply with 7.5.2 or the requirements in CSA C22.2 No. 94.1 / UL 50.

7.5.2 For enclosures of low voltage circuits, the thickness of a sheet-metal enclosure shall not be less than that specified in Table 7.3 and Table 7.4. 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.

Exception No. 1: The thickness of a sheet metal enclosure is not prohibited from being less than specified in Table 7.3 and Table 7.4 when investigated and determined to be mechanically equivalent per the applicable deflection requirements and tests in UL 50.

Exception No. 2: For enclosures for low voltage circuits, the thickness of an enclosure may be two gauge sizes less than indicated in Table 7.3 and Table 7.4, when uninsulated live parts are located at least 64 mm (2-1/2 inches) from the surface, and 4 gauge sizes less when the uninsulated live parts are located at least 128 mm (5 inches) from the surface. The thickness shall be not less than No. 24 MSG or GSG (steel), or 18 AWG (aluminum, copper, or brass), unless a lesser thickness is acceptable in accordance with Table 7.3 and Table 7.4. An example of 2 gauge sizes less is No. 18 MSG instead of No. 16 MSG; an example of 4 gauge sizes less is No. 20 MSG instead of No. 16 MSG.

Table 7.3
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		Uncoated		Metal Coated	
cm	(Inches)	cm	(Inches)	cm	(Inches)	cm	(Inches)				
10.2	(4.0)	Not limited		15.9	(6.25)	Not limited					
12.1	(4.75)	14.6	(5.75)	17.1	(6.75)	21.0	(8.25)	0.51[d]	(0.020)	0.58[d]	(0.023)
15.2	(6.0)	Not limited		24.1	(9.5)	Not limited					
17.8	(7.0)	22.2	(8.75)	25.4	(10.0)	31.8	(12.5)	0.66[d]	(0.026)	0.74[d]	(0.029)
20.3	(8.0)	Not limited		30.5	(12.0)	Not limited					
22.9	(9.0)	29.2	(11.5)	33.0	(13.0)	40.6	(16.0)	0.81	(0.032)	0.86	(0.034)
31.8	(12.5)	Not limited		49.5	(19.5)	Not limited					
35.6	(14.0)	45.7	(18.0)	53.3	(21.0)	63.5	(25.0)	1.07	(0.042)	1.14	(0.045)
45.7	(18.0)	Not limited		68.6	(27.0)	Not limited					
50.8	(20.0)	63.5	(25.0)	73.7	(29.0)	91.4	(36.0)	1.35	(0.053)	1.42	(0.056)
55.9	(22.0)	Not limited		83.8	(33.0)	Not limited					
63.5	(25.0)	78.7	(31.0)	88.9	(35.0)	109.2	(43.0)	1.52	(0.060)	1.60	(0.063)
63.5	(25.0)	Not limited		99.1	(39.0)	Not limited					
73.7	(29.0)	91.4	(36.0)	104.1	(41.0)	129.5	(51.0)	1.70	(0.067)	1.78	(0.070)
83.8	(33.0)	Not limited		129.5	(51.0)	Not limited					
96.5	(38.0)	119.4	(47.0)	137.2	(54.0)	167.6	(66.0)	2.03	(0.080)	2.13	(0.084)
106.7	(42.0)	Not limited		162.6	(64.0)	Not limited					
119.4	(47.0)	149.9	(59.0)	172.7	(68.0)	213.4	(84.0)	2.36	(0.093)	2.46	(0.097)
132.1	(52.0)	Not limited		203.2	(80.0)	Not limited					
152.4	(60.0)	188.0	(74.0)	213.4	(84.0)	261.6	(103.0)	2.74	(0.108)	2.82	(0.111)
160.0	(63.0)	Not limited		246.4	(97.0)	Not limited					
185.4	(73.0)	228.6	(90.0)	261.6	(103.0)	322.6	(127.0)	3.12	(0.123)	3.20	(0.126)

[a] See 7.5.4 and 7.5.5.

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure are not prohibited from having supports in common and being 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 when metal coated and not less than 0.81 mm (0.032 inch) thick when uncoated.

Table 7.4
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			
cm	(Inches)	cm	(Inches)	cm	(Inches)	cm	(Inches)	mm	(Inches)
7.6	(3.0)	Not limited		17.8	(7.0)	Not limited		0.58[d]	(0.023)
8.9	(3.5)	10.2	(4.0)	21.6	(8.5)	24.1	(9.5)		

Table 7.4 Continued on Next Page

Table 7.4 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]					
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		Minimum thickness	
cm	(Inches)	cm	(Inches)	cm	(Inches)	cm	(Inches)	mm	(Inches)
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	(0.153)
152.4	(60.0)	188.0	(74.0)	330.2	(130.0)	406.4	(160.0)		

[a] See 7.5.4 and 7.5.5

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure are not prohibited from having supports in common and being made of a single sheet.

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

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

7.5.3 It should be noted that Table 7.3 and Table 7.4 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.

7.5.4 With reference to Table 7.3 and Table 7.4, 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. An example of a construction that has equivalent reinforcement is one that produces a structure that is as rigid as one built with a frame of angles or channels as demonstrated by compliance with the applicable deflection requirements and tests in UL 50. In addition to the requirements of UL 50, as a result of the UL 50 deflection testing the unit shall not have:

a) Permanent distortion to the extent that spacings are reduced below the values specified in Table 25.1;

b) Transient distortion that produces contact of the enclosure with uninsulated live parts other than those connected in a low-voltage circuit; and

c) Development of openings that expose uninsulated live parts that involve a risk of electric shock or electrical energy – high current levels. Any openings resulting from the tests are to be judged under the requirements in Section 8, Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing.

Wet location units shall apply the Deflection Tests of UL 50 / CSA C22.2 No. 94.1 as preconditioning for the Rain Test in Section 103, Performance.

7.5.5 With reference to 7.5.4 and Table 7.3 and Table 7.4, 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.

7.6 Nonmetallic enclosures

7.6.1 A polymeric enclosure or polymeric part of an enclosure for low voltage components, circuits, and wiring shall comply with the requirements for stationary equipment in CSA C22.2 No. 0.17 / UL 746C.

7.6.2 A component, piece, or nonmetallic part that forms part of an enclosure housing only low voltage components, circuits, and wiring need not comply with the requirement in 7.6.1 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 component 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 give access to the user, when the part is removed, to live parts involving a risk of fire, electric shock, electric energy-high current levels, or to moving parts;

c) The part covers an opening that has no dimension greater than 101.6 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 (see 4.66) closer than 101.6 mm (4 inches) 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.

The flammability classification shall be in accordance with UL 94.

Exception: A part of a component need not be classed V-0, V-1, V-2, or HB when it complies with the same flammability class applicable to the component.

7.6.3 An external polymeric material enclosure having in any single unbroken section, a projected surface area greater than 0.93 m^2 (10 square feet), or a single linear dimension greater than 1.83 m (6 feet) shall have a flame-spread rating of 200 or less when tested in accordance with UL 723 or IEC 60695-2-13.

7.6.4 A material with a flame-spread rating higher than specified in 7.6.3 is not prohibited from being used as 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 7.6.3.

7.6.5 A conductive coating applied to a nonmetallic surface (such as the inside surface of a cover or an enclosure) shall comply with the applicable requirements in CSA C22.2 No. 0.17 / UL 746C.

Exception: When flaking or peeling of the coating does not result in a risk of fire or electric shock as a result of a reduction of spacings or the bridging of live parts, then the coating need not comply with CSA C22.2 No. 0.17 / UL 746C.

7.6.6 Engine and exhaust areas that are part of an enclosure that incorporate thermal insulation shall comply with the thermal insulation 20-mm (3/4-inch) flame test of 103.4.

7.6.7 Intake plenum areas that are part of an enclosure that incorporate sound insulation lining shall comply with the thermal insulation 20-mm (3/4-inch) flame test of 103.4 or have a flame spread index of 0 – 25 when tested in accordance with UL 723 / IEC 60695-2-13.

7.6.8 For internal areas of the engine generator walk-in enclosure where users or service persons are intended to enter the space to operate or service it, polymeric materials such as polymeric enclosures, polymeric access barriers, walls of an enclosure, or insulation on the walls of an engine generator shall be rated as follows. Any single unbroken section greater than 0.93 m^2 (10 square feet) or a single linear dimension greater than 1.83 m (6 feet) shall have a maximum flame spread index and smoke developed index as shown in Table 7.5 as tested in accordance with the UL 723.

Exception: This requirement does not apply to the following:

a) Wire and cables; and

b) Materials less than 0.9 mm (0.036 inch) thick directly applied to walls, floors, or ceiling surfaces.

Table 7.5
Sound and thermal enclosure insulation index

Location within enclosure	Flame spread index	Smoke developed index
Walk-in area	0 – 25	0 – 50
Intake Plenum area	0 – 25	0 – 50
Void area	76 – 200	0 – 450

7.7 Viewing panes

7.7.1 A viewing pane covering an opening in a low voltage compartment shall be secured in place so that it is not readily displaced in service and provides mechanical protection for the enclosed parts.

7.7.2 Glass for an opening in a low voltage compartment shall comply with the following dimensions:

a) 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;

b) Glass for an opening not more than 929 cm^2 (144 square inches) in area and having no dimension greater than 305 mm (12 inches) shall not be less than 3.2 mm (1/8 inch) thick; and

c) Glass used to cover an area larger than noted in (b) shall not be less than 3.2 mm (1/8) inch thick and shall:

1) Be of a non-shattering or tempered type, wire reinforced that, when broken, complies with CAN/CGSB 12.1-M90 / ANSI Z97.1; or

2) Be subjected to the test described in 80.2.

7.7.3 Viewing panes covering an opening in a medium voltage compartment shall:

a) Be of clear safety-type glass or wire-reinforced glass or another clear material found suitable with respect to flammability and UV resistance in accordance with CSA C22.2 No. 0.17 / UL 746C;

b) Comply with the tests described in Section 81, Mechanical Tests of Viewing Panes for Medium Voltage Compartments; and

c) Be secured in such a manner that it cannot be removed without tools.

7.8 Openings for wiring

7.8.1 The requirements described in 7.8.2 – 7.8.9 apply to fixed units.

7.8.2 Where threads for the connection of conduit are tapped all the way through a hole in an enclosure wall or where 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 properly attached. Where threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or similar device, 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.

7.8.3 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, and similar devices that are supplied as a part of an enclosure shall comply with CSA C22.2 No. 18.1 / UL 514A and CSA C22.2 No. 18.3 / UL 514B.

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

7.8.5 A knockout shall be provided with a flat surrounding surface intended for proper seating of a conduit bushing, 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 Section 25, Spacings.

7.8.6 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as specified in 7.8.5, it is to be assumed that a bushing having the dimensions specified in Table 7.6 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

Table 7.6
Knockout or hole sizes and dimensions of bushings

Trade size of conduit		Knockout or hole diameter		Bushing dimensions			
				Overall diameter		Height	
mm	(Inches)	mm	(Inches)	mm	(Inches)	mm	(Inches)
15	(1/2)	22.2	(7/8)	25.4	(1)	9.5	(3/8)
20	(3/4)	27.8	(1-3/32)	31.4	(1-15/64)	10.7	(27/64)
25	(1)	34.5	(1-23/64)	40.5	(1-19/32)	13.1	(33/64)
32	(1-1/4)	43.7	(1-23/32)	49.2	(1-15/16)	14.3	(9/16)
40	(1-1/2)	50.0	(1-31/32)	56.0	(2-13/64)	15.1	(19/32)
50	(2)	62.7	(2-15/32)	68.7	(2-45/64)	15.9	(5/8)

Table 7.6 Continued on Next Page

Table 7.6 Continued

Trade size of conduit		Knockout or hole diameter		Bushing dimensions			
				Overall diameter		Height	
mm	(Inches)	mm	(Inches)	mm	(Inches)	mm	(Inches)
65	(2-1/2)	6.2	(3)	81.8	(3-7/32)	19.1	(3/4)
78	(3)	92.1	(3-5/8)	98.4	(3-7/8)	20.6	(13/16)
91	(3-1/2)	104.8	(4-1/8)	112.7	(4-7/16)	13.8	(15/16)
103	(4)	117.5	(4-5/8)	126.2	(4-31/32)	25.4	(1)
116	(4-1/2)	130.2	(5-1/8)	140.9	(5-35/64)	27.0	(1-1/16)
129	(5)	42.9	(5-5/8)	158.0	(6-7/32)	30.2	(1-3/16)
155	(6)	171.5	(6-3/4)	183.4	(7-7/32)	31.8	(1-1/4)

7.8.7 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum specified in Section 25, Spacings, shall be provided between uninsulated live parts and a conduit bushing installed at any location to be used during installation. Permanent marking on the enclosure, a template, or a drawing furnished with the unit is used to specify such a location. The specified location of the openings shall be such that damage to internal parts shall not result when openings are made.

7.8.8 With respect to the requirement in 7.8.7, 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 accomplished by the use of a removable, bolted plate.

7.8.9 A polymeric- or metal-closure plug for an unused conduit opening shall comply with CSA C22.2 No. 18.1 / UL 514A.

7.9 Openings in an engine generator or electrical panel enclosure

7.9.1 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.

7.9.2 Barriers shall be provided behind all ventilating openings into medium-voltage compartments. The barrier shall be effectively secured in place and shall prevent drawing a straight line from any point outside the enclosure to any medium voltage live part, including insulated parts such as cables (other than shielded cables). These barriers shall be metallic barriers, or shall be of a non-metallic material type and thickness sufficient to meet the impulse and dielectric voltage withstand voltages specified in this Standard.

7.9.3 All ventilation openings in low and medium voltage compartments, including perforations, louvers, and openings protected by means of wire screening, expanded metal, or a perforated cover, shall comply with the rod entry test specified in Section 90, Rod Entry Test. The use of screening, expanded metal, or perforated covers does not eliminate the need for the barriers behind openings into medium voltage compartments as required by 7.9.2.

7.9.4 With reference to 7.9.3, the diameter of the wires of a screen shall be not less than 1.3 mm (0.050 in) if the screen openings are 320 mm^2 (0.497 in^2) or less in area, and shall be not less than 2.06 mm (0.081 in) for larger screen openings. Perforated sheet steel and sheet steel employed for expanded metal mesh shall be not less than 1.07 mm (0.042 in) thick for mesh openings or perforations 320 mm^2 (0.497 in^2) or less in area, and shall be not less than 2.03 mm (0.080 in) thick for larger openings.

7.10 Enclosure bottom openings

7.10.1 A complete noncombustible bottom or a construction employing individual noncombustible barriers under components, groups of components, or assemblies, as specified in Figure 7.1 is required in accordance with 7.9.1. Open bottom engine generator enclosures shall indicate in the installation instruction that they are to be installed on a noncombustible surface.

Exception No. 1: Ventilating openings along the base of an enclosure are not prohibited when there is no access to live electrical components. Ventilating openings in the bottom of an electrical panel are not prohibited 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.

Exception No. 2: Ventilation openings in the bottom of an electrical panel enclosure are not prohibited when the openings incorporate a perforated metal plate as described in Table 7.7, or a galvanized or stainless steel screen having a 14 by 14 mesh per inch (25.4 mm) constructed of wire with a diameter of 0.4 mm (0.018 inch) minimum.

Exception No. 3: The bottom of the enclosure under areas containing only materials classed V-0 or better in accordance with UL 94 shall have openings no larger than 6.4 mm (1/4 inch) square. Openings that are not square shall not have an area greater than 40 mm^2 (1/16 square inch).

Exception No. 4: Ventilating openings without limitation on their size and number and complying with 8.12 and provided in the base of the engine generator enclosure or bottom panel are not prohibited when in areas that contain only wires, cables, plugs, receptacles, transformers, and impedance protected or thermally protected motors.

Exception No. 5: Ventilating openings are not prohibited in the bottom panel or along the base when:

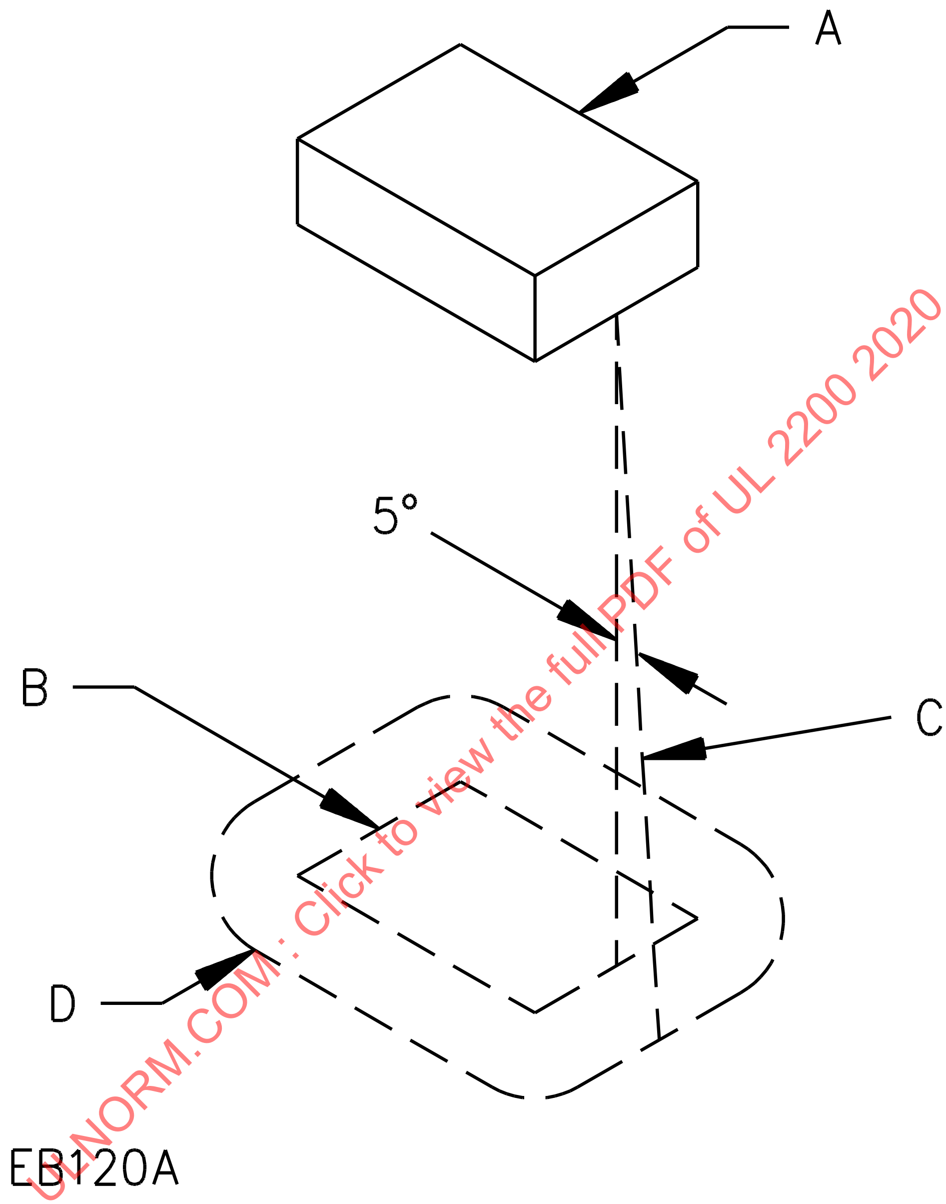
a) The installation instructions state that the generator assembly shall be installed over non-combustible materials; and

b) The generator assembly is located such that it prevents combustible materials from accumulating under the generator set.

7.10.2 With reference to 7.10.1, including all exceptions, any ventilation openings into medium voltage compartments shall be provided with the barriers required by 7.9.2

Figure 7.1

Enclosure bottom



A – Region to be shielded by guard 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 panel bottom-enclosure baffle

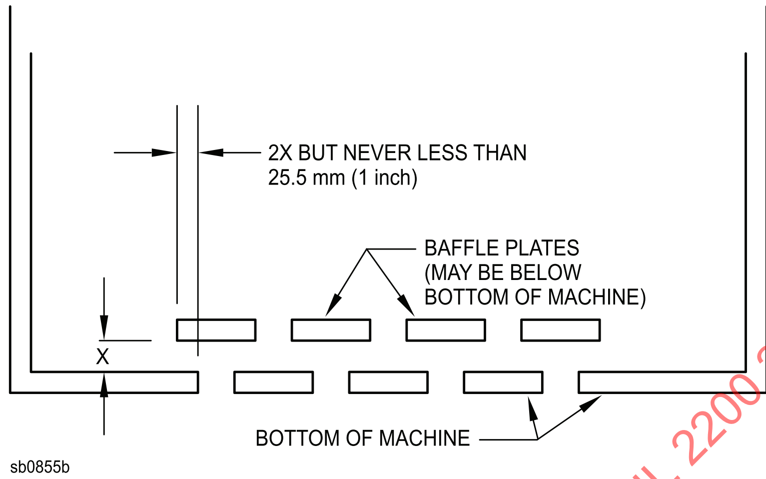


Table 7.7
Perforated metal plates for enclosure bottom

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)
				233 holes per 645 mm^2 (1 inch^2)	
0.66	(0.026)	1.19	(0.047)	2.36	(0.093)
0.76	(0.030)	1.14	(0.045)	1.70	(0.067)
0.76	(0.030)	1.19	(0.047)	2.36	(0.093)
0.81	(0.032)	1.91	(0.075)	3.18	(0.125)
				72 holes per 645 mm^2 (1 inch^2)	
0.89	(0.035)	1.90	(0.075)	3.18	(0.125)
0.91	(0.036)	1.60	(0.063)	2.77	(0.109)
0.91	(0.036)	1.98	(0.078)	3.18	(0.125)
0.99	(0.039)	1.60	(0.063)	2.77	(0.109)
0.99	(0.039)	2.00	(0.079)	3.00	(0.118)
Note – In accordance with Exception No. 2 to 7.10.1.					

7.11 Indoor enclosure top openings

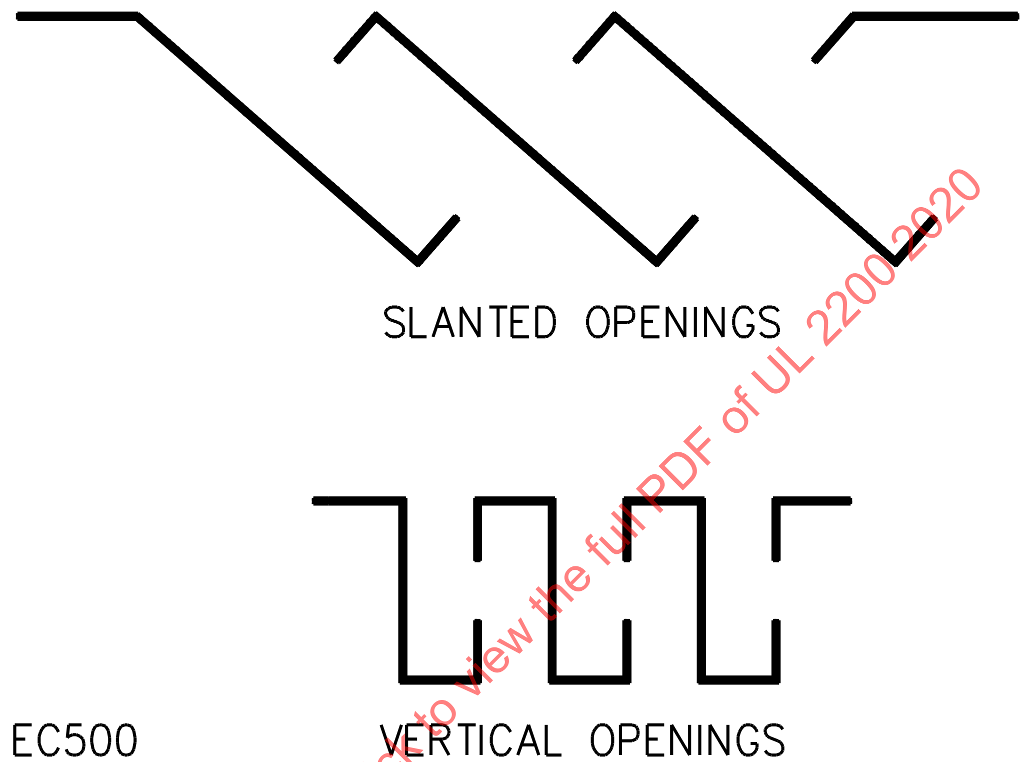
7.11.1 The minor dimension (see 8.8) of any opening in the top of an enclosure directly over an uninsulated live part involving a risk of electric shock or electrical energy – high current levels – shall not exceed 4.8 mm (3/16 inch) unless the configuration is such that direct vertical entry of a falling object is prevented from reaching such uninsulated live parts by means of a trap or restriction. See Figure 7.3 for examples of top surface openings that prevent direct entry.

Exception: Openings located 1.8 m (6 feet) or higher from the floor, when the unit is installed in accordance with the manufacturer's instructions, are not prohibited from having a dimension greater than 34.8 mm (3/16 inch). Such openings shall comply with the accessibility requirements in Section 8, Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing.

7.11.2 With reference to 7.11.1, including all exceptions, any ventilation openings into medium voltage compartments shall be provided with the barriers required by 7.9.2.

Figure 7.3

Cross sections of panel top-enclosure indoor designs



7.12 Sharp edges

7.12.1 An enclosure, a frame, a guard, a handle, or similar device shall have smooth well rounded edges that do not constitute a risk of injury to persons in normal maintenance and use.

Exception: This requirement does not apply to a part or portion of a part that is required to be sharp to perform a working function.

7.12.2 Wherever reference measurements are required to determine that a part as specified in 7.12.1 is not sharp enough to constitute a risk of injury to persons, the method described in UL 1439 shall be employed.

8 Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing

8.1 The requirements in 8.2 – 8.17 apply only to low voltage parts that are accessible to the user and are isolated from medium voltage circuits. See 8.18 for requirements for medium voltage parts and low voltage parts that are not isolated from medium voltage circuits. For protection of service personnel requirements, refer to Section 43, Protection of Service Personnel.

8.2 Uninsulated live parts at a potential involving a risk of electric shock, risk of electrical high energy levels, or risk of injury due to moving parts that are located in an area containing access to controls or disconnects by the user shall be insulated or enclosed to reduce the likelihood of contact with such parts, regardless of their location.

8.3 Engine generator assemblies intended to be located within a restricted access area are not considered user accessible when provided with the following:

a) Marked as required by 94.14; and

b) Provided with instructions as specified in 96.4(s).

8.4 To reduce the risk of unintentional contact that involves a risk of 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 (a) or (b):

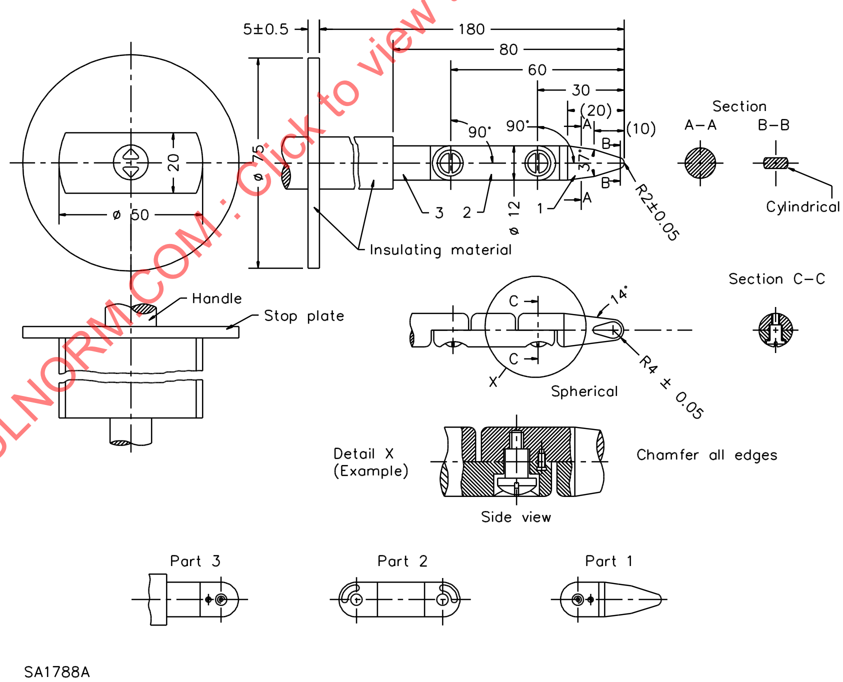
a) For an opening that has a minor dimension (see 8.8) less than 25.4 mm (1 inch), such a rotating part, live part or wire shall not be contacted by the probe illustrated in Figure 8.1.

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.

Exception: An opening in an integral enclosure of a motor or alternator is not required to comply with these requirements when it complies with 8.5.

Figure 8.1

Articulate probe



All dimensions are in mm.

Table 8.1
Minimum 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	(Inches)	mm	(Inches)
19.1 [c]	(3/4)	114.3	(4-1/2)
25.4 [c]	(1)	165.1	(6-1/2)
31.8	(1-1/4)	190.5	(7-1/2)
38.1	(1-1/2)	317.50	(12-1/2)
47.6	(1-7/8)	393.70	(15-1/2)
54.0	(2-1/8)	444.5	(17-1/2)
d	d	762.0	(30)

[a] See 8.8.

[b] Between 19.1 and 54.0 mm (3/4 and 2-1/8 inches), interpolation is to be used to determine a value between values specified in the table.

[c] Any dimension less than 25.4 mm (1 inch) applies to a generator only.

[d] More than 54.0 mm (2-1/8 inches) and not more than 152.4 mm (6 inches).

8.5 With respect to a part or wire as specified in 8.4, in an integral enclosure of a generator as specified in the Exception to 8.4:

a) An opening that has a minor dimension (see 8.8) less than 19.1 mm (3/4 inch) complies when:

1) A moving part is not contacted by the probe illustrated in Figure 8.2;

2) Film-coated wire is not contacted by the probe illustrated in Figure 8.3;

3) In a directly accessible generator (see 8.10), an uninsulated live part is not contacted by the probe illustrated in Figure 8.1; and

4) In an indirectly accessible generator (see 8.9), an uninsulated live part is not contacted by the probe illustrated in Figure 8.2.

b) An opening that has a minor dimension of 19.1 mm (3/4 inch) or more complies when a part or wire is spaced from the opening as specified in Table 8.1.

Figure 8.2

Probe for moving parts and uninsulated live parts in engine generator assemblies

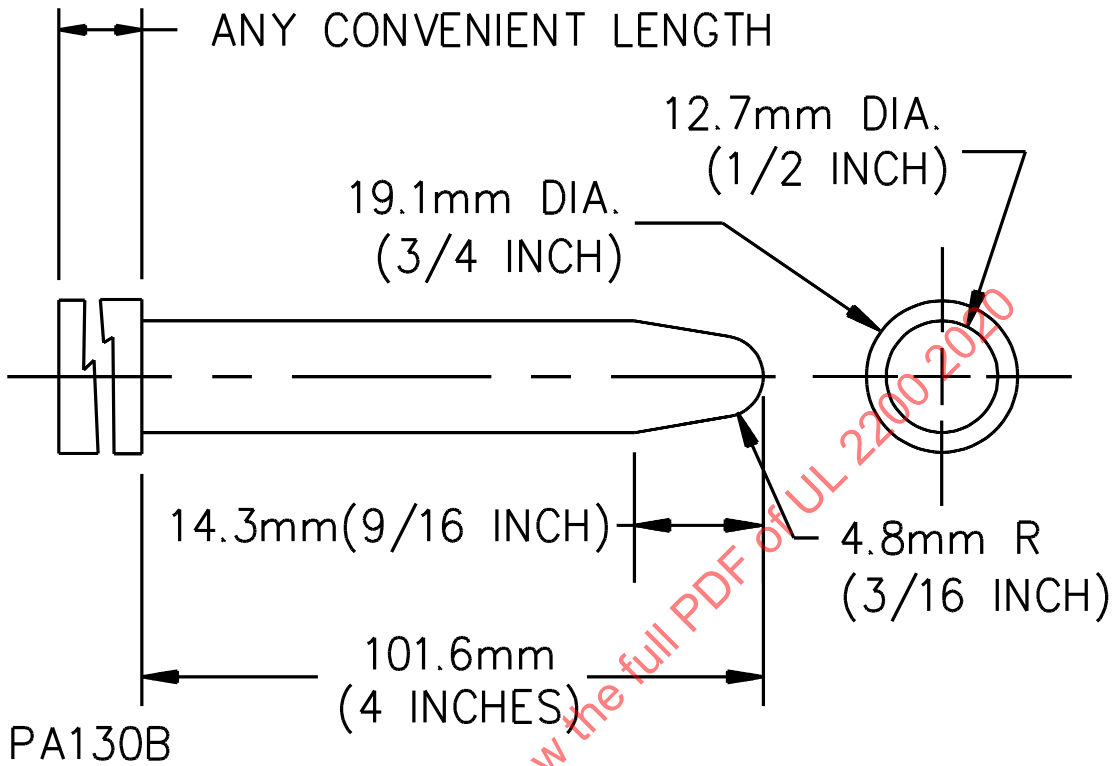
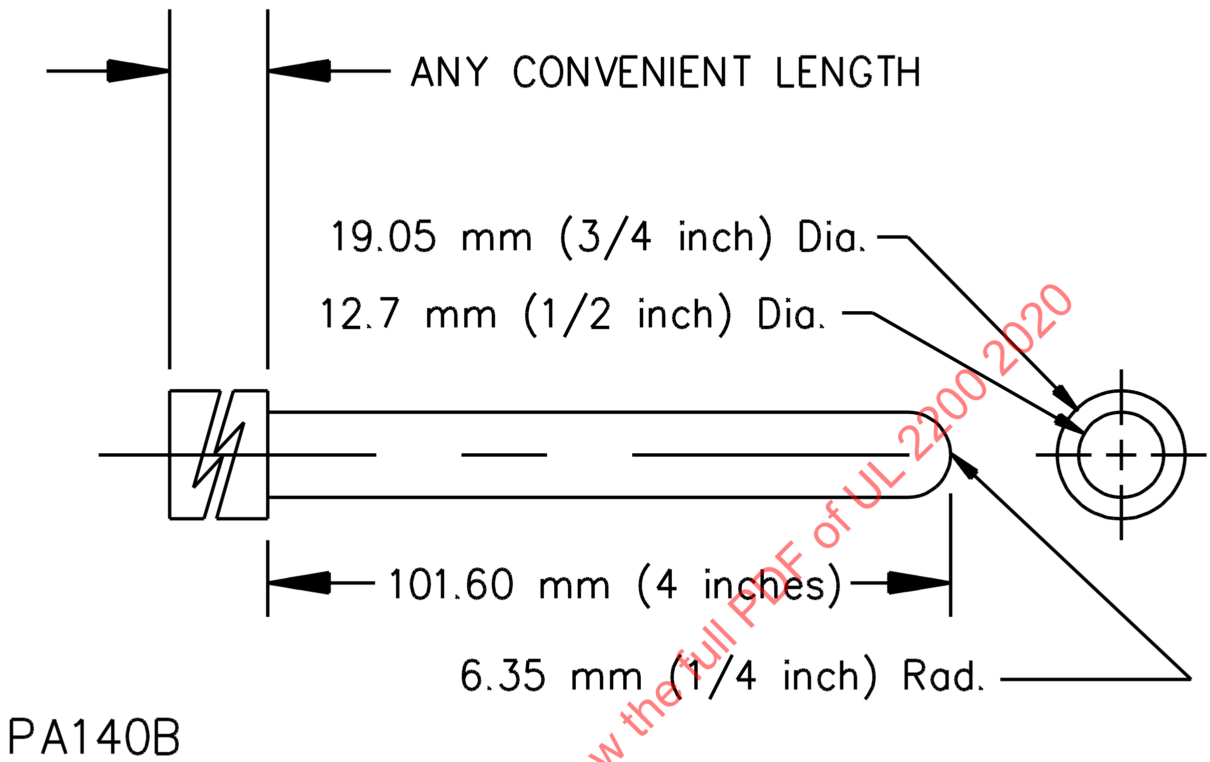


Figure 8.3

Probe for film-coated wire in generators



8.6 The probes specified in 8.4 and 8.5 and illustrated in Figure 8.1 – Figure 8.3 shall be applied to the maximum possible 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.

8.7 The probes specified in 8.6 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).

8.8 With reference to the requirements in 8.4 and 8.5, the minor dimension of an opening is the diameter of the largest cylindrical probe that is inserted through the opening.

8.9 With reference to the requirements in 8.5, an indirectly accessible generator is a generator:

a) That is accessible only by opening or removing a part of the outer enclosure, such as a guard or panel, that is opened or removed without using a tool (see 4.77);

b) That is guarded or enclosed so that the risk of contact is small; or

c) That is determined to have a low risk of contact (see 8.11) due to its location.

8.10 A directly accessible generator is a generator:

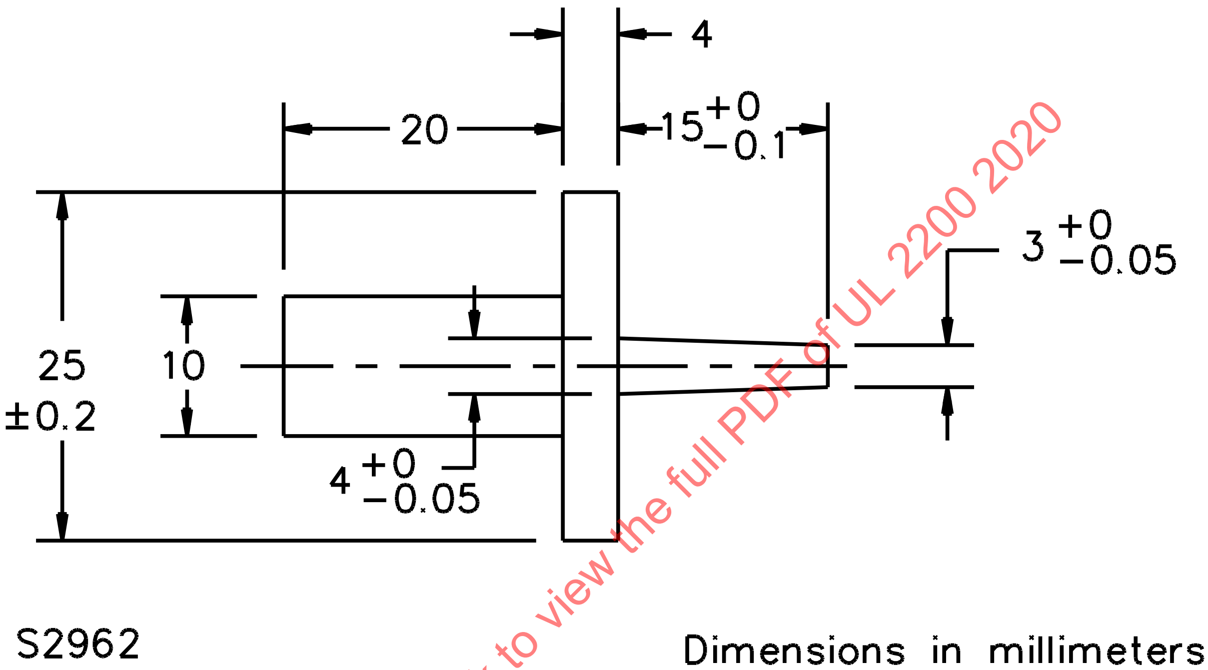
a) That is contacted without opening or removing any part; and

b) That is located so as to be accessible to contact.

8.11 The test pin illustrated in Figure 8.4, when inserted as specified in 8.6 through an opening in an enclosure, shall not touch any uninsulated live part that involves a risk of electric shock.

Figure 8.4

Test pin



1 mm = 0.039 inch

8.12 The probe shown in Figure 8.1 and the test pin shown in Figure 8.4 are to be inserted as specified in 8.6 into all openings, including those in the bottom of the unit. The probe and test pin are to 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.

8.13 During the examination of a unit to determine whether it complies with the requirements in 8.4 or 8.5, a part of the enclosure that is 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 7.6, 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.

8.14 With reference to the requirements in 8.4 and 8.5, insulated brush caps are not required to be additionally enclosed.

8.15 The maximum voltage of a battery supply of a unit employing batteries intended for user replacement shall not exceed 60 V in dry locations or 30 V in wet locations.

Exception: Higher battery voltage is permitted when the batteries and battery wiring comply with applicable shock hazard requirements such as but not limited to enclosures, accessibility, and shock hazard *markings. The instruction manual shall include warnings for the associated hazards and also include service procedures and guidance for qualified service persons to perform the work.*

8.16 Uninsulated live parts at a potential involving a risk of electric shock that are located in the area containing batteries intended for replacement by the user shall be insulated or enclosed to reduce the risk of contact with such parts, regardless of their location.

8.17 The instruction manual for a unit containing batteries intended for user installation or replacement shall include instructions for battery replacement as specified in 96.4.

8.18 Insulated and uninsulated medium voltage components and wiring, including low voltage circuits that are not isolated from medium voltage circuits as defined in Section 30, shall not be accessible to the user. They shall be located behind bolted covers or interlocked doors that are not required to be opened by the user. See 7.9.2 and 7.9.3 with respect to accessibility of medium voltage parts when enclosures are ventilated.

9 Electric Shock

9.1 Voltage

9.1.1 The requirements described in 9.1.2 and 9.2.2 are used to determine when the voltage of an accessible live part poses a risk for electric shock. Determination of whether a live part is accessible to users and service personnel is specified in Section 8, Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing, and Section 43, Protection of Service Personnel.

9.1.2 A live part is determined not to be a risk for electric shock when the voltage of the part does not exceed the values specified in Table 9.1.

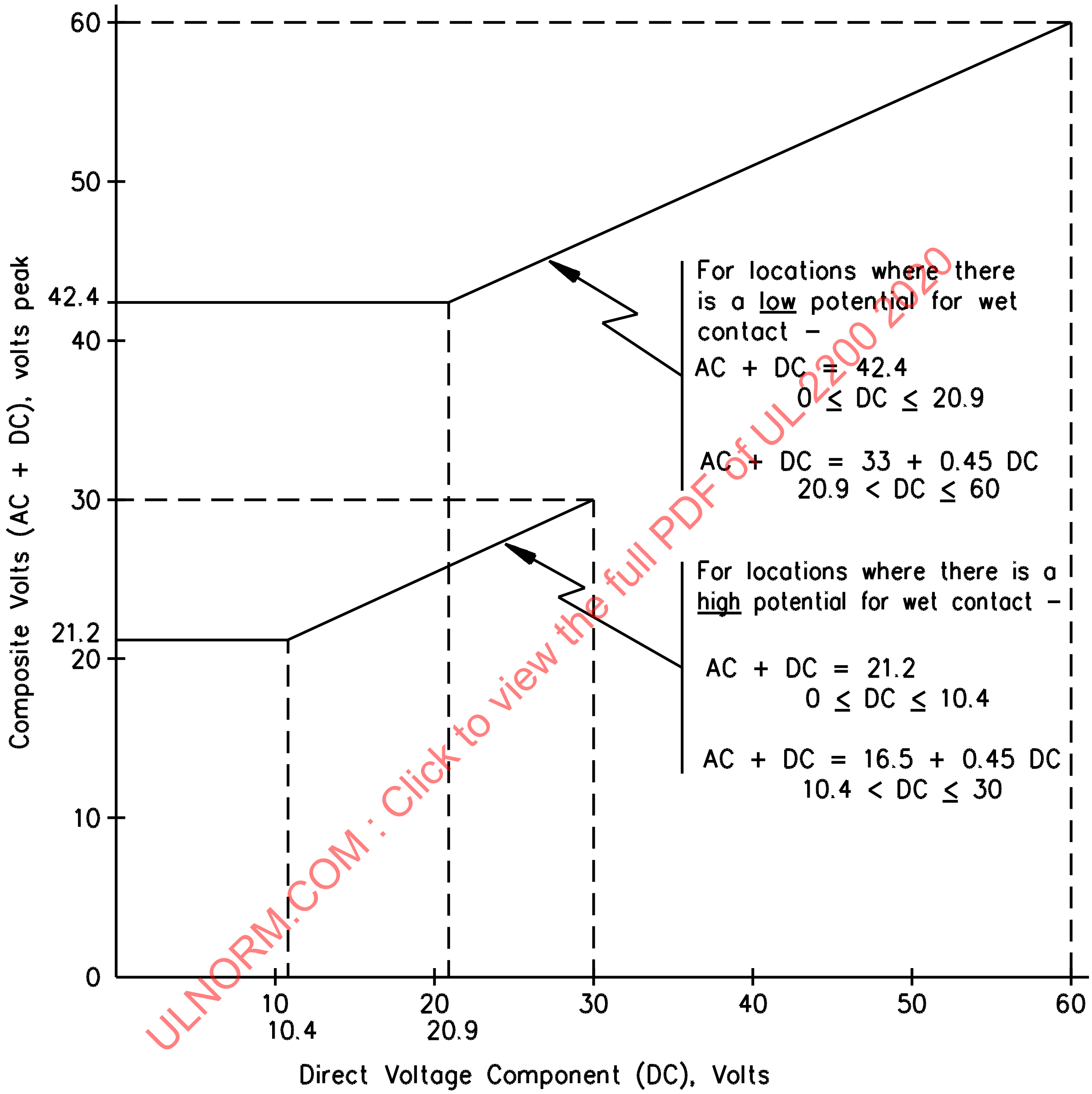
Table 9.1
Risk of electric shock – maximum voltage

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

[a] This value was reduced from 60 V to 42.4 V for consistency with the Canadian Electrical Code, Part I.

Figure 9.1

Maximum voltage



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9.2 Stored energy

9.2.1 The capacitance between capacitor terminals that are accessible as determined by the requirements in Section 8, Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing, and Section 43, Protection of Service Personnel, shall satisfy the following expressions:

$V < 40{,}000$ where $C < 0.00328$

$V < 729\ C^{-0.7}$ where $0.00328 \le C < 2.67$

$V < 367$ where $2.67 \le C < 13.9$

$V < 2314\ C^{-0.7}$ where $13.9 \le C < 184.5$ in a DRY environment

$V < 60$ where $C \ge 184.5$ in a DRY environment

$V < 2314\ C^{-0.7}$ where $13.9 \le C < 497$ in a WET environment

$V < 30$ where $C \ge 497$ 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.

Table 9.2
Risk of electric shock – stored energy current

Environment	Capacitance, microfarads[a]	Maximum voltage across the capacitor, 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

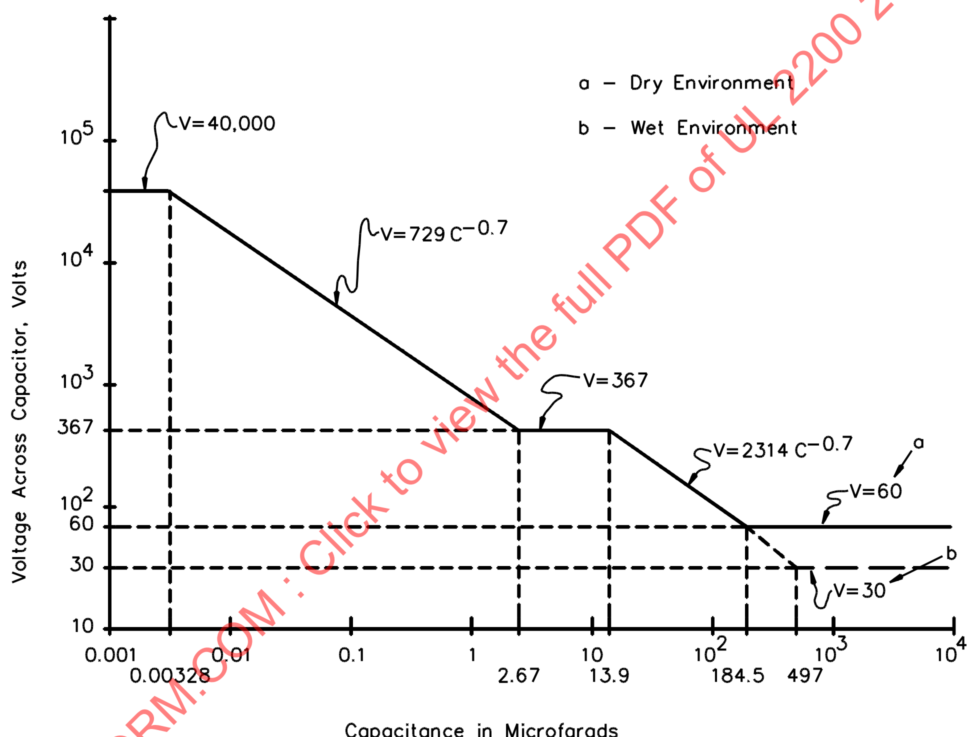
Table 9.2 Continued

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

[a] See 9.2.1 and Figure 9.2.

Figure 9.2

Limited for voltage across capacitance



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9.2.2 With reference to 9.2.1, a part involving a potential of more than 40 kV peak is to be investigated to determine whether or not it involves a risk of electric shock.

10 Corrosion Protection

10.1 Outdoor enclosure sheet steel having a thickness of 3.05 mm (0.12 inch) or more that may be exposed to the weather shall be made corrosion-resistant by one of the following coatings:

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

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 0.010 mm (0.00041 inch) on each surface with a minimum thickness of 0.009 mm (0.00034 inch). The thickness of the coating shall be established by the Metallic Coating Thickness Test of 103.3.

c) An organic or inorganic protective coating system on both surfaces, applied after forming. The results of an evaluation of the coating system in accordance with UL 1332 shall demonstrate that it provides protection at least equivalent to that provided by the zinc coating described in (a). See 7.6, Nonmetallic enclosures, and 103.6, Corrosive atmosphere test.

d) Any one of the means specified in 10.2.

10.2 Sheet steel having a thickness of less than 3.05 mm (0.12 inch) which may be exposed to the weather shall be made corrosion-resistant by one of the following coatings:

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

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 0.015 mm (0.00061 inch) on each surface with a minimum thickness of 0.014 mm (0.00054 inch). The thickness of the coating shall be established by the Metallic Coating Thickness Test of 103.3. An annealed coating shall also comply with 10.5.

c) A zinc coating conforming with 10.1 (a) or (b) with one coat of outdoor paint. The coating system shall comply with 10.3.

d) An organic or inorganic protective coating system on both surfaces, applied after forming. The results of an evaluation of the coating system in accordance with UL 1332 shall demonstrate that it provides protection at least equivalent to that provided by the zinc coating described in 10.2 (a). See 7.6, Nonmetallic enclosures, and 103.6, Corrosive atmosphere test.

10.3 With reference to 10.2 (c) and (d), the results of an evaluation of the coating system shall demonstrate that it provides protection at least equivalent to that provided by the zinc coating as described (G90) in 10.2(a). See 7.6, Nonmetallic enclosures, and 103.6, Corrosive atmosphere test.

10.4 With reference to 10.1 and 10.2, other finishes, including paints, other metallic finishes, and combinations of the two may be accepted when comparative tests with galvanized sheet steel (without annealing, wiping, or other surface treatment) conforming with 10.1 or 10.2(a) as applicable, indicate they provide equivalent protection. See 103.6, Corrosive atmosphere test.

10.5 An annealed coating on sheet steel that is bent or similarly formed or extruded or rolled at edge of holes after annealing shall additionally be painted in the bent or formed area if the bending or forming process damages the zinc coating. If flaking or cracking of a zinc coating at the outside radius of a bent or formed section is visible at 25 power magnification, the zinc coating is considered damaged.

10.6 Simple sheared or cut edges and punched holes are not required to be additionally protected.

10.7 Iron or steel serving as a necessary part of the product but not exposed to the weather shall be plated, painted, or enameled for protection against corrosion.

Exception: This requirement does not apply to cast iron engine blocks, cast iron manifolds, or aluminized carbon steel exhaust tubing and piping.

10.8 Aluminum, stainless steel, and polymeric materials may be used without corrosion-resistant coatings or plating.

10.9 Aluminum enclosures constructed from other than 5052, 6061 alloys shall comply with 10.1(c).

10.10 Materials not specifically mentioned in this Section shall be evaluated on an individual basis. The tests described in 7.6, Nonmetallic enclosures, and 103.6, Corrosive atmosphere test, may be used for the evaluation.

10.11 Indoor ferrous metal enclosures and external ferrous metal parts attached to these enclosures either:

a) Shall be protected against corrosion by enameling, painting, galvanizing, or other equivalent means; or

b) Shall be tested in accordance with the 24-hour salt spray test requirements of CSA C22.2 No. 94.2 / UL 50E.

11 Mechanical Assembly

11.1 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.

11.2 Screws, nuts, bolts, and fittings with properly applied thread locking compounds, lock washers, safety wire (locking-wire), screws, nuts and bolts tightened by means of a power tool, rivets, and staked and upset screws are not subject to loosening. See 11.3.

11.3 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 is accomplished by:

a) The use of a center punch applied to the end of a bolt after assembly;

b) Mismatching of the nut and bolt threads; or

c) The equivalent (distorted thread locknut).

11.4 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.

Exception: A keyed part, a press fit, a part locked in place with a pin, or equivalent means used to hold a rotating part in place is not prohibited.

11.5 A switch, fuseholder, lampholder, AC convenience receptacle, motor-attachment plug, or other component that is handled by the operator shall:

a) Be mounted securely;

b) Not turn; and

c) Comply with the requirements specified in 11.6.

Exception: The requirement that a switch shall not turn does not apply 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 does not loosen the switch during operation;

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

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

11.6 The means of securing components specified in 11.5 shall include more than friction between surfaces. A lock washer is not prohibited from being used as a means to secure a device having a single-hole mounting means.

11.7 A blower or fan motor including the blower or fan blade itself shall be secured by any of the following or equivalent means in order to reduce the risk of the motor, blower, or fan blade from vibrating loose and falling from its mounting support:

a) Bolts, screws and nuts complying with 11.3;

b) Bolts, screws and nuts having holes or slots with properly applied cotter pins;

c) Bolts and screws having a compression type lock nut;

d) Rivets.

Exception: A blower or fan motor, including the blower or fan blade itself, secured by means described in 11.2 and oriented, positioned, or located above a barrier such that either the motor, blower, or fan blade does not contact other components resulting in a risk of fire, electric shock, or electrical energy – high current levels in the event that such parts vibrated loose from their support, is not required to comply with this requirement.

12 Switches and Control Devices

12.1 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.

12.2 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:

a) Rated not less than twice the maximum load current under normal operating conditions; or

b) Investigated for the application.

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

12.4 A switch or other device controlling a relay, solenoid coil, or similar device shall have a pilot duty or VA rating.

Exception: This requirement does not apply to engine mounted starter solenoids.

12.5 Each pole of a snap switch rated as a 2-circuit, 3-circuit, or multi-circuit switch is not prohibited from controlling a separate load at the full voltage rating of the switch. Each pole of a snap switch rated as a 240 V, 2-pole switch is not prohibited from controlling a separate 120 V load. Both poles are not prohibited from being used to control both legs of a single 240 V load. Each pole of a snap switch rated as a 240 V, 3-pole switch is not prohibited from controlling a separate load not exceeding 139 V. The three poles are not prohibited from being used to control the three legs of a 3-phase, 240 V load.

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

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

a) The grounded conductor is disconnected by a switch that simultaneously disconnects all conductors of the circuit.

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

12.8 A transfer switch used to connect the load shall comply with requirements in CSA C22.2 No. 178.1 / UL 1008 or CSA C22.2 No. 178.3 / UL 1008A. Where a transfer switch is not contained inside the product enclosure, the transfer switch may be provided as an accessory.

12.9 Mechanical and electromechanical switches shall comply with the applicable requirements for switches in CSA C22.2 No. 111 / UL 20, CSA C22.2 No. 14 / UL 508, or other applicable standards.

12.10 When 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.

Exception: This requirement does not apply to:

a) A switching device having more than one "on" position (such as a bypass switch);

b) A double throw switch;

c) A rotationally-operated switch; or

d) A rocker switch.

12.11 Output circuit breakers 1000 Vac or less that are drawout-mounted type integrated to the engine generator shall comply with Sections 43, 90, 94, 96, and CSA C22.2 No. 268 / UL 1066 and shall be removable only through the use of tools.

12.12 Output circuit breakers rated over 1000 Vac shall comply with IEEE C37.09 and with NEMA C37.54 if of the drawout type.

13 Alternators and Generators

13.1 The alternator or generator relied upon to provide rated output power shall comply with CSA C22.2 No. 100 / UL 1004-4 and additionally to UL 1004-9 for greater than 1000 V output.

14 Output Power Disconnection Device

14.1 The generator assembly shall be provided with the following:

a) An output power disconnection device or a lockout switch that electrically isolates the generator assembly from other electrical energy sources and also prevents motoring; and

b) Installation instructions that a disconnect shall be installed with the generator.

NOTE: A disconnect means is required to be provided for an installed generator. The disconnect device may be a separate device that is installed with the generator or it may be integral to the generator.

14.2 When a disconnection device is provided, it shall:

a) Open all ungrounded conductors;

b) Consist of either a manually or electrically operated switch or circuit breaker;

c) Employ an operating handle that is either accessible from outside of the enclosure or located under a door or hinged cover; and

d) Be marked in accordance with 93.15.

14.3 A signal contact shall be available to indicate that the generator assembly is out of service when the lockout switch is operated.

NOTE: A stationary engine generator assembly may operate or be operated when the output disconnect is open therefore the generator assembly may not be out of service.

14.4 The operating handle referenced in 14.2 (b) shall be operable without exposing the operator to uninsulated live low voltage parts, or to any medium voltage parts, whether insulated or uninsulated.

14.5 Medium voltage power output disconnection panels shall comply with CSA C22.2 No. 253 / UL 347, IEEE C37.20.2, or IEEE C37.20.3. If not provided, the disconnection panel shall be referenced in the site installation instructions.

14.6 To prevent generator 'motoring" rotation, engine generators that are rated for paralleling with other output sources such as utility interactive generators or generators used in parallel with other generators are required to be additionally marked in accordance with 94.18.

15 Engine Start Disable

15.1 The generator assembly shall be provided with a prime mover start disable function or disconnection device or a lockout switch that positively prevents the startup and operation of the generator assembly either by local or remote actuation. The circuit shall be fail safe and shall not result in the inadvertent movement or starting of the generator. Programmable control features relying on software, firmware, or microelectronics shall comply with Section 27, Engine Generator Programmable Controls, and Section 28, Product Manufacturers' Design Risk Assessment, to evaluate the functional safety of the circuit.

Exception: Compliance may be demonstrated by use of manual disconnecting device (s) for all starting energy source(s): AC power and/or all DC power cables and/or air hoses that are able to be removed and visibly secured with a lock out/tag out device.

15.2 The generator assembly shall be provided with instructions to identify the actions and procedures necessary to comply with 15.1. If necessary these instructions shall include discharge instructions to reduce stored energy below hazardous levels.

16 Disconnects Used in Service Equipment Applications

16.1 An engine generator assembly provided with a low voltage disconnect means intended to comply with service equipment rating requirements as defined in Article 225.36 of the National Electrical Code, NFPA 70, and/or Section 6 of the Canadian Electrical Code, Part I, shall comply with CSA C22.2 No. 0.19 / UL 869A.

16.2 An engine generator assembly provided with a medium voltage power output disconnect panel means intended to comply with service equipment rating requirements as defined in Article 225.36 of the National Electrical Code, NFPA 70, and/or Section 6 of the Canadian Electrical Code, Part I, shall comply with the requirements for service equipment in CSA C22.2 No. 253 / UL 347.

17 Output Connections

17.1 General

17.1.1 A unit shall have provision for connection of a wiring system in accordance with 17.1.2 – 17.1.5.

17.1.2 Provision for connection of a low voltage wiring system shall consist of:

a) Either wiring terminals as specified in 17.1.8 – 17.1.18, circuit breaker load terminals or wiring leads as specified in 17.1.19 – 17.1.23;

b) A means for connection of cable or conduit as specified in 17.1.26 and 17.2.1; and

c) Bus bars with field wiring terminal lugs or provisions for field wiring lugs that complies with 17.1.12.

Exception: The requirements described in 17.1.8 – 17.1.26 do not apply to the means for connection to accessible signal circuits complying with the requirements specified in Section 30, Accessible Signal Circuits.

17.1.3 Provision for connection of a medium voltage wiring system shall consist of one of the following:

a) Bus bars provided with hole patterns meeting the requirements of NEMA CC1; or

b) Connectors complying with CSA C22.2 No. 65 / UL 486A-486B rated for the conductor size required based on 125 percent of the rated current.

17.1.4 For wiring system connections to medium voltage generators, there shall be provisions for bonding of conductor shields to the ground bus. These provisions shall be located:

a) Such that the shield bonding conductor need not exceed 1 m (3.3 ft); and

b) In the same compartment as the wiring terminal for the associated shielded conductors.

17.1.5 Medium voltage equipment shall not be provided with field wiring leads for connections to medium voltage circuits. As such, 17.1.19 – 17.1.23 do not apply to medium voltage conductors.

17.1.6 When the generator is provided with AC convenience receptacles in addition to the output connections in 17.1.1, the AC convenience receptacle shall comply with 17.4.

17.1.7 The requirement in 17.1.1 applies to the wiring connection means for the output power circuits of a unit. These connections are intended to be made in the field when the unit is installed.

17.1.8 A field wiring terminal for low voltage conductors shall be sized for the connection of a conductor having an ampacity based on Table 310.15(B)(16) of the National Electrical Code, NFPA 70, and/or Tables 1 to 4 of the Canadian Electrical Code, Part I, of no less than 115 percent of the maximum rated current to the first distribution device (s) containing overcurrent protection. For medium voltage conductors, the conductor ampacity shall be based on Table 17.1.

Table 17.1
Insulated copper conductor ampacities for medium voltage connections

Conductor Size AWG – kcmil	2001 – 5000 V Conductors A	5001 – 15000 V Conductors A
8	64	–
6	85	90
4	110	115
2	145	155
1	170	175
1/0	195	200
2/0	220	230
3/0	250	260
4/0	290	295
250	320	325
350	385	390
500	470	465
750	585	565
1000	670	640

17.1.9 A field wiring terminal for low voltage conductors shall comply with the requirement in 17.1.8 for a wire of each metal for which it is marked. See 93.7.

17.1.10 A field wiring terminal for low voltage conductors 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.

Exception No. 1: A pressure terminal connector, including a crimping type, when used is field-installed in accordance with 17.1.12.

Exception No. 2: A wire-binding screw employed at a wiring terminal intended for connection of a 10 AWG (5.3 mm^2) or smaller conductor is not prohibited when upturned lugs, a cupped washer, or the equivalent is provided to hold the wire in position.

17.1.11 A field wiring terminal shall be prevented from turning or shifting in position by a means other than friction between surfaces. This is to 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.

Exception: A pressure terminal connector of the type that secures the wire by crimping and used in accordance with the requirements in 17.1.12 is not prohibited from turning when the least spacing between adjacent terminals and also between terminals and dead metal parts, complies with Spacings, Section 25, for when connectors are oriented in such a position that results in these spacings.

17.1.12 In accordance with Exception No. 1 to 17.1.10, a pressure terminal connector is not required to be provided when the conditions in (a) – (e) are met:

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 96.4 (b) and (c).

b) The fastening hardware such as a stud, nut, bolt, spring or flat washer, or similar device, as required for an effective installation, shall either be:

1) Provided as part of the terminal assembly;

2) Mounted on or separately packaged with the unit; or

3) 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) When the pressure terminal connector provided in a terminal assembly requires the use of other than a 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 96.4(d).

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

17.1.13 An insulating base for support of a pressure terminal connector shall be subjected to the test described in 76.1 and 76.2.

17.1.14 A wire-binding screw at a field-wiring terminal shall not be smaller than No. 10 (4.8 mm diameter).

Exception No. 1: A No. 8 (4.2 mm diameter) screw is used at a terminal intended only for the connection of a:

a) 14 AWG (2.1 mm^2) conductor; or

b) A 16 or 18 AWG (1.3 or 0.82 mm^2) control-circuit conductor.

Exception No. 2: A No. 6 (3.5 mm diameter) screw is used for the connection of a 16 or 18 AWG (1.3 or 0.82 mm^2) control-circuit conductor.

17.1.15 A wire-binding screw shall thread into metal.

17.1.16 A terminal plate tapped for a wire-binding screw shall be of metal not less than 1.27 mm (0.050 inch) thick.

Exception: A terminal plate less than 1.27 mm (0.050 inch) thick is not prohibited for use in a LVLE circuit or limited energy circuit (see 4.43 and 4.47) when the tapped threads have the mechanical strength to withstand the tightening torque specified in Table 17.2 withstanding 10 cycles of tightening to and releasing from the applicable value of torque specified in Table 17.2 without:

a) Damage to the terminal supporting member;

b) Loss of continuity;

c) Short circuiting of the electrical circuit to accessible metal; or

d) Stripping of threads.

Table 17.2
Tightening torque for wire-binding screws

Size of terminal screw, number	Wire sizes to be tested, AWG[a] or mm^2	Tightening torque	
		Newton meters	(Pound-inches)
6	16 – 18 / 1.3 – 0.83 (ST)	1.4	(12)
8	14 / 2.1(S) and 16 – 18 (ST)	1.8	(16)
10	10 – 14 / 4.8 – 2.1 (S) and 16 – 18 (ST)	2.3	(20)

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

17.1.17 There shall be two or more full threads in the metal of a terminal plate. Extruding the metal at the tapped hole to provide at least two full threads is not prohibited.

Exception: Two full threads are not required for a terminal in a LVLE or limited-energy circuit (see 4.43 and 4.47) 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 17.2.

17.1.18 A terminal for connection of a grounded conductor of an alternating current power circuit shall be identified as described in 93.10.

17.1.19 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 (13.3 mm^2) field-provided conductor. A field-wiring lead shall not be less than 152.4 mm (6 inches) long.

Exception No. 1: A 18 AWG size field-wiring lead is not prohibited for connection to a 12 AWG (3.3 mm^2) size branch circuit conductor.

Exception No. 2: A lead, 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), is not prohibited 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 96.4(e).

Exception No. 3: The requirements in 17.1.19 do not apply to control circuits. See Section 26, Control Circuits.

17.1.20 A field-wiring lead shall be rated for the voltage, current, and installation environment including but not limited to moisture, oil exposure, corrosion, temperature and mechanical damage.

17.1.21 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:

a) The lead is insulated at the unconnected end; and

b) A marking is provided on the unit in accordance with 93.16.

17.1.22 The free end of a field-wiring lead that is not used in every installation, such as a tap for a multi-voltage transformer, shall be insulated. For a grounding lead, see 20.8.

17.1.23 A field-wiring lead for connection of a grounded conductor shall be identified as described in 93.10.

17.1.24 A wiring compartment 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.

17.1.25 Wiring compartments, raceways, and similar equipment, 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.

17.1.26 For a unit intended for installation on a raised floor or over a cable vault, and having provision for entrance of field wiring through the bottom of the enclosure, the following requirements apply:

a) The bottom enclosure openings shall comply with 7.10.1; and

b) Conduit or knockout openings in accordance with 7.8 shall be provided.

17.1.27 Output conductors exposed to flexing from vibration or other normal generator functions or maintenance shall be of a stranded type.

17.1.28 Output conductors and cables exposed to water and UV shall be rated for water and UV exposure.

17.2 Openings for conduit or cable connection

17.2.1 An opening or knockout complying with the requirements specified in 7.8 shall be provided for connection of conduit or cable wiring system.

Exception: A unit complying with 7.8.7 and 7.8.8 is not required to be provided with an opening or a knockout.

17.3 Openings for class 2 circuit conductors

17.3.1 An opening for the entry of a conductor or conductors of a Class 2 circuit shall be provided with an insulating bushing. The bushing is not prohibited from being mounted in place in the opening or from being within the enclosure so that it is properly mounted when the unit is installed.

Exception: The bushing may be omitted when:

a) The opening is capable of accommodating armored cable or conduit; and

b) The installation instructions indicate that Class 1 wiring methods are to be used as indicated in 96.4(o).

17.3.2 A bushing of rubber or rubber-like material provided in accordance with 17.3.1 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 when 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 material that is capable of damaging the bushing.

17.3.3 Openings for conductors of a Class 2 circuit shall be located such that the wiring will be separated from all Class 1 circuit wiring. Wiring troughs or barriers may be required to ensure that field wiring conductors for hazardous circuits and Class 1 circuits will be adequately separated from the Class 2 circuit wiring.

17.4 Receptacles

17.4.1 AC convenience and output receptacles mounted in wet locations shall be provided with either:

a) An “extra-duty” outlet box hood in accordance with CSA C22.2 No. 42.1 / UL 514D; or

b) A self-closing enclosure, door, or hinged cover that prevents wetting of live parts with the attachment plug inserted or removed. The construction shall comply with the requirements in Section 7, Frame and Enclosure, and Section 77, Cycling Test, as preconditioning for the tests and requirements for Outdoor-Use Units in Section 71, Abnormal Tests.

17.4.2 Output receptacles shall be rated for the application including electrical and environmental conditions.

18 Wiring Space and Wire Bending Space

18.1 Wiring space

18.1.1 There shall be space within the enclosure of the equipment for the installation of those wires and cables likely to be used in connecting the mains and branch circuits, including feed through conductors that may continue to other portions of the equipment.

18.1.2 The adequacy of wiring space shall be judged using:

a) The size, type, and conductor material of a wire used at a terminal in accordance with 17.1.8 except that for low voltage circuits with ampacities of 110 A or less, the size shall be based on 60°C (140°F) insulated conductors although the marking specifies 75°C (167°F) wire;

b) The full complement of branch circuit devices which necessitate that the largest wiring space will be installed; and

c) At least one neutral terminal for each branch circuit position identified in (b) above.

18.1.3 If a terminal is for use with two or more combinations of conductors in multiple, each of which would be appropriate for that terminal in accordance with 17.1.8, the combination necessitating the largest wiring space shall be used. If a terminal is provided for conductors in multiple, the size of each conductor shall be based on the use of multiple conduits.

18.2 Wire bending space for low voltage conductors

18.2.1 Wire bending space for field installed wires including grounding conductors shall be provided opposite any wire connector and also opposite any opening or knockout for a conduit or wireway as specified in 18.1.2 and either 18.2.2 or 18.2.5.

18.2.2 If a conductor is likely to enter or leave the enclosure surface or open bottom opposite its wire connector, the wire bending space shall be as specified in Table 18.1. A wire is considered likely to enter or leave a top, back, or side surface if there is an opening or knockout for a wireway or conduit.

18.2.3 The wire bending space may be in accordance with Table 18.2 where wire connectors are readily removable as follows:

a) Only removable or lay-in wire connectors receiving one wire each are used (there may be more than one removable wire connector per terminal); and

b) The removable wire connectors can be removed from their intended location without disturbing structural or electrical parts other than a cover and can be reinstalled with the conductor in place.

18.2.4 The wire bending space may be in accordance with Table 18.3 if:

a) A barrier is provided between the connector and the opening; or

b) 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 18.1.

18.2.5 If a conductor is not likely to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 18.3.

18.2.6 If there is no barrier between two sections of a group, up to one third of the required wire bending space may be in the adjacent section.

18.2.7 If a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance is to be measured from the end of the barrier.

18.2.8 For a unit not provided with a conduit opening or knockout (see 7.8.7), the minimum wiring bending space specified in 18.2.2, 18.2.5, and 18.2.7 shall be based on:

a) Any enclosure wall that is used for installation of the conduit; or

b) Only specific walls that are to be used as determined by a marking, drawing, or template furnished with the unit.

18.2.9 The distance mentioned in 18.2.1 – 18.2.5 is to 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 18.1. 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 its turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or the like. A barrier, shoulder, or the like is to be disregarded when the measurement is being made if it does not reduce the radius to which the wire must be bent. If a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance is to be measured from the wire opening closest to the wall of the enclosure. If the connectors for a circuit are fixed in position – for example, by the walls of a recess – so that they are turned toward each other, the distance is to be measured at the wire opening nearest to the wall in a direction perpendicular to the wall.

18.2.10 The width of a wiring gutter in which one or more knockouts are provided shall be large enough to accommodate (with respect to bending) conductors of the maximum size to be used at that knockout. The values of the minimum intended width of a wiring gutter, with respect to conductors entering a knockout, are the same as the values of minimum intended bending space given in Table 18.3. See illustration E of Figure 18.1.

Exception: The wiring space is not prohibited from being of less width when:

a) Knockouts are provided elsewhere that are in compliance with these requirements;

b) The wiring space at such other point or points is of a width that accommodates the conductors in question; and

c) The knockout or knockouts at such other points are used in the intended wiring of the unit.

18.2.11 When measuring bending space for compliance with Table 18.3, the distance may be measured in a straight line from the center of the wire opening in the direction the wire leaves the terminal.

18.2.12 A wiring space in which one or more knockouts are provided shall be of a width that will accommodate (with respect to bending) conductors of the maximum size likely to be used at that knockout. The values of the minimum width of a wiring space, with respect to conductors entering a knockout, are the same as the values of minimum bending space given in Table 18.3. In the determination of the available width of a wiring gutter, no credit is given for the space within or immediately above a terminal compartment intended for an ungrounded conductor.

18.2.13 The wiring space may be of less width if 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 will accommodate the conductors in question, and the knockout or knockouts at such other points can be conveniently used in the intended wiring of the device.

18.2.14 A terminal compartment is considered to be a space into which wires will normally be brought only for connection to terminals in that space.

18.2.15 Where a conductor is not likely to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 18.3. The wire bending space is in accordance with Table 18.3 where:

a) A barrier is provided between the connector and the opening; or

b) 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 18.1.

Table 18.1
Minimum wire-bending space at terminals

Wire Size	Wires per Terminal							
	1		2		3		4 or More	
(AWG or kcmil)	mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)
14 – 10	Not specified		–	–	–	–	–	–
8	38.1	(1.5)	–	–	–	–	–	–
6	50.8	2 (1.5)	–	–	–	–	–	–
4	76.2	3 (2)	–	–	–	–	–	–
3	76.2	3 (2)	–	–	–	–	–	–
2	88.9	3.5 (2.5)	–	–	–	–	–	–
1	114	4.5 (3)	–	–	–	–	–	–
1/0	140	5.5 (5)	140	5.5 (5)	178	(7)	–	–
2/0	152	(6)	152	(6)	190	(7.5)	–	–
3/0	165	(6.5)	165	(6.5)	203	(8)	–	–

Table 18.1 Continued on Next Page

Table 18.1 Continued

Wire Size	Wires per Terminal							
	1		2		3		4 or More	
(AWG or kcmil)	mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)
4/0	178	(7)	190	7.5 (7)	216	(8.5)	–	–
250	216	8.5 (8)	216	8.5 (8)	229	(9)	254	(10)
300	254	(10)	254	(10)	279	(11)	305	(12)
350	305	(12)	305	(12)	330	13 (12)	356	(14)
400	330	13 (12)	330	13 (12)	356	(14)	381	(15)
500	356	14 (12)	356	14 (12)	381	15 (14)	406	(16)
600	381	15 (14)	406	(16)	457	(18)	483	(19)
700	406	16 (14)	457	18 (16)	508	20 (18)	559	22 (19)
750	432	(17)	483	(19)	559	(22)	610	(24)
800	457	(18)	508	20 (19)	559	(22)	610	(24)
900	483	19 (18)	559	22 (19)	610	(24)	610	(24)
1000	508	(20)	–	–	–	–	–	–
1250	559	(22)	–	–	–	–	–	–
1500	610	(24)	–	–	–	–	–	–
1750	610	(24)	–	–	–	–	–	–
2000	610	(24)	–	–	–	–	–	–

Table 18.2
Minimum wire-bending space at terminals where wire connectors are readily removable

Wire Size	Wires per Terminal							
	1		2		3		4 or More	
(AWG or kcmil)	mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)
14 – 10	Not specified		–	–	–	–	–	–
8	38.1	(1.5)	–	–	–	–	–	–
6	50.8	(2)	–	–	–	–	–	–
4	76.2	(3)	–	–	–	–	–	–
3	76.2	(3)	–	–	–	–	–	–
2	88.9	(3.5)	–	–	–	–	–	–
1	114	(4.5)	–	–	–	–	–	–
1/0	140	(5.5)	140	(5.5)	178	(7)	–	–
2/0	152	(6)	152	(6)	190	(7.5)	–	–
3/0	152	(6)	152	(6)	203	(8)	–	–
4/0	152	(6)	152	(6)	203	(8)	–	–
250	165	(6.5)	165	(6.5)	203	(8)	254	(10)
300	178	(7)	203	(8)	254	(10)	305	(12)
350	229	(9)	229	(9)	254	(10)	305	(12)
400	254	(10)	254	(10)	279	(11)	305	(12)

Table 18.2 Continued on Next Page

Table 18.2 Continued

Wire Size	Wires per Terminal							
	1		2		3		4 or More	
(AWG or kcmil)	mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)
500	279	(11)	279	(11)	305	(12)	330	(13)
600	305	(12)	330	(13)	381	(15)	406	(16)
700	330	(13)	381	(15)	432	(17)	483	(19)
750	356	(14)	406	(16)	483	(19)	533	(21)
800	457	(18)	508	(20)	559	(22)	610	(24)
900	483	(19)	559	(22)	610	(24)	610	(24)
1000	508	(20)	–	–	–	–	–	–
1250	559	(22)	–	–	–	–	–	–
1500	610	(24)	–	–	–	–	–	–
1750	610	(24)	–	–	–	–	–	–
2000	610	(24)	–	–	–	–	–	–

NOTE – The values in this table apply to:

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

2) The removable wire connectors can be removed from their intended location without disturbing structural or electrical parts other than a cover, and can be reinstalled with the conductor in place.

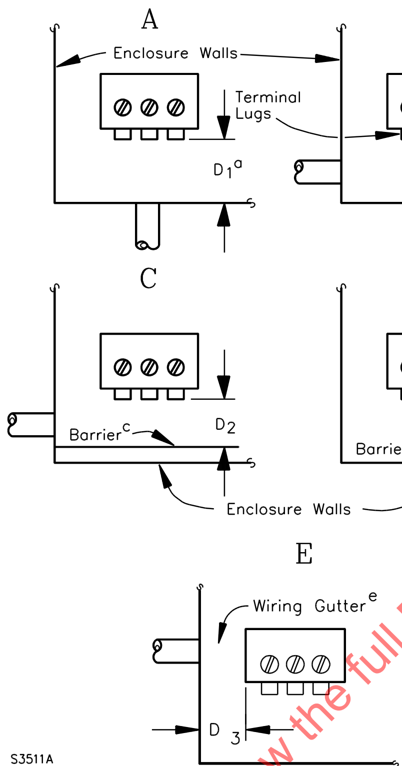
Table 18.3
Minimum width of gutter and wire-bending space for conductors through a wall not opposite terminals in mm (inches)

Size of wire		Wires per terminal (pole)									
AWG or kcmil	(mm^2)	1		2		3		4		5	
14 – 10 AWG	(2.1 – 5.3)	Not specified		–		–		–		–	
8 – 6	(8.4 – 13.3)	38.1	(1-1/2)	–		–		–		–	
4 – 3	(21.1 – 26.7)	50.8	(2)	–		–		–		–	
2	(33.6)	63.5	(2-1/2)	–		–		–		–	
1	(42.4)	76.2	(3)	–		–		–		–	
1/0 – 2/0	(53.5 – 74)	88.9	(3-1/2)	127	(5)	178	(7)	–		–	
3/0 – 4/0	(85.0 – 107)	102	(4)	152	(6)	203	(8)	–		–	
250 kcmil	(127)	114	(4-1/2)	152	(6)	203	(8)	254	(10)	–	
300 – 350	(152 – 177)	127	(5)	203	(8)	254	(10)	305	(12)	–	
400 – 500	(203 – 253)	152	(6)	203	(8)	254	(10)	305	(12)	356	(14)
600 – 700	(304 – 355)	203	(8)	254	(10)	305	(12)	356	(14)	406	(16)
750 – 900	(380 – 456)	203	(8)	305	(12)	356	(14)	406	(16)	457	(18)
1000 – 1250	(507 – 633)	254	(10)	–		–		–		–	
1500 – 2000	(760 – 1010)	305	(12)	–		–		–		–	

NOTE – The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned are not prohibited from being given further consideration.

Figure 18.1

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 18.1.

[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 18.3.

[c] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. In addition, a conduit opening or knockout is provided in the wall opposite the terminal lugs, however, a barrier preventing the use of the opening is provided. D_2 shall not be less than the minimum wire bending space specified in Table 18.3.

[d] When a barrier or other means is provided restricting bending of the conductor, the distance D_1 or D_2, as applicable (see notes for D_1 and D_2 above) is to 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 18.3.

18.3 Wiring space for low voltage conductors

18.3.1 The wiring space, independent of all projections, obstructions, or interference from moving parts of a switching mechanism shall:

a) Not be smaller in width or in depth than the values indicated in Table 18.1; and

b) Accommodate the wiring of the device, and shall not be smaller in total area than 250 percent of the total cross-sectional area of the maximum number of wires that may be used in such space.

18.3.2 In determining wiring space requirements, consideration is to be given to the actual size of wires that will be used in that space. In computing the area of a wiring space, consideration is to be given to all the available space that may be used for the placement of wires. Minimum areas of the more common multiple wire connections are specified in Table 18.1. The area occupied by a terminal compartment, as well as the area above such a compartment is not included when wiring space is determined; but space above or around an individual terminal or neutral located in a gutter is considered to be available space.

Exception: This Standard does not apply to enclosures of equipment intended to be wired with conductors that are smaller than 14 AWG.

18.3.3 For applications where generator field wiring comes up through the floor into a panelboard, switchboard, or switchgear enclosure, the minimum wiring space between the bottom of where conduit or other raceway may enter and between insulated or uninsulated bus bars shall:

a) Be 203 mm (8 inches) for insulated bus bars, their supports, or other obstructions; and

b) Be 254 mm (10 inches) for uninsulated bus bars.

NOTE: This requirement is related to 408.5 of the National Electrical Code, NFPA 70.

18.3.4 A bus bar or other obstruction may be located lower than specified if the clearances of 18.3.3 (a) or (b) will exist in the area directly above the conduit or raceway entry point if:

a) The section is intended for a specific installation where the conduit or raceway location is so specified; or

b) Information about intended conduit or raceway location is contained in the manufacturer's catalog (including the catalog number or other designation that also appears on the switchboard).

18.3.5 An operating mechanism and its relation to the wiring space shall be such that it will not damage wires with which it may come in contact during its operation.

18.3.6 Wiring space and other compartments intended to enclose wire shall be smooth and free from any sharp edge, burr, fin, or the like, that might damage the conductor insulation.

18.3.7 No uninsulated live part shall be located within a wiring space for field-installed conductors.

Exception: Field installed conductors of different circuits may be separated in accordance with 32.3.2.

18.3.8 To determine if the equipment complies with the requirement in 18.3.7, consideration is to be given to the probable ways in which it may be wired, considering the number, size, and relative location of knockouts and terminals.

18.3.9 A neutral bus or terminal strip with its line connections is a live part. It is considered as being in the wiring compartment unless covered or located so that circuit wires other than those connected to it will not be brought into contact with it.

18.3.10 An individual terminal is not considered as being in a wiring compartment if it is countersunk between closely fitting walls to such a depth that, when wired with a conductor of the size corresponding to the rating of the terminal, the top of the terminal will not be in contact with a straight edge placed across the walls. In general, more than one terminal in the same recess may not be used unless additional protection is provided.

18.4 Wire bending space for medium voltage conductors

18.4.1 Wire bending space shall be such that, during installation, field-installed conductors need not be bent to a radius less than:

a) 8 times the overall diameter for non-shielded conductors; or

b) 12 times the overall diameter for shielded or lead-covered conductors.

18.4.2 With respect to 18.4.1, equipment rated above 2.4 kV will always be installed using shielded conductors. Equipment rated 2.4 kV or less may be installed using shielded or non-shielded conductors. For equipment rated 2.4 kV or less, if wire bending space is insufficient for the use of shielded conductors, installation instructions shall specifically require the use of non-shielded conductors only.

18.4.3 When determining wire bending space requirements, consideration shall be given to the type and maximum size of wire, the need to use stress cones for shielded conductors, and detailed instructions provided by the manufacturer as described in 96.7.

18.4.4 For the purposes of determining the required bending space, the conductor size shall be determined using the worst case for type MV-90 cables from Tables 311.60(C)(73) through 311.60(C)(80), unless the equipment is provided with instructions limiting the type of cables (copper or aluminum only, single conductor, triplexed, or three conductor cable) and raceway location (in earth or air).

19 Output Circuit Grounding

19.1 General

19.1.1 The generator assembly shall be provided with a means for grounding the output circuits in accordance with the National Electrical Code, NFPA 70, Article 250, and the Canadian Electrical Code, Part I, Section 10.

19.1.2 An output alternating current power circuit shall be grounded when:

a) The circuit has no electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another wiring system;

b) The circuit is rated 50 – 600 V; and

c) The circuit is as described, and not limited to those in (1) – (3) [see Article 250.20 (b) of the National Electrical Code, NFPA 70, and the Canadian Electrical Code, Part I, Section 10, for other circuits]:

1) A circuit that is grounded so the maximum voltage to ground on the ungrounded conductors does not exceed 150 V. This requires that one conductor of each of the following circuits be grounded:

i) 120 V, 2-wire;

ii) 240/120 V, single-phase, 3-wire;

iii) 208/120 V, two-phase, 3-wire;

iv) 208/120 V, three-phase, 4-wire.

2) A circuit nominally rated 480 wye/277 V or 600 wye/347 V, 3-phase, 4-wire in which the neutral is used as the grounded circuit conductor.

3) A circuit-nominally rated 240/120 V, 3-phase, 4-wire in which the midpoint of one phase is used as the grounded circuit conductor.

4) For other units, an output alternating current power circuit complying with (a) is not prohibited from being grounded when the construction complies with the requirements described in 19.1.3 and 19.1.6.

5) Output circuits over 1,000 V in the US shall comply with article 490 of the National Electrical Code, NFPA 70. Output circuits over 750 V in Canada shall comply with CE Code Part I Section 36.

19.1.3 With reference to 19.1.2, the conductor to be grounded shall be as follows:

a) Single-phase alternating current system, 2-wire – one conductor.

b) Single-phase alternating current system, 3-wire – the neutral conductor.

c) Multiphase alternating current system having one wire common to all phases – the common conductor.

d) Multiphase alternating current system where one phase is used as in (b) above – the neutral conductor.

In Canada, the grounded conductor on a single-phase alternating current system, 2-wire is known as the Identified Conductor.

19.1.4 Grounding of the circuits specified in 19.1.2 and 19.1.3 shall be made by a bonding jumper (see 19.1.5) connected between the grounded conductor referenced in 19.1.3 and to:

a) The enclosure of a metal-enclosed unit; or

b) The metal chassis that is bonded to the equipment grounding conductor or terminal of a nonmetallic enclosed unit.

Exception: The following provisions are to be provided in order for the circuit to be grounded in the field:

a) A field-wiring terminal intended for use with a conductor size specified in Column 4 of Table 19.1 and identified in accordance with 93.10, shall be connected to the circuit by a bonding jumper of a size not less than specified in Column 4 of Table 19.1; and

b) A marking identifying the circuit as a separately derived source and referencing the instruction manual.

Table 19.1
Size of circuit bonding, equipment-grounding, and grounding electrode conductors

Column 1	Column 2				Column 3				Column 4			
	Minimum size of equipment grounding or bonding conductor AWG or kcmil (mm^2)[b]				Minimum size of grounding electrode conductor AWG or kcmil (mm^2)				Minimum size of output circuit bonding jumper AWG or kcmil (mm^2)[e]			
Maximum current rating[a], Amperes	Copper		Aluminum or copper-clad aluminum		Copper		Aluminum or copper-clad aluminum		Copper		Aluminum or copper-clad aluminum	
20	12	(3.3)	10	(5.3)	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
60	10	(5.3)	8	(8.4)	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
90	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
100	8	(8.4)	6	(13.3)	6	(13.3)	6	(13.3)	6	(13.3)	4	(21.2)
150	6	(13.3)	4	(21.2)	6	(13.3)	4	(21.2)	6	(13.3)	4	(21.2)
200	6	(13.3)	4	(21.2)	4	(21.2)	2	(33.6)	4	(21.2)	2	(33.6)
300	4	(21.2)	2	(33.6)	2	(33.6)	1/0	(53.5)	2	(33.6)	1/0	(53.5)
400	3	(26.7)	1	(42.4)	1/0[c]	(53.5)	3/0[c]	(85.0)	1/0[c]	(53.5)	3/0[c]	(85.0)
500	2	(33.6)	1/0	(53.5)	2/0	(67.4)	4/0	(107.2)	1/0	(53.5)	3/0	(85.0)
600	1	(42.4)	2/0	(67.4)	2/0	(67.4)	4/0	(107.2)	2/0	(67.4)	4/0	(107.2)
800	1/0	(53.5)	3/0	(85.0)	3/0	(85.0)	250	(127)	2/0	(67.4)	4/0	(107.2)
1000	2/0	(67.4)	4/0	(107.2)	3/0	(85.0)	250	(127)	3/0	(85.0)	250	(127)
1200	3/0	(85.0)	250	(127)	3/0	(85.0)	250	(127)	250[d]	(127)	250	(127)
1600	4/0	(107.2)	350	(127)	3/0	(85.0)	250	(127)	300[d]	(152)	400[d]	(203)
2000	250	(127)	400	(203)	3/0	(85.0)	250	(127)	400[d]	(203)	500[d]	(253)
2500	350	(177)	600	(304)	3/0	(85.0)	250	(127)	500[d]	(253)	700[d]	(355)
3000	400	(203)	600	(304)	3/0	(85.0)	250	(127)	600[d]	(304)	750[d]	(380)
4000	500	(253)	800	(405)	3/0	(85.0)	250	(127)	700[d]	(355)	1000[d]	(508)
5000	700	(355)	1200	(608)	3/0	(85.0)	250	(127)	900	(456)	1250	(635)
6000	800	(405)	1200	(608)	3/0	(85.0)	250	(127)	1200	(608)	1500	(759)

NOTE – See Table 19.2 for equivalent area of bus.

[a] Maximum ampere rating of the output circuit overcurrent protective device described in 33.3.1 – 33.3.3.

[b] The equipment grounding conductor is not prohibited from being the same size as the current-carrying conductors.

[c] When the wire terminal connectors for the input or output circuit conductors, as applicable, are rated for two 3/0 AWG copper or two No. 250 kcmil aluminum conductors and do not accept a No. 600 kcmil conductor, these values are not prohibited from being reduced to 2 AWG copper or 1/0 AWG aluminum.

[d] The cross-section is not prohibited from being reduced to 12.5 percent of the total cross section of the largest input or output circuit conductor, as applicable, of the same material (copper or aluminum) for any phase on units rated 1200 amperes and above. This applies when the cross section of the circuit conductors is limited by the wire terminal connectors provided.

[e] The bonding jumper for a stationary unit is not prohibited from being the same size as the current-carrying conductors of the output circuit.

Table 19.2
Equivalent cross-sectional areas of conductors

Wire size		Minimum cross section	
mm^2	(AWG or kcmil)	mm^2	(In^2)
2.1	(14)	2.08	0.003
3.3	(12)	3.31	(0.005)
5.3	(10)	5.26	(0.008)
8.4	(8)	8.39	(0.013)
13.3	(6)	13.55	(0.021)
21.2	(4)	21.29	(0.033)
26.7	(3)	26.45	(0.041)
33.6	(2)	33.55	(0.052)
42.4	(1)	42.58	(0.066)
53.5	(1/0)	53.55	(0.083)
67.4	(2/0)	67.74	(0.105)
85	(3/0)	85.16	(0.132)
107	(4/0)	107.10	(0.166)
127	(250)	126.45	(0.196)
152	(300)	152.26	(0.236)
177	(350)	177.42	(0.275)
203	(400)	202.58	(0.314)
253	(500)	253.55	(0.393)
304	(600)	304.0	(0.471)
355	(700)	354.84	(0.550)
380	(750)	380.00	(0.589)
405	(800)	405.16	(0.628)
507	(1000)	506.45	(0.785)
608	(1200)	607.73	(0.742)
633	(1250)	632.90	(0.981)
760	(1500)	760.00	(1.178)
887	(1750)	887.00	(1.374)
1010	(2000)	1013.00	(3.100)

19.1.5 The size of the bonding jumper specified in 19.1.4 shall be, based on the current rating of the circuit, not less than the value specified in Column 4 of Table 19.1.

19.1.6 A fixed unit shall be provided with a terminal that complies with 17.1.9 – 17.1.18 for connection of the grounding electrode conductor to the metal enclosure or equipment grounding conductor described in 19.1.4 (a) and (b). The terminal shall be:

a) Capable of securing a conductor size, based on the maximum current rating of the circuit, as specified in Column 3 of Table 19.1; and

b) Marked as described in 93.11.

19.1.7 For an alternating current output circuit of a unit having a polarized AC convenience receptacle, lead, or terminal identified as a grounded circuit (see 93.10) that is not grounded at the unit itself because of an electrical connection to supply conductors originating in another wiring system – see 19.1.2(a), a potential involving a risk of electric shock shall not exist between ground and the grounded circuit contact, terminal, or lead. Compliance with this requirement is to be determined by the test specified in 65.1.

Exception: The test described in 65.1 is not required when the ac input neutral and ac output neutral conductors are solidly connected together, that is, no electronic components connected between the neutral conductors.

19.1.8 Neutral grounding devices shall comply with IEEE C57.32 and CSA C22.2 No. 295.

19.2 Ground fault protection

19.2.1 All output circuits for supplying 120 V, 60 Hz, 2-wire with ground and 120/240 V, 60 Hz, 3-wire with ground to convenience outlets shall be protected by ground fault circuit interrupters designed for the current involved.

19.2.2 When installed on the generator, the ground fault circuit interrupter shall have a current rating not less than 115 percent of the circuit rating and shall be installed in accordance with its installation instructions.

Exception: Dedicated purpose generator component outlets shall comply with the following:

a) The dedicated purpose generator receptacle shall be grounded;

b) The dedicated generator outlets shall be provided with protection rated for the marked branch circuit for the outlet and for the specific dedicated load(s) connected to them;

c) A single outlet may be provided per dedicated purpose generator component; and

d) Dedicated purpose generator outlets shall be marked in accordance with 94.15.

19.2.3 Ground fault protection for circuits operating at 120/240 V shall comply with CSA C22.2 No. 144.1 / UL 943.

19.2.4 Ground fault protection for circuits other than addressed in 19.2.1 shall comply with CSA C22.2 No. 144 / UL 943C.

20 Equipment Grounding

20.1 There shall be provisions for grounding all dead metal parts of a unit that are exposed or that are capable of being contacted by a person during intended operation or adjustment and that are capable of becoming energized as a result of electrical malfunction.

20.2 The provisions for equipment grounding specified in 20.1 shall be provided for each wiring system to be connected to the alternating current output circuit.

Exception: Accessible signal circuits described in Accessible Signal Circuits, Section 30, are not required to have provisions for equipment grounding.

20.3 To determine whether a part is capable of becoming energized, factors such as construction, the proximity of wiring, and the results of a dielectric voltage-withstand test (conducted after the applicable overload, endurance, and abnormal tests) are to be evaluated.

20.4 For low voltage equipment, the grounding means shall consist of an equipment-grounding terminal or lead. For medium voltage equipment, the grounding means shall consist of a grounding terminal or a ground bus having a hole pattern meeting the requirements of NEMA CC1.

20.5 An equipment-grounding terminal or lead-grounding point shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection. To reduce the risk of being inadvertently disconnected, the removal or opening of covers shall not require the ground lead to be disconnected. The bolt head of a grounding stud shall not be accessible from the outside of the unit.

20.6 An equipment-grounding connection shall penetrate a non-conductive coating, such as paint or vitreous enamel.

20.7 An equipment-grounding point shall be located so that the risk the grounding means is inadvertently removed during servicing is reduced.

20.8 A free end of an equipment-grounding lead shall be insulated (for example, the end is to be folded back and taped to the lead) unless the lead is located so that it does not contact live parts in the event that the lead is not used in the field.

20.9 An equipment-grounding lead for low voltage equipment shall be a size specified in Column 2 of Table 19.1. The lead shall have a free length of at least 152 mm (6 inches) and the surface of the insulation shall be green with or without one or more yellow stripes. No other lead in a field-wiring compartment or visible to the installer shall be so identified.

Exception: The color coding requirement does not apply to low-voltage Class 2 circuits provided the low-voltage leads are:

a) Located remote from the line-voltage connections and the segregation complies with the requirements in Section 32, Separation of Circuits; or

b) Marked in accordance with 93.17.

20.10 An equipment-grounding conductor shall not be spliced. If the equipment grounding conductor consists of a ground bus, the bus may be provided with a bus splice, if the splice is of the same material and cross sectional area as the ground bus.

20.11 An equipment-grounding connection, equipment-grounding conductor, enclosure, frame, component mounting panel, or any other part connected to earth ground shall not carry current except during an electrical malfunction. See 26.1.

Exception: A line bypass capacitive impedance circuit for a radio frequency signal circuit or a transient voltage surge suppressor is not required to comply.

20.12 A grounded circuit conductor shall not be connected to any equipment-grounding or bonding circuit in a unit.

Exception: The output circuit of a unit as described in 19.1.1 and 19.1.2 is not prohibited from being connected to an equipment-grounding or bonding circuit.

20.13 A soldering lug, a connection means that depends on solder, a screwless (push-in) connector, a quick-connect, or other friction-fit connector shall not be used for equipment-grounding.

20.14 The equipment-grounding terminal shall be capable of securing a conductor of a size intended for the application in accordance with Column 2 of Table 19.1 and shall be constructed in accordance with the requirements specified in 17.1.9 – 17.1.17.

20.15 A wire-binding screw employed for the connection of a field-installed equipment grounding conductor shall have a green colored head that is either hexagonal, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be marked as described in 93.8.

20.16 When two or more units are interconnected electrically and one of them is grounded, they shall be bonded together, such as by means of a conductor included in an interconnecting cable or by a conductive mechanical means, including the use of starwashers or the equivalent (see 21.6 – 21.10).

20.17 An equipment-grounding bus bar shall be sized per specified in Column 2 of Table 19.1.

21 Bonding of Internal Parts

21.1 On a generator having provisions for grounding (see 20.1), all exposed dead metal parts that are capable of becoming energized through electrical fault that involves a risk of electric shock or electrical energy – high current levels, shall be conductively connected to the equipment grounding means.

21.2 All uninsulated metal parts of the enclosure, motor frames and mounting brackets, 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 grounding when they are capable of being contacted by the user or inadvertently contacted by service personnel.

Exception: A metal part as described in (a) – (g) is not required to be bonded for grounding:

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 grounded metal parts so that they do not become energized;

b) An isolated metal part, such as a magnet frame and an armature, a small assembly screw, or similar part, 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 it does not become energized;

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 94.10; and

g) A capacitor sleeved with insulating tubing complying with 25.2.2.

21.3 An internal metal-to-metal connection for bonding internal parts to an enclosure for grounding, and not for a field-installed grounding conductor or for the grounding wire in a supply cord, is not prohibited from employing a quick-connect terminal when:

a) The connector is not displaced;

b) The terminal has the dimensions specified in Table 21.1; and

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

Table 21.1
Quick-connect terminals for bonding internal parts

Nominal size of terminal, mm (inches)					
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)

21.4 Where the continuity of the grounding system relies on the dimensional integrity of a nonmetallic material, the material meets the intent for the purpose when investigated for creep in accordance with UL 746A. See also 21.8.

21.5 A separate component bonding conductor shall be of copper, a copper alloy, or other material intended for use as an 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:

a) Be protected from mechanical damage or be located within the outer enclosure or frame;

b) Not be secured by a removable fastener used for any purpose other than bonding for grounding, unless the bonding conductor remains after removal and replacement of the fastener; and

c) Not be spliced.

21.6 The bonding shall be by a positive means, such as by 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 and provide metal-to-metal contact. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material, other than as indicated in 21.8.

21.7 With reference to 21.6 where penetration of a nonconductive coating is not determined by examination, a Grounding Impedance Test, Section 73, shall be conducted.

21.8 A connection that depends upon the clamping action exerted by rubber or similar material is not prohibited when it complies with the requirements in the Bonding Conductor Test, Section 79, for bonding conductors under any normal degree of compression exerted by a variable clamping device and when the results are unchanged 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 taken into account with particular emphasis on it being reassembled in its intended position.

21.9 A separate component-bonding conductor shall:

a) Not be smaller than the size specified in Column 2 of Table 19.1 (see 21.10);

b) Not be smaller than the conductor supplying the component; or

c) Comply with the applicable marking requirements.

21.10 With reference to Column 2 of Table 19.1, where more than one size branch-circuit overcurrent device is involved, the size of the bonding conductor is to be based on the rating of the overcurrent device intended to provide ground-fault protection for the component bonded by the conductor.

22 Internal Wiring

22.1 Wires

22.1.1 The internal wiring of a generator 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 including but not limited to the effects of vibration, impact, and exposure.

22.1.2 Wiring exposed to flexing from vibration or other normal generator functions or maintenance shall be of a stranded type.

22.1.3 All low voltage wiring shall be polyvinyl chloride (PVC), polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), or neoprene insulated, or shall comply with the vertical wire flame test requirements in CSA C22.2 No. 75 / UL 83. Medium voltage wiring shall be type MV cable or equivalent.

Exception: The requirements in 22.1.1 – 22.1.3 do not apply to wiring for Class 2 circuits.

22.1.4 Wire and cables exposed to water shall be rated for water exposure.

22.1.5 Wire and cables exposed to UV shall be rated for UV exposure.

22.2 Protection of wiring

22.2.1 Internal wiring shall not be accessible when judged in accordance with Section 8, Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing.

Exception: Internal wiring is capable of being accessed when it is located and secured within the enclosure so that it is not subjected to stress or mechanical damage.

22.2.2 Wires within an enclosure, compartment, wireway, 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 is capable of damaging the conductor insulation. Wireways shall comply with the requirements in CSA C22.2 No. 26 / UL 870.

22.2.3 Internal wiring shall be so routed and secured that neither it nor related electrical connections are subjected to stress or mechanical damage in such a manner that a broken termination does not present a risk of fire or electric shock by contacting parts of different circuits or other parts that may introduce a risk of fire or electric shock to the user.

22.2.4 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.

22.2.5 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 intended for the application – such as porcelain, phenolic fiber at least 1.2 mm (3/64 inch) thick, a material complying with the requirements in CSA C22.2 No. 0.17 / UL 746C or smooth, rounded metal. A soft-rubber bushing or similar device is not to be used for other than low-voltage wiring (see 17.3.2) unless the material has been evaluated and found to comply for the purpose.

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

22.2.7 Auxiliary mechanical protection that is not electrically conductive shall be provided:

a) 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

Exception: Auxiliary mechanical protection is not required for conductors having cross-linked synthetic insulation.

b) On any wire or wires that are subject to motion.

22.2.8 Conductors greater than 10 AWG (5.26 mm^2) of an alternating-current circuit that pass through a wall or partition of metal having magnetic properties shall comply with 33.4.

23 Current-Carrying Parts

23.1 General

23.1.1 A current-carrying part shall be of silver, copper, a copper-base alloy, stainless steel, aluminum, or other materials intended for the application.

Exception No. 1: Plated steel may be used 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).

Exception No. 2: Blued steel or steel with equivalent corrosion resistance may only be used for the current-carrying arms of mechanically or magnetically operated leaf switches, within a motor and its governor, motor terminals included, or where the temperature is in excess of 100°C (212°F).

23.1.2 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 25.

23.2 Bus bars

23.2.1 Each bus bar shall be plated at each current carrying joint with tin, silver, or nickel.

Exception No. 1: A welded or brazed joint is not required to be plated.

Exception No. 2: A low voltage copper bus bar is not required to be plated when the current at the joint is 600 amperes or less.

Exception No. 3: Other coatings are not prohibited from being used for low voltage aluminum bus bars when they are investigated for the application in accordance with the requirements for current-carrying parts described in Bus Bar Tests, Section 84.

Exception No. 4: A low voltage bus bar provided with an oxide inhibiting compound over the joint surfaces is not required to be plated. See 23.7.1.

23.2.2 The bending of a bus bar shall not result in visible cracks, but roughening or slight surface crazing is acceptable.

23.2.3 The phase arrangement of bus bars in a 3-phase generator, but not including the connections to meter sockets, shall be A, B, C from front to back, top to bottom, or left to right as viewed from outside of the generator field wiring compartment.

23.2.4 Other bus bar arrangements are permitted for a generator or for connection to meter sockets, transformers, or current transformers if the arrangement of the bus bars is indicated by a marking.

23.2.5 The phase arrangement in a 240 V, 3-phase, 3-wire generator employing two phase buses and a neutral and intended for use on a grounded B phase system is to be A, C with the neutral as the B phase.

23.2.6 Spring-loaded connections to low voltage bus bars, such as at plug-in circuit breakers and switches, shall be investigated in accordance with the applicable requirements in CSA C22.2 No. 29 / UL 67.

23.3 Riveted construction (not for medium voltage equipment)

23.3.1 Each riveted connection involving current carrying parts shall have a spring washer at one end and either a spring washer or a flat washer at the other end.

23.3.2 Washers may be omitted in a construction that has been tested in accordance with the temperature test.

23.3.3 Washers may be omitted in a connection rated 225 A or less having copper bus bars only.

Exception: Other constructions employing a rivet are not prohibited when they are investigated in accordance with the applicable requirements in Bus Bar Tests, Section 84.

23.3.4 A spring washer shall be used at one end of a bolt securing current carrying parts together.

23.3.5 A spring washer may be replaced with a split-ring lock washer and flat washer if each aluminum bus in the joint has a tensile yield strength of at least 138 MPa (20,000 pounds per square inch).

23.3.6 A flat washer, a split-ring lock washer, or a bolt head that has an outer diameter of at least 150 percent of the bolt shaft may be used in place of a spring washer if:

a) The joint does not include any aluminum;

b) Aluminum bolts are used with aluminum bus bars; or

c) The only aluminum in the joint is the tang of a pressure terminal connector.

Exception: Other constructions comply when they are investigated in accordance with the applicable requirements in Bus Bar Tests, Section 84.

23.3.7 A type of fastening means specified in the installation instructions supplied with a pressure terminal connector may be used with such a connector.

23.3.8 A spring washer is not required at a bolted contact of an aluminum alloy conductor (bus) used in a grounding circuit within the switchboard.

23.3.9 A bolted connection between two bus bars or between a bus bar and another current carrying part shall not depend on polymeric insulation to maintain the clamping force and shall not depend on thermoplastic material in any case.

23.3.10 A bolted joint in a bus bar shall be accessible for tightening without removing insulating tape. Use of bus boots that are secured by nonmetallic, reusable hardware is acceptable for bus bar joint insulation.

23.3.11 Bolts, nuts, and washers as specified in 23.3.4 shall be provided for connecting through bus to other sections. The length of the bolts shall be such that the electrical spacings are maintained.

23.4 Washers

23.4.1 The flat washer specified in 23.3.1 and 23.3.5 shall have a thickness of at least 1/6 the diameter of the rivet shank or bolt and shall have an outer diameter at least 150 percent of the rivet shank or bolt but not less than the outer diameter of the spring washer.

23.4.2 A spring washer as mentioned in 23.3.1 and 23.3.5 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 1/8 of the bolt diameter, and dished not less than 3-1/2 percent of the bolt diameter.

23.5 Ampacity

23.5.1 Bus bar ampacity shall be determined by compliance with the Temperature Test of Section 58. For low voltage assemblies, bus bar ampacity may be determined as specified in 23.5.2 – 23.5.10.

23.5.2 Other than as covered in 23.5.4, the ampacity or size of a bus bar is considered sufficient if the current density is not more than that specified in Table 23.1 or the size is not less than that specified in Table 23.2.

23.5.3 The ampacity of a clamped joint may be higher as covered in 23.5.17.

23.5.4 A bus bar shall be sized in accordance with Table 23.1 and Table 23.2 if it is connected to a low voltage power switching device, fused power circuit device, molded case circuit breaker, or transfer switch incorporating Class L fuses, any of which is rated over 2,500 A for continuous use at 100 percent of its rating.

23.5.5 Beyond a minimum distance of 1.2 m (4 feet) along the current path from the 100 percent rated device, the bus bar may be reduced in size, in accordance with the limitations specified in Table 23.2.

23.5.6 A single bus bar intended to carry 800 A or less may be sized in accordance with Table 23.2 if plated and bolted joints are used.

23.5.7 The cross section of a bus as covered in Table 23.1 and Table 23.2 may be reduced by not more than 5 percent due to rounding, shaping, or dimensional tolerances.

23.5.8 Part of the bus material may be removed for slots or holes (whether used or not) if the remaining material at any cross section along the length of the bus bar has at least 70 percent of the required ampacity and the remaining metal in any 152 mm (6 inches) length of bus is at least 93 percent of the metal of a bus having the required ampacity in accordance with 23.5.7, Table 23.1, and Table 23.2. For example, a 25.4 mm (1 inch) wide bus could have 7.1 mm (9/32 inch) holes on 25.4 mm (1 inch) centers or a 102 mm (4 inch) wide bus could have 10.3 mm (13/32 inch) wide slots 81.3 mm (3.2 inch) long every 152 mm (6 inches).

23.5.9 Bus bars with a larger amount of material removed may be used if the construction is acceptable under the Temperature Test conditions specified in Section 58.

23.5.10 The limitations on current density mentioned in Table 23.1 or Table 23.2 do not apply to:

a) A connecting strap, bus, or the like, comprising a part of a circuit breaker, switch, or fuseholder employed in the switchboard; or

b) A portion of a strap, bus, jumper, or the like, adjacent and connected to a terminal of a switch, circuit breaker or fuseholder [but not more than 25.4 mm (1 inch) from the terminal], if a reduced cross section in that portion is necessary because of the recessing of the terminal or because of barriers adjacent to it.

23.5.11 A wire or bus bar leading to a fuseholder shall have an ampacity not less than the rating of the largest fuse the fuseholder will accommodate unless marked to reference the maximum fuse rating to not exceed the maximum ampacity of the bus bar.

23.5.12 A wire or bus bar leading to a non-interchangeable trip circuit breaker shall have an ampacity not less than the current rating of the breaker.

23.5.13 A wire or bus bar leading to a circuit breaker frame designed for use with interchangeable trip units shall have an ampacity not less than the maximum current rating of the frame unless marked in accordance with the current rating of the breaker.

23.5.14 The ampacity of a branch, section, or supply bus bar or wire supplying more than one overcurrent protective device shall not be less than the percentage of the sum of the ratings for the number of branch circuit overcurrent protective devices provided. The overcurrent protective device rating used in the calculations shall correspond with the branch bus ampacity rating.

23.5.15 The section or supply bus ampacity need be not greater than the rating of the overcurrent device used to protect the bus as a main or sub-main.

23.5.16 The section or supply bus ampacity may be as noted in 23.5.15.

23.5.17 For the following constructions in low voltage generators, the contact area may result in current densities greater than the maximum of 31 A per cm^2 (200 A per in^2) specified in 23.5.2, Table 23.1, and Table 23.2:

a) The contact area between a plated bus bar and circuit breaker or switch shall not be less than the area on the pressure wire connector that is supplied with a breaker of appropriate rating, or not less than the contact area available for back connection.

b) If the full available contact area between a bus bar and pressure terminal connector is not used, the contact area shall not be less than the area that would result when two of the same type connectors are bolted together back-to-back with wires leaving in opposite directions or at right angles, whichever results in the smallest area.

Exception: A bus bar contained in a unit having forced air ventilation that does not result in maximum bus bar temperatures exceeding the values specified in Table 58.2 is not prohibited from having a current density exceeding that of Table 23.1 and Table 23.2.

23.5.18 In determining the area of contact surfaces of bolted or riveted connections in low voltage generators, no subtraction shall be made for diameters of holes containing bolt or rivets, and no additions shall be made for the diameters and areas of screws, bolts, washers, or rivets.

23.6 Support and securement of live parts

23.6.1 A bus bar shall either be supported independently of any unit to which it is connected (switch, circuit breaker, or the like) or shall be supported by units that are factory installed and that do not depend on the bus bar for support.

23.6.2 A bus bar or uninsulated live part, other than a pressure wire connector as mentioned in 76.1, shall be secured so that ordinary vibration will not loosen the securing means and shall be prevented from turning or shifting in position if any spacings less than those specified in Section 25, Spacings, would result from such turning or shifting. A bus bar provided with one or more insulators that must be removed when a branch circuit unit is installed shall be prevented from any turning that would result in spacings less than those specified in Section 25 with all insulators in place, or that would result in spacings less than 3.2 mm (1/8 inch) for a voltage up to 250 V, or 9.4 mm (0.37 inch) for a voltage between 251 to 600 V, with any insulators omitted.

23.6.3 Friction between surfaces may not be used as a means to prevent turning or shifting of an uninsulated live part. Turning or shifting may be prevented by the use of two screws or rivets; by noncircular 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. No reliance is to be placed on a single branch circuit fuseholder, circuit breaker, or switch unit for preventing turning of the branch bus feeding such unit if such turning would reduce spacings to less than those specified in 23.6.2 or Section 25, Spacings.

23.6.4 In determining the adequacy of means to prevent turning or shifting, any screw or nut is to be loosened and retightened finger-tight without a tool. The bus is then to be pushed to the extent limited by the screws or other means and the resulting spacings checked.

23.6.5 If a branch circuit unit (circuit breaker or switch unit) rated 600 A or less is removable from the front of the panel, the replacement or removal of such unit shall not result in the likelihood of a short circuit from turning or dropping of parts.

23.6.6 A bolt, nut, or washer used to secure a branch circuit unit is not considered likely to fall if it is visible and readily reached. A branch bus is considered likely to fall if the bolts that secure the branch circuit unit to the branch bus are the same as those used to secure the branch bus to the bus on its line side.

Exception: A connection rated 225 amperes or less employing copper bus bars only is not required to comply.

Table 23.1
Ampacity of single or multiple bus bars and clamped joints for low voltage generator output

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

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

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

[c] See also Table 23.2 for 800 ampere maximum single bus bars.

[d] See 23.1.1, 23.5.11 – 23.5.13.

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

Table 23.2
Rating and sizes of single bus bars – 800 amperes maximum for low voltage generator output

Current rating in amperes	Copper bus				Aluminum bus[b]			
	Bus size[a]		Cross section		Bus size[a]		Cross section	
	mm	(Inches)	mm^2	(in^2)	mm	(inches)	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 23.1	See Table 23.1	518.1	(0.800)
800	6.4 by 76.2	(0.250 by 3.000)	483.9	(0.750)	See Table 23.1	See Table 23.1	688.4	(1.067)

NOTE 1 – See 23.5.11 – 23.5.13. For multiple buses in parallel, refer to Table 23.1. The minimum contact area at a clamped joint shall provide not less than 6.5 cm^2 (1 square inch) per 200 amperes.

NOTE 2 – Bolted joints shall be plated with silver, tin, nickel, or cadmium. Bus bars shall also be plated with silver, tin, nickel, or cadmium for ampacities greater than 600 A.

NOTE 3 – 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 58.1 under the test conditions indicated in Section 58, Temperature Test.

[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.

23.7 Heat sinks

23.7.1 A current-carrying, aluminum heat sink shall be plated, conductive anodized, irradiated or the equivalent at surfaces contacting the solid state component.

Exception No. 1: This requirement does not apply to a heat sink provided with an oxide inhibiting compound over the heat sink surfaces contacting the solid state component.

Exception No. 2: This requirement does not apply to a heat sink subjected to the heat cycling tests described in Section 82, Heat Sink Temperature Cycling Test.

24 Electrical Connections

24.1 The requirements described in 24.2 – 24.7 apply to connections of internal wiring that are factory installed.

24.2 A splice or connection shall be done with a splicing device rated for the electrical and environmental application. It shall be mechanically secure and shall make electrical contact of not less than that of the original conductor prior to the splice. The insulation on a splice shall be at least equal to the conductors being joined.

24.3 A soldered connection is mechanically secure where the lead is one of the following or equivalent:

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 properly inserted or secured (as in a surface mounted component) and wave- or lap-soldered; or

c) Twisted with other conductors.

24.4 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 is accomplished by use of pressure terminal connectors, soldering lugs, crimped eyelets, soldering of all strands together, or by any other equivalent means. Wire binding screws shall not be used to secure medium voltage conductors.

24.5 A nominal 2.8 mm (0.110 inch), 3.2 mm (0.125 inch), 4.7 mm (0.187 inch), 5.2 mm (0.205 inch), or 6.4 mm (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 investigated 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. Quick connect terminals shall not be used to secure medium voltage conductors.

24.6 An open-end spade lug does not comply 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. Open-end spade lugs shall not be used to secure medium voltage conductors.

24.7 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 of the splice shall be one of the following or equivalent:

a) A splicing device such as a pressure wire connector is not prohibited when insulated for the voltage and temperature to which the device will be subjected;

b) Insulating tubing or sleeving used to cover a splice shall be used in accordance with 25.2.2; or

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

Exception: A splicing device, insulating tubing, sleeving, or tape is not required for use on splices within coil windings.

24.8 Electrical studs, terminals and connection shall be prevented from rotation.

25 Spacings

25.1 General

25.1.1 The spacings for a generator intended for use in a general environment shall not be less than the applicable values specified in Table 25.1. The spacing, for voltages rated up to 1000 V, between field-wiring terminals of opposite polarity, and the spacing between a field-wiring terminal and any other uninsulated metal part (electrically energized or not and not always of the same polarity) shall comply with Section 18, Spacings, of UL 1004-1. The spacing, for voltages above 1000 V, between field-wiring terminals of opposite polarity, and the spacing between a field-wiring terminal and any other uninsulated metal part, including removal of metal enclosures shall comply with Section 6, Spacings, of UL 1004-9.

Exception No. 1: The spacing requirements of 25.1.1 shall not apply when the generator complies with 25.2.1 and where liners and barriers are used.

Exception No. 2: The spacing requirements of 25.1.1 shall not apply to the area between adjacent foils on printed-wiring boards involving low voltage circuits only, and provided with a conformal coating complying with the requirements in CSA C22.2 No. 0.17 / UL 746C. See 25.1.2.

Exception No. 3: On printed-wiring boards involving low voltage circuits only, and having a flammability classification of V-0 in accordance with UL 94 and constructed from a base material having a minimum Comparative Tracking Index (CTI) rating of 100 and 175 volts (as determined by CSA C22.2 No. 0.17 / UL 746C) for controlled and general environments respectively, spacings (other than spacings to ground, between primary and secondary circuits, between the battery supply circuit and other circuits, and at field wiring terminals) are not specified between traces of different potential connected in the same circuit when:

a) The spacings comply with the requirements in Evaluation of Reduced Spacings on Printed-Wiring Boards, Section 78; or

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

Exception No. 4: For multilayer printed-wiring boards involving only low voltage circuits, the minimum spacing between adjacent internal foils of opposite polarity and between an internal foil and a plated-through hole is 0.79 mm (1/32 inch). When these foils are in circuits described in 25.1.10 or 25.1.11, no spacing is specified.

Exception No. 5: The spacing requirements in Table 25.1 do not apply to inherent spacings of a component such as a switch, lampholder, power switching semiconductor, or a motor. See 25.1.5.

Exception No. 6: Spacing requirements do not apply between adjacent terminals of a power switching semiconductor device including the connection points of the terminals of the device.

Exception No. 7: For voltages above 34,000 V, conduct the Dielectric Test or alternatively the Impulse Test to validate product construction spacings of the field wiring box if those spacings are less than those in Table 6.1, Minimum Spacings for Voltages Above 1,000 V, of UL 1004-9.

Exception No. 8: If cast insulation bus bars are used to reduce spacings of the field wiring box to less than those specified in Table 6.1, Minimum Spacings for Voltages Above 1,000 V, of UL 1004-9, the Dielectric Test or alternatively the Impulse Test and Partial Discharge (Corona) Test shall be conducted.

Table 25.1
Spacings

Potential involved	Minimum spacings, mm (inch)		
	Between an uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[a]		Between an uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[b]
Volts rms (Vpeak)	Through air	Over surface	Shortest distance
0 – 50 (0 – 70.7)	1.6 (1/16)[c,d]	1.6 (1/16)[c,d]	1.6 (1/16)[c]
Greater than 50 to 150 (70.7 to 212.1)	3.2 (1/8)[c,d]	6.4 (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)

Table 25.1 Continued on Next Page

Table 25.1 Continued

Potential involved Volts rms (Vpeak)	Minimum spacings, mm (inch)		
	Between an uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[a]		Between an 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
Greater than 600 to 1000 (848.8 to 1414)	14 (0.55)	21.6 (0.85)	25.4 (1.0)
Greater than 1000 to 1500 (1414 to 2121)	17.8 (0.7)	30.5 (1.2)	41.9 (1.65)
Greater than 1500 to 2500[e]	25.4 (1.0)	50.8 (2.0)	76.2 (3.0)
Greater than 2500 to 7200[e]	50.8 (2.0)	88.9 (3.5)	101.6 (4.0)
Greater than 7200 to 15 kV[e]	101.6 (4.0)	124.3 (4.5)	127 (5)
Greater than 15 kV to 38 kV[e]	153 (6)	203 (8)	203 (8)

[a] For printed-wiring boards, see Exception Nos. 2 – 4 to 25.1.1.

[b] A metal piece attached to the enclosure shall be investigated as a part of the enclosure where 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 a insulated stud mounted in metal, the spacing shall not be less than 1.2 mm (3/64 inch).

[e] Because of the effect of configuration, spacings in excess of those indicated may be required to meet the performance requirements of this Standard.

NOTE 1: Where line voltage is connected to control circuits, the line voltage spacings shall apply.

NOTE 2: In a series circuit, the spacings between resistor circuits, transformer taps, and the like shall be based on the normal operating voltage existing between those parts.

NOTE 3: Linear interpolation for spacings values is permitted for voltages between specified table values.

25.1.2 With reference to Exception No. 2 to 25.1.1 concerning conformal coatings, minimum spacings between adjacent foils are based on voltage transient and dielectric voltage-withstand tests in accordance with CSA C22.2 No. 0.17 / UL 746C. A conformal coating on printed-wiring boards is not 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.

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

25.1.4 With reference to 25.1.3, a properly applied lock washer is a method of rigidly securing a part.

25.1.5 Inherent spacings of the components specified in Exception No. 5 of 25.1.1 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.

25.1.6 With respect to evaluating spacings, an uninsulated live part is considered to be at opposite polarity to uninsulated live parts in another circuit. Spacings between circuits are to be based on the highest of the circuit voltages.

25.1.7 Film-coated wire is considered to be an uninsulated live part when evaluating spacings.

25.1.8 Spacings at field-wiring terminals are to be measured with conductors installed in the terminals. The size of these conductors is to be based on the rating of the circuit containing the terminals, see 17.1.8.

25.1.9 Spacings between uninsulated live parts of different potential and between such parts and dead metal that are capable of being grounded in service are not specified for parts of LVLE circuits in accordance with 4.47 nor in accessible signal circuits described in Accessible Signal Circuits, Section 30.

25.1.10 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 4.43. Spacings in these circuits exceeding 30 volts rms (42.4 volts peak) or 60 volts dc are judged by the Dielectric Voltage-Withstand Test, Section 59.

25.1.11 Spacings within the following circuits that are not safety circuits are not specified:

a) Secondary circuits supplied by a transformer winding of less than 200 volt-amperes or at a potential of 60 volts or less; and

b) Battery circuits at a potential of 60 volts or less.

The spacings in these circuits shall be evaluated on the basis of the Dielectric Voltage-Withstand Test, Section 59.

25.1.12 The compliance of spacings between live and dead metal parts connected to the enclosure within an instrument shall be determined by conducting the dielectric voltage-withstand test described in the Dielectric Voltage-Withstand Test, Section 59.

Exception: A meter that complies with CSA C22.2 No. 61010-2-030 / UL 61010-2-030 is not required to be subjected to the Dielectric Voltage-Withstand Test.

25.2 Insulation barriers

25.2.1 An insulating liner or barrier of material such as vulcanized fiber is not prohibited from being employed in low voltage applications in lieu of required spacings specified in Exception No. 1 to 25.1.1 and shall not be the sole support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current. When so used, it shall be not less than 0.71 mm (0.028 inch) thick and be 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 CSA C22.2 No. 0.17 / UL 746C. Vulcanized fiber shall not be employed in lieu of spacings in medium voltage equipment.

Exception No. 1: Vulcanized fiber not less than 0.33 mm (0.013 inch) thick is not prohibited in low voltage applications when used:

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.

Exception No. 2: Mica not less than 0.165 mm (0.006 inch) is not prohibited from being used as insulation between a heat sink and a live case of a low voltage semiconductor device.

25.2.2 Other than as indicated in 25.2.3, insulating tubing complying with the requirements in CSA C22.2 No. 198.1 / UL 224 are not prohibited from being used in low voltage equipment as insulation of a:

a) Conductor including bus bars in lieu of the minimum spacings; and

b) Capacitor case in lieu of bonding the case for grounding, when the following conditions are met:

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

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

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

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

25.2.3 Insulating tubing complying with CSA C22.2 No. 198.1 / UL 224 shall not be used as insulation over a bolted joint of a bus bar as provided in 23.3.10.

25.2.4 A wrap of thermoplastic tape, complying with CSA C22.2 No. 197 / UL 510 is not prohibited from being used in low voltage equipment 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, Section 58;

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 23.3.10).

25.3 Alternate spacings for low voltage equipment – clearances and creepage distances

25.3.1 Other than specified in 25.3.2 and 25.3.3, as an alternative approach to the spacing requirements for low voltage equipment specified in Spacings, Section 25, clearances and creepage distances may be investigated in accordance with the requirements in C22.2 No. 0.2 / UL 840 as described in 26.4. See Section 9, Electric Shock. This section does not apply to clearance and creepage distances in medium voltage circuits.

25.3.2 The clearances between an uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable, shall be as specified in Table 25.1. The clearances are to be determined by physical measurement.

25.3.3 The clearances and creepage distances at field wiring terminals shall comply with Section 25, Spacings.

25.3.4 In conducting investigations in accordance with C22.2 No. 0.2 / UL 840, the following requirements shall be used:

a) Spacings shall be based upon the pollution degrees defined in Table 25.2;

b) A generator that operates in parallel with or exports to the electric utility grid shall comply with the requirements for Overvoltage Category IV. Other generator applications shall comply with the requirements for Overvoltage Category III;

c) Pollution degree 2 applies on a printed-wiring board between adjacent conductive material which is covered by any coating which provides an uninterrupted covering over at least one side and the complete distance up to the other side of conductive material;

d) All printed-wiring boards shall be identified as having a minimum Comparative Tracking Index (CTI) of 100 without further investigation;

e) The use of a coating which complies with the requirements for conformal coatings in CSA C22.2 No. 0.17 / UL 746C is in compliance with the C22.2 No. 0.2 / UL 840 to achieve pollution degree 1;

f) Pollution degree 1 is achievable at a specific printed-wiring board location by application of at least a 0.79 mm (1/32 inch) thick layer of silicone rubber or for a group of printed-wiring boards through potting, without air bubbles, in epoxy or potting material;

g) The phase-to-ground rated system voltage used in the determination of clearances shall be the equipment rated supply voltage rounded to the next higher value (in the table for determining clearances for equipment) for all points on the supply side of an isolating transformer or the entire product when no isolating transformer is provided. The system voltage used in the evaluation of secondary circuitry is able to be interpolated across the table for the Rated Impulse Withstand Voltage Peak and Clearance; and

h) Determination of the dimensions of clearance and creepage distances shall be conducted in accordance with C22.2 No. 0.2 / UL 840.

i) As an alternative to the requirements in Section 25, Spacings, the construction shall comply with Dielectric Voltage-Withstand Test for the operating voltage.

25.3.5 Other than at field-wiring terminals, the spacing between uninsulated live parts of opposite polarity and between an uninsulated live part and a dead metal part that is exposed to contact by persons or that may be grounded shall either not be less than the appropriate value specified in Table 25.1, or alternatively be evidenced through compliance with C22.2 No. 0.2 / UL 840.

Table 25.2
Generator pollution degree for application of C22.2 No. 0.2 / UL 840

Generator location	Pollution degree
Areas exposed to brush dust	4
Inside sealed non-ventilated enclosures and enclosures with filtered air	2
Generator engine compartment	3
Generator intake plenum	3
Inside hermetically sealed enclosures and potted equipment	1
Conformal coating rated for PWB material[a]	1
Generic or conformal coating not rated for PWB material	2

[a] Only applies to the printed-wiring board (PWB) surfaces covered by conformal coating. Does not apply to components mounted on the PWB, PWB locations under components, and component leads (above and below the PWB).

25.3.6 The spacing requirements do not apply to the inherent spacings of a component of the machine, such as a snap switch. Such spacings are judged on the basis of the requirements for the component in question.

26 Control Circuits

26.1 A LVLE circuit as described in 4.47 or a limited-energy circuit as described in 4.43 is not prohibited from being connected to a single-point reference ground.

26.2 Except as indicated in 26.3, a LVLE circuit is not required to be investigated. Printed-wiring boards and insulated wire used in such circuits shall be types that are required for the application. See 22.1.1 and 37.1.

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

26.4 A control circuit, including associated electronic components on printed-wiring boards, that does not extend out of the unit is not required to be investigated when the maximum voltage and current are limited as specified in (a) and (b):

a) A control circuit is not required to comply when the maximum voltage is as specified in the voltage limits of Table 9.1; and

b) A control circuit is not required to comply when the maximum voltage and current is:

1) 8 amperes for 0 – 42.4 volts peak ac, or 0 – 30 volts dc; or

2) Amperes equal to 150 divided by the maximum voltage for 30 – 60 volts dc.

Printed-wiring boards, insulated wires, and motors used in such circuits shall be types that are required for the application. See 22.1, 22.1.3, and 37.1.

Exception: The value of current specified in (b) is not prohibited from being exceeded when the circuit includes an overcurrent protection device as described in 26.7 and 26.8.

26.5 With reference to the current specified in 26.4(b), the maximum current is to 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. The current shall not exceed the value indicated in 26.4(b).

26.6 With reference to the voltage limit specified in 26.4(a), measurement is to be made with the unit connected to the voltage specified in 57.2 and with all loading circuits disconnected. When a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement is to be made from either end of the winding to the tap.

26.7 When the control circuit specified in 26.4 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 26.11) the circuits in which the current is limited in accordance with 26.8, 26.9, or 26.10 are not required to be investigated.

26.8 A fuse or circuit-protective device provided in the control circuit used to limit the current in accordance with 26.7 shall be rated or set at not more than the values specified in Table 26.1.

Table 26.1
Rating for secondary fuse or circuit protector

Circuit voltage (volts, rms)	Maximum overcurrent protection (amperes)
20 or less	5
More than 20 and not greater than 60	100/V[a]
[a] V is the maximum output voltage, regardless of load, with the primary energized in accordance with 57.2.	

26.9 A fuse or circuit protective device is not prohibited from being connected in the primary of a transformer to limit the current in accordance with 26.7 when the protection is equivalent to that specified in 26.8 as determined by conducting the Overcurrent Protection Calibration Test, Section 74.

26.10 One or more resistors or a regulating network used to limit the current in accordance with 26.7 shall be such that the current under any condition of load including short circuit does not exceed the values indicated in 26.4 (b)(1) or (2).

26.11 When a regulating network is used to limit the voltage or current in accordance with 26.4 – 26.10, 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; and

b) Critical components shall be derated.

26.12 In a circuit of the type described in 26.7, 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 judged under the applicable requirements in this Standard.

27 Engine Generator Programmable Controls

27.1 Engine generator controls may be located concurrent with or separate from engine controls.

27.2 Engine generator controls that perform one or more safety functions where the failure of which can result in a risk of fire, electric shock, or other hazard as defined by this standard, shall be evaluated in accordance with UL/ULC 6200 including the requirements for Safety Circuits.

27.3 Engine generators that employ a converter/inverter component, sub-assembly, or that have utility interactive controls shall comply with the applicable interconnect requirements contained in CSA C22.2 No. 107.1 / UL 1741 and Section 46, Inverters, Converters, Power Production Controllers, and Interconnection System Programmable Controls for Generators.

28 Product Risk Assessment

28.1 When required by specific portions of this Standard, a safety risk assessment based on the end product application shall be conducted to identify safety circuits performing functions that are the primary means to mitigate risk of fire, electric shock, or other hazards that could cause personal injury. The risk assessment shall take into account hardware failures, design faults, operator errors, and environmental impacts. Guidelines for the safety risk assessment are provided in Safety of machinery – General principles for design – Risk assessment and risk reduction, ISO 12100, Sections 5.4, 5.5, and 6.

28.2 To achieve this, the design for safety process shall eliminate the hazard or reduce the risk associated with the hazard by applying measures, in the following order:

a) Design for safety with passive protective measures in accordance with this Standard;

b) Apply active protective measures (e.g. automatic protection intervention if preset limit values are exceeded) accordance with this Standard;

c) Communicate the information for use about the residual risk to the installer/operator by instructions to reduce the risk to a tolerable level as specified in Sections 92 – 98.

See ISO 12100 clauses 5.4, 5.5, and 6.

28.3 Engine generator assemblies shall comply with the safety requirements and/or protective measures of this Standard for the hazards associated with the product. In addition, the engine generator assembly shall be designed according to the principles of ISO 12100 for the identified relevant and significant hazards to work in conjunction with this Standard. The risk assessment shall also address the additional abnormal risks in accordance with Section 71, Abnormal Tests.

29 Safety Circuits

29.1 Where required by specific portions of this Standard, a safety risk assessment based on the end product application shall be conducted to identify safety circuits performing functions that are the primary means to mitigate risk of fire, electric shock, or other hazards that could cause personal injury. The risk assessment shall take into account hardware failures, design faults, operator errors, and environmental impacts. Guidelines for the safety risk assessment are provided in Safety of machinery – General principles for design – Risk assessment and risk reduction, ISO 12100, Sections 5.4, 5.5, and 6. These requirements apply to circuits implementing functions that:

a) Limit the effects of abnormal voltage and/or power for standalone power applications;

b) Limit the effects of an overcurrent condition or current limiting in a short circuit condition for standalone power applications;

c) Maintain line pressure of an engine driven fire pump system;

d) Monitor critical system sensors for safety indications and shutdowns in emergency power systems and fire pump applications;

e) Control the detection time and energy parameters of a paralleling device controller for closing permissive for standalone power applications;

f) Control the detection time of electronic protection of the engine, fuel, generator, pump, and other components of the system;

g) Provide a means to remove output power to a generator system from the load upon actuation of an emergency stop device;

h) Provide a means to shut down the prime mover upon actuation of an emergency stop device;

i) Control the synchronization of a generator system of a distributed resource to an electric power system; and

j) Incorporate signal and communication circuits that interconnect systems or devices to provide the safety functions described above including prevention of prime mover rotation.

k) Provides electromechanical interlock protection to prevent access to Medium Voltage equipment as defined in 7.3.4.

29.2 Solid-state switching circuitry relied on for safety circuit fuel flow control functions per 29.1, shall be evaluated for reliability per the UL/ULC 6200 Exception to 22.1.6.

29.3 Safety circuits that rely on embedded software or firmware shall be identified by microprocessor model and firmware/software version. In addition, that software and firmware shall comply with one of the following functional safety standards:

a) IEC 61508-3, Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 3: Software requirements (minimum of SIL 1);

b) UL 60730-1 , Automatic Electrical Controls – Part 1: General Requirements for the United States, and/or CAN/CSA-E60730-1, Automatic electrical controls – Part 1: General requirements (Annex H.11.12 only) (minimum of Software Class B) for Canada;

c) UL 1998, Software in Programmable Components (minimum of Software Class 1) for the United States; and/or

d) CSA C22.2 No. 0.8, Safety functions incorporating electronic technology (minimum of Software Class B) for Canada.

Exception No. 1: Software/firmware that is performing a supplementary function supported by external and independent limiting protection is not required to comply with functional safety requirements.

Exception No. 2: Safety Control circuits that meet the requirements of proven in use elements in Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems, IEC 61508-2, are not required to comply with (a) – (d).

29.4 Control circuits become supplementary functions when supported by external and independent limiting protection. Some examples include, but are not limited to:

a) Overload protection provided by the programmable controller when a separate fuse or circuit breaker is provided to protect the generator and generator output conductors.

b) Software controlled interlock of a transfer switch controller when the transfer switch complies with the specific transfer switch product standard

c) Additional software-based limiting device that meets the requirements of 29.3.

30 Accessible Signal Circuits

30.1 The requirements in 30.2 and 30.3 apply to accessible signal circuits having provision for external connections such as RS232 communication ports or similar devices.

30.2 A signal circuit that extends out of a unit shall be isolated from the alternating current input circuit by any of the following:

a) An optical isolator having an isolation voltage rating of not less than the Dielectric Voltage-Withstand test potential required in 59.4 and complying with the requirements in CSA Component Acceptance Service Notice No. 5 / UL 1577;

b) An isolation transformer complying with the requirements in CSA C22.2 No. 66.1 / UL 5085-1 and CSA C22.2 No. 66.3 / UL 5085-3;

c) An isolation transformer complying with the requirements in 31.1; or

d) An Impedance network consisting of one or more resistors or a regulating network complying with 26.10, 26.11, and 30.3, the spacings shall comply with Section 25, Spacings, or CSA C22.2 No. 0.2 / UL 840.

e) Insulation and isolation devices between non-low voltage circuits and signal or control circuits shall be rated for the higher circuit voltage.

NOTE: Examples include isolation transformer sourced optical signal transmitters, receivers, transceivers and fiber optic cable network complying with the requirements in 31.1(b).

30.3 The maximum voltage and current available from an accessible signal circuit shall comply with the requirements in 26.4 – 26.11.

30.4 The maximum power available from an accessible signal circuit that employs an overcurrent protection device to limit the current as described in the Exception to 26.4 shall not exceed the values specified in Table 30.1.

Table 30.1
Maximum power of accessible signal circuits

Circuit voltage volts, rms	Maximum power, volt-amperes
15 or less	350
More than 15 and not greater than 60	250

31 Transformers

31.1 Transformers provided with the generator assembly shall be evaluated in accordance with the following Standards where applicable:

a) CSA C22.2 No. 66.1 / UL 5085-1, CSA C22.2 No. 66.2 / UL 5085-2, and CSA C22.2 No. 66.3 / UL 5085-3;

b) CSA C61869-1, CSA C61869-2, CSA C61869-3, CSA C61869-5 / IEEE C57.13, IEEE C57.13.2, IEEE C57.13.5;

c) CSA C22.2 No. 13 / UL 506; and

d) CSA C22.2 No. 47 / UL 1561.

32 Separation of Circuits

32.1 Factory wiring

32.1.1 Insulated conductors of different circuits (see 32.1.2) within an engine generator assembly, 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.

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

32.1.2 For the purpose of the requirement in 32.1.1, different circuits include those separated in Table 32.1. Medium voltage circuits shall be separated from all low voltage circuits.

Table 32.1
Circuit characteristics

Hazardous voltage circuits		Non-hazardous low voltage circuits	
Characteristics	**Examples**	**Characteristics**	**Examples**
> 30 V_{rms} (sinusoidal)	Output power circuit	≤ 30 V_{rms} (sinusoidal)	Limited energy circuit
>30 V_p (non-sinusoidal)	Power supply to control circuit and starting circuit	≤30 V_p (non-sinusoidal)	Limited voltage circuit, starting battery[b]
>42.4 V_p (non-sinusoidal)	Output/sense/monitor/control/ feedback circuits (non-sinusoidal) (or output side of these circuits, when isolation[a] provided to low voltage circuits)	≤42.4 V_p (non-sinusoidal)	Low voltage side of output feedback circuits, when isolation[a] provided
>60 V_{DC} (if >10% ripple, composite voltage, subject to 42.2 V_p limit)	Supply voltage for AC/DC starter battery charger, when provided	≤ 60 V_{DC}	Low voltage side of AC/DC starter battery charger, when provided
Any circuit not isolated from a hazardous voltage circuit, regardless of working voltage (e.g., a 5 V control circuit is hazardous when referenced to a 240 V output circuit: 5 V across circuit, and 240 V to ground)	AC convenience receptacles, when provided		Control/signal circuits accessible to the user/operator, or intended for external or remote connections (e.g., Class 2 Remote-Control, Signaling Circuits – Article 725 of the NEC)
	Engine ignition coil output		
	Gas turbine ignition exciter output		

[a] Isolation that meets applicable requirements including construction, spacings, electrical strength, abnormal operation.

[b] See 26.4 for fusing requirements, source may have amperage potential of up to 300 A – 1,000 A.

32.1.3 Segregation of insulated conductors is to 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.

32.2 Separation barriers

32.2.1 A barrier used to provide separation between the wiring of different low voltage circuits shall be:

a) Grounded metal or insulating material complying with the requirements in Section 38, Insulating Materials, and no less than 0.71 mm (0.028 inch) thick; and

b) Supported so that it is not capable of being readily deformed so as to defeat its purpose.

32.2.2 A barrier used to provide separation between field wiring and parts of a different circuit (field wiring, factory wiring, or uninsulated live parts) 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.

32.2.3 Barriers used to separate medium voltage circuits from low voltage circuits shall be grounded metal or insulating material capable of complying with the impulse and dielectric test requirements in this standard.

32.3 Field wiring

32.3.1 The equipment shall be constructed so that a field-installed conductor of a low voltage circuit shall be separated by barriers as specified in 32.2.1 and 32.2.2 or be separated by segregation as specified in 32.3.2 from:

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

b) An uninsulated live part of another low voltage 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; and

c) Field-installed conductors connected to any other low voltage circuit unless:

1) Both circuits are Class 2 or Class 3 (not for Canada); or

2) Both circuits are other than Class 2 or Class 3 (not for Canada), and both circuits are insulated for the maximum voltage of either circuit.

32.3.2 Field installed low voltage conductors and the live parts of different circuits as indicated in 32.3.1, shall be reliably separated by a barrier in accordance with 32.2. When evaluating the separation requirements, the field installed conductors shall be wired as would be done in the field including a service loop for each conductor. No more than average care is to be exercised in routing the wiring and stowing the conductor slack into the wiring compartment. The field installed conductors are to be wired as follows:

a) When each opening is located opposite a set of terminals, it is to be assumed that a conductor entering an opening is to be connected to the terminal opposite that opening.

b) When each opening is located other than the one opposite the terminal to which it is intended to be connected the potential for it to contact insulated conductors or uninsulated current-carrying parts connected to a different circuit is to be evaluated.

32.3.3 The equipment shall be constructed so that all field-installed conductors of medium voltage circuits are separated from any factory or field installed low voltage conductors or components by barriers as specified in 32.2.3.

32.4 Equipment above 7,200 V

32.4.1 For equipment operating above 7,200 V, instruments, meters, relays, secondary control devices, and their wiring shall be isolated by grounded metal barriers from the primary circuit elements, with the exception of short lengths of wire such as at instrument transformer terminals and secondary disconnecting devices.

32.5 Medium voltage circuits

32.5.1 Circuits that are connected to medium voltage circuits or circuits that do not have the required isolation and the required spacing from adjacent medium voltage circuits shall be treated as medium voltage circuits and shall comply with the medium voltage spacings defined in Table 25.1 as well as the medium voltage tests in Section 59, Dielectric Voltage-Withstand Test, for the highest voltage in either circuit.

33 Overcurrent Protection

33.1 General

33.1.1 An overcurrent protective device, the intended functioning of which requires renewal, replacement, or resetting, shall be accessible:

a) From outside of the enclosure (applicable to low voltage devices only); or

b) Behind a door (see 7.3.1).

33.1.2 With reference to 33.1.1, a control-circuit fuse does not require renewal as an intended function when the fuse and the load are contained within the same enclosure.

33.1.3 A fuse and a fuseholder shall have voltage and current ratings intended for the circuit in which they are connected. A low voltage fuseholder shall be of the cartridge or extractor type.

Exception: Medium voltage fuses and fuses intended to be replaced by only service personnel (see Section 43, Protection of Service Personnel) are not prohibited from being bolted in place.

33.1.4 A circuit breaker connected in the output circuit shall open all ungrounded conductors. When fuses are provided for protection of the output circuit, a fuse shall be provided in each ungrounded conductor.

Exception: When a low voltage generator has provision for connection of a grounded neutral conductor, individual single-pole circuit breakers are not prohibited 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 V. This exception does not apply to medium voltage circuit breakers.

33.1.5 A generator shall be marked in accordance with 94.7 when it is provided with overcurrent protection consisting of an interchangeable fuse and when the fuse is:

a) Accessible to the user; or

b) Used to comply with the requirements in this Standard.

33.1.6 An overcurrent protective device shall not be connected in the grounded (neutral) side of the line.

Exception No. 1: Additional overcurrent protection provided in the grounded side of the supply circuit is not prohibited when the protective device simultaneously disconnects the grounded and ungrounded conductors of the supply circuit.

Exception No. 2: A low voltage unit that incorporates a single-pole overcurrent protective device connected in the grounded (neutral) side of the line is not prohibited when:

a) Each ungrounded circuit conductor is provided with an overcurrent protective device having a current rating no higher than that of the overcurrent protective device in the grounded circuit conductor;

b) The unit is marked in accordance with 94.12.

33.1.7 Temperature or current-sensitive devices such as temperature limiting thermostats, thermal cutoffs, appliance protectors, fuses, circuit breakers, or similar devices that comply with Section 71, Abnormal Tests, shall comply with the requirements for such devices.

33.1.8 Overcurrent protection employing solid state component circuitry used for protection of circuits described in (a) – (b) shall comply with the requirements in CSA C22.2 No. 5 / UL 489.

a) Control circuits per 33.2.1 – 33.2.7.

b) Low voltage alternating current power output circuits per 33.3.1 – 33.3.3.

Exception No. 1: Overcurrent protection whose performance is not affected by malfunction, either by short circuit or open circuit, of any single component is not required to comply.

Exception No. 2: A solid state overcurrent protection circuit provided in addition to other overcurrent protection devices such as a fuse or circuit breaker that is intended for the application is not required to comply.

33.2 Control circuits wiring and protection

33.2.1 A control circuit that extends from the generator to a remote control panel, status panel, or similar device shall be protected in accordance with 33.2.2 – 33.3.3 to reduce the risk of fire and electric shock that results from overload and short circuit conditions.

33.2.2 The overcurrent protective device specified in 33.2.1 shall be a circuit breaker or fuse that is either:

a) Intended for branch circuit use; or

b) A supplementary type.

When the protective device consists of a fuse, the generator shall be marked in accordance with 94.7.

33.2.3 A Class 1 power-limited circuit, in accordance with the National Electrical Code, NFPA 70 and the Canadian Electrical Code, Part I, used to supply an external control circuit shall be supplied from a source having a rated output of no more than 30 V and 1000 volt-amperes. When the source of a Class 1 circuit 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.

33.2.4 An external control circuit derived from a Class 2 transformer described in 4.17 is not required to be provided with overcurrent protection specified in 33.2.1.

33.2.5 An external control circuit derived from the secondary of a transformer other than that described in 33.2.3 and 33.2.4 shall be provided with overcurrent protection in accordance with 33.2.6 and 33.2.7. For transformers not having a rating, the rated primary or secondary current specified in 33.2.6 and 33.2.7 is to consist of the maximum current during normal operation of the unit.

33.2.6 Except as described in 33.2.7, a low voltage transformer used to supply a control circuit shall be provided with overcurrent protection in the primary circuit rated as indicated in Table 33.1.

Exception: When 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 is not prohibited from being used. Standard ratings of protective devices are specified in Article 240-6 of the National Electrical Code, NFPA 70, and Rule 26-256 of the Canadian Electrical Code, Part I.

Table 33.1
Primary overcurrent protection for low voltage 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

33.2.7 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.

Exception No. 1: When 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 is not prohibited from being used in the secondary circuit. Standard ratings of protective devices are specified in Article 240-6 of the National Electrical Code, NFPA 70 and Rule 26-256 of the Canadian Electrical Code, Part I.

Exception No. 2: When 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.

33.3 Output alternating current power circuits

33.3.1 An output circuit shall be provided with overcurrent protection for all ungrounded conductors as described in 33.3.3. The voltage rating of the overcurrent protection shall not be less than the rating of the circuit with which it is used. The overcurrent protection device shall be a circuit breaker, fuse or equivalent means intended for use as branch circuit protection and located within 7.62 meters (25 feet) of the generator output terminals.

Exception: The overcurrent protection is not required to be provided with the generator when the installation instructions specify the required overcurrent protection for the output power circuit.

33.3.2 The voltage rating specified in 33.3.1 for a 3-phase circuit shall be based on the phase-to-phase voltage.

33.3.3 The rating of the overcurrent protection shall not exceed the ampacity of the conductors intended to be connected to the generator as determined in accordance with 17.1.8.

33.4 AC conductor inductive heating

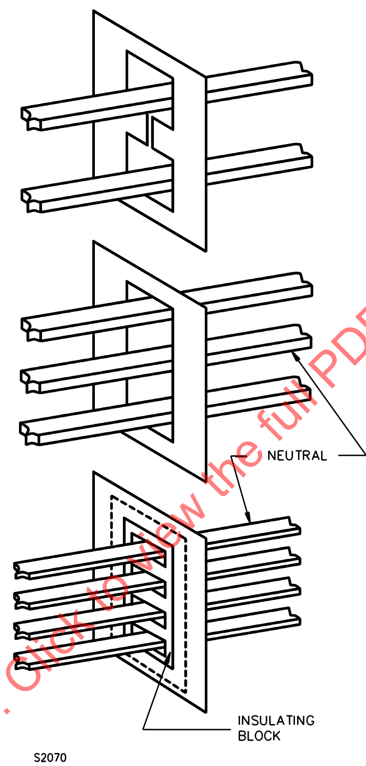
33.4.1 If the conductors of an alternating current circuit pass through a wall or partition of metal having magnetic properties, all the conductors of the circuit including the neutral shall be run through the same opening. The requirement does not apply to a component unit such as a panelboard or switch which has been evaluated for the application.

33.4.2 With respect to the requirement in 33.4.1 and to Figure 33.1, the conductors may pass through individual openings in a wall or partition if the openings are connected by slots cut in the metal wall. The conductors may be run through individual openings in an insulating block used to cover an opening in the metal wall for all the conductors of the circuit if no metal bracket, brace, or the like is placed across the insulating material between the conductors.

Exception: This construction may be permitted if, during the Temperature Test, temperatures are recorded on interposed metal to determine that conductor insulation is not adversely affected and the insulation is used within its rated temperature limit. The conductors may be run through individual openings in an insulating block used to cover an opening in the metal wall sufficiently large for all the conductors of the circuit if no metal bracket, brace, or the like, is placed across the insulating material between the conductors.

Figure 33.1

Conductors through openings



34 Air Filters

34.1 Air filters for combustion air intakes shall either comply with the backfire resistance requirements in Section 63, Intake Air Filter and Intake Backfire-Deflector Test, or they shall be provided with a backfire deflector/flame arrestor that complies with the backfire resistance requirements in Section 63.

34.2 Backfire deflector/flame arrestors if provided shall be located in the combustion air intake path so as to protect the air filter from engine backfires.

34.3 Backfire deflectors/flame arrestors are not required for gas turbine or reciprocating diesel engines.

34.4 Air filters not for combustion air intakes shall comply with the requirements in ULC-S111 / UL 900, or shall be constructed of materials classed V-2 or HF-2 or less flammable in accordance with UL 94.

Exception No. 1: This requirement does not apply to air filters in closed systems. A closed system is defined as that which, although not required to be air-tight, is not intended to be vented outside the enclosure.

Exception No. 2: This requirement does not apply to air filters located external to the enclosure and constructed of materials classed HB or HBF or less flammable.

34.5 Air filters for ventilation openings of enclosures containing medium voltage equipment, circuits and wiring shall comply with (a) or (b) below:

a) The filters shall be located in a medium voltage compartment so that the filters cannot be replaced without opening the door to the compartment. The door of the compartment shall be interlocked in accordance with the requirements for Door Interlocks, 5.11.203, of CSA C22.2 No. 253 / UL 347.

b) The filters shall be located outside of a medium voltage compartment, so that the filters may be replaced without opening the medium voltage compartment. The construction of the ventilation openings shall comply with the requirements for Ventilating Openings, Vent Outlets (Openings in Enclosures), 5.102.206, of CSA C22.2 No. 253 / UL 347. During any period of filter replacement, including with no filter installed, the construction shall comply with 5.102.206 of CSA C22.2 No. 253 / UL 347. The filter shall not be considered to be the barrier that is required behind ventilation openings.

35 Capacitors

35.1 A capacitor used for electromagnetic interference elimination or power-factor correction that is oil filled shall comply with the requirements in CSA C22.2 No. 190 / UL 810.

35.2 A capacitor connected across a low voltage input or output ac circuit that is connected to a utility shall comply with the requirements for across-the-line capacitors in CSA-E60384-14 / UL 60384-14 or CSA C22.2 No. 8 / UL 1283.

35.3 UL 810A shall be applied to electrochemical capacitors that are often referred to as “electric double layer capacitors”, ”ultracapacitors”, “double layer capacitors” or “supercapacitors”.

35.4 The materials and construction of a capacitor or its case within a generator assembly shall be of a type that prevents overpressure conditions in the event of malfunction of the capacitor or the circuit in which it is connected.

35.5 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, explosion, or electric shock and shall be constructed to reduce the risk of expelling dielectric medium from the enclosure of the generator assembly. See 35.6 and 35.7.

35.6 With reference to the requirement in 35.5, a capacitor complying with the requirements for protected oil-filled capacitors in CSA C22.2 No. 190 / UL 810 is considered to be constructed to reduce the risk of expelling the dielectric medium.

35.7 With reference to 35.5, a unit having a capacitor other than that described in 35.6 shall be provided with a complete non-combustible bottom panel below the capacitor.

35.8 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 is considered to exist if the voltage across the capacitor exceeds the limits specified in Section 9, Electric Shock. A risk of electrical energy – high current level – is considered to exist if the stored energy exceeds 20 joules as determined by the following equation:

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

in which:

C is in microfarads; and

V is in volts.

Exception No. 1: This requirement does not apply if a tool is necessary to remove a panel to reach the capacitor and the generator assembly is marked as specified in 94.8.

Exception No. 2: This requirement does not apply if the unit is marked in accordance with 94.9.

Exception No. 3: This requirement does not apply if:

a) The capacitor terminals and all parts connected to these terminals are insulated to reduce the likelihood of contact of these terminals and parts by the service person; and

b) A cautionary marking per 95.1(d) is provided.

36 Resistors

36.1 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.

36.2 An assembly employing lock washers complies with the requirement in 36.1.

37 Printed-Wiring Boards

37.1 Printed-wiring boards shall comply with the requirements in CSA C22.2 No. 0.17 / UL 796 and UL 94 for a flammability classification of:

a) V-0, V-1, or V-2 for printed-wiring boards totally within non-hazardous secondary circuits;

b) V-0 when the printed-wiring board assembly is to be evaluated as a flame barrier; or

c) V-0 or V-1 for generator output voltage sensing circuits; or

d) V-0, V-1, or V-2 for all other applications.

Exception: 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 is not required to be classed as minimum V-2.

37.2 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 is not capable of displacing and resulting in a risk of electric shock or fire by a force that is exerted on it during assembly, intended operation, or servicing of the generator set.

37.3 Consideration is to be given to 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.

38 Insulating Materials

38.1 The generator insulation system shall comply with the construction requirements contained in UL 1446.

38.2 A material that is used for the direct support of a low voltage uninsulated live part shall comply with the Relative Thermal Index (RTI), Hot Wire Ignition (HWI), High-Current Arc Resistance to Ignition (HAI), and Comparative Tracking Index (CTI) values indicated in Table 38.1. A material is in direct support of an uninsulated live part when:

a) It is in direct physical contact with the uninsulated live part; and

b) It serves to physically support or maintain the relative position of the uninsulated live part.

Exception No. 1: The generic materials complying with Table 38.2 are not prohibited for the direct support of uninsulated live parts without additional evaluation.

Exception No. 2: Those materials without HWI Performance Level Category (PLC) values or with HWI PLC values higher (worse) than those required by Table 38.1 shall alternatively be subjected to the end-product Abnormal Overload Test in accordance with CSA C22.2 No. 0.17 / UL 746C.

Exception No. 3: Those materials without HAI Performance Level Category (PLC) values or with HAI PLC values higher (worse) than those required by Table 38.1 shall alternatively be subjected to the end-product Special Arcing Test in accordance with CSA C22.2 No. 0.17 / UL 746C.

Exception No. 4: Those materials that are used in devices that do not incorporate contacts are not required to comply with the HAI Performance Level Category (PLC) requirements.

Exception No. 5: Those materials that are used in devices that incorporate contacts and are not used within 12.7 mm (1/2 inch) of the contacts are not required to comply with the HAI Performance Level Category (PLC) requirements.

Exception No. 6: Those materials without CTI Performance Level Category (PLC) values or with CTI PLC values higher (worse) than the CTI required by Table 38.1 shall alternatively be subjected to the end-product Special Arcing Test in accordance with CSA C22.2 No. 0.17 / UL 746C.

Exception No. 7: Those materials without CTI Performance Level Category (PLC) values or with CTI PLC values higher (worse) than the CTI required by Table 38.1 shall be in compliance with the CTI PLC requirement when:

a) They have a High-Voltage-Arc Tracking (HVTR) PLC value of 1 or lower (better); or

b) The over surface spacings between the uninsulated live parts are at least 12.7 mm (1/2 inch).

Table 38.1
Minimum material characteristics required for the direct support of low-voltage uninsulated live parts

UL 94[a] Flame Class	RTI Elec	HWI[c]	HAI[c]	CTI[d]
HB	b	2	1	4
V-2	b	2	2	4
V-1	b	3	2	4
V-0	b	4	3	4

[a] Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Table 38.1 Continued on Next Page

Table 38.1 Continued

UL 94[a] Flame Class	RTI Elec	HWI[c]	HAI[c]	CTI[d]
[b] The electrical RTI value of a material is to be determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B by test or by use of the generic RTI table. This material characteristic is dependent upon the minimum thickness at which the material is being used and shall not be exceeded during the Temperature Test, Section 58.				
[c] The HAI and HWI Performance Level Category (PLC) value of a material is to be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used.				
[d] The CTI PLC value of a material is to be determined by test in accordance with UL 746A. This material characteristic is not dependent upon the minimum thickness at which the material is being used.				

Table 38.2
Generic materials used for the direct support of low-voltage uninsulated live parts

Generic material	Thickness		RTI
	mm	(inch)	°C
Any cold-molded composition (i.e. concrete)	No limit	No limit	No limit
Ceramic, Porcelain, and Slate	No limit	No limit	No limit
Diallyl Phthalate	0.71	(0.028)	105
Epoxy	0.71	(0.028)	105
Melamine	0.71	(0.028)	130
Melamine-Phenolic	0.71	(0.028)	130
Phenolic	0.71	(0.028)	150
Unfilled Nylon	0.71	(0.028)	105
Unfilled Polycarbonate	0.71	(0.028)	105
Urea Formaldehyde	0.71	(0.028)	100
NOTE – Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Test, Section 58.			

38.3 In low voltage circuits, insulating material – such as a relay dust cover, transformer bobbin, inductor bobbin, insulating sheet, encapsulation, or similar material that is used as a barrier in lieu of the required over surface, or through air spacings, or both, shall comply with the requirements in 38.6 – 38.11.

38.4 Vulcanized fiber is not prohibited from being used for insulating bushings, washers, separators, and barriers, but shall not be used as sole support for uninsulated live parts. Vulcanized fiber shall not be used in contact with, or as support for, medium voltage parts.

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

38.6 Insulating material is not prohibited from being used as a barrier in lieu of the required spacings in low voltage circuits per 25.1.1.

38.7 The insulating material specified in 38.6 shall comply with the requirements in 38.8 when:

a) The material is in direct physical contact with an uninsulated live part;

b) The material serves to physically support, or maintain the relative position of the uninsulated live part; and

c) The material is used as a barrier in lieu of the required over surface or through air spacings.

38.8 An insulating material used as noted in 38.6 shall:

a) Comply with 38.2; and

b) Be at least 0.71 mm (0.028 inch) thick.

Exception No. 1: A material that complies with 38.2 and does not comply with the thickness limit in (b) shall alternatively be subjected to a 5000 Vac Dielectric Voltage-Withstand Test in accordance with the Internal Barrier requirements in CSA C22.2 No. 0.17 / UL 746C.

Exception No. 2: A material that complies with 37.1 and is used in addition to not less than one-half the required through-air spacings is not prohibited from being less than 0.71 mm (0.028 inch) thick, and shall be at least 0.33 mm (0.013 inch) thick. This material shall:

a) Have the required mechanical strength when exposed or otherwise subjected to mechanical damage;

b) Be held in place; and

c) Be located so that it is not adversely affected by operation of the equipment in service.

38.9 The requirements specified in 38.8 (a) and (b) are independent of each other. For example, even when a material complies with 37.1 at a thickness less than the 0.71 mm (0.028 inch) limit, then the material still is required to be provided at a thickness at least equal to the 0.71 mm (0.028 inch) limit or at a thickness allowed for by the Exceptions to 38.8.

38.10 Insulating material in low voltage circuits shall also comply with the requirements in 38.8 when:

a) The material is in direct physical contact with an uninsulated live part;

b) The material does not serve to physically support or maintain the relative position of that uninsulated live part; and

c) The material is used in lieu of the required over-surface, or through-air spacings.

Exception: The generic insulating materials in Table 38.3 comply for this application without additional evaluation.

Table 38.3
Generic materials used as a barrier in low-voltage circuits

Generic material[a]	Minimum thickness		RTI
	mm	(inch)	°C
Aramid Paper	0.25	(0.010)	105
Cambric	0.71	(0.028)	105
Electric grade paper	0.71	(0.028)	105
Epoxy	0.71	(0.028)	105
Mica	0.15	(0.006)	105
Mylar (PETP)	0.18	(0.007)	105

Table 38.3 Continued on Next Page

Table 38.3 Continued

Generic material[a]	Minimum thickness		RTI
	mm	(inch)	°C
RTV	0.71	(0.028)	105
Silicone	0.71	(0.028)	105
Treated cloth	0.71	(0.028)	105
Vulcanized fiber	0.71	(0.028)	105

[a] Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Tests, Section 58.

38.11 An insulating material in low voltage circuits shall also comply with the requirements in 38.8 when:

a) The material is not in direct physical contact with an uninsulated live part;

b) The material does not serve to physically support, or maintain the relative position of that uninsulated live part; and

c) The material is used in lieu of the required through-air spacings.

Exception No. 1: The generic insulating materials in Table 38.3 comply for this application without additional evaluation.

Exception No. 2: The Hot Wire Ignition (HWI), High – Current Arc Resistance to Ignition (HAI) and Comparative Tracking Index (CTI) Performance Level Category (PLC) requirements do not apply for materials that are located at least 0.8 mm (1/32 inch) from uninsulated live parts.

Exception No. 3: The Hot Wire Ignition (HWI), High – Current Arc Resistance to Ignition (HAI) and Comparative Tracking Index (CTI) Performance Level Category (PLC) requirements and RTI requirements do not apply for materials that are located at least 12.7 mm (1/2 inch) from uninsulated live parts.

38.12 Insulating material for the support of an uninsulated medium voltage part shall be porcelain, glass polyester, or other material found acceptable for the support of an uninsulated live part. These materials shall withstand the most severe conditions likely to be met in service, including the impulse and dielectric requirements specified in this standard. When the equipment has been previously subjected to the complete series of conformance tests, an alternate insulating material for the above applications, may be substituted as permitted by ANSI C37.55 without performing another complete series of conformance tests on the equipment.

39 Adhesives

39.1 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 CSA C22.2 No. 0.17 / UL 746C.

39.2 The requirement in 39.1 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 required values; or

d) Short-circuits live parts.

40 Battery Heaters and Miscellaneous Heaters

40.1 Battery heaters and heating appliances rated at 600 V or less for use in unclassified locations as defined in and in accordance with the National Electrical Code, NFPA 70, and the Canadian Electrical Code CSA C22.1, shall comply with CSA C22.2 No. 46 / UL 499.

40.2 Compartment heaters with exposed heating elements inside the engine compartment shall be placed at the highest point within the engine compartment. These heaters shall be located at least 1 m (3.28 ft) away from lubricating system components, fuel train components, and lines or hoses of other flammable fluids or gases. Heaters shall not be located in areas where flammable liquids can come in contact with the heating elements under normal or abnormal failure conditions including leaks.

Exception: Heaters rated for use in T3, T4, T5, or T6 hazardous classified locations in accordance with UL 823 and CSA C22.2 No. 88 to protect against ignition of accumulated explosive gases and or liquids do not have an installation height limitation.

41 Engine Starting Equipment

41.1 Generator assemblies rated for use in NFPA 110 applications shall be provided with starting equipment in accordance with CSA C282 / NFPA 110.

41.2 When an automatic battery charger is provided in addition to the engine driven charger of the generator assembly, the charger shall comply with CSA C22.2 No. 107.2 / UL 1236.

42 Batteries

42.1 Battery compartment

42.1.1 When a separate lead-acid storage battery is intended to be placed in a compartment provided with, or as part of, the engine generator assembly, it shall be secured in position to prevent contact with conducting materials in the area and be readily accessible for servicing.

42.1.2 Arcing parts, such as the contacts of switches, circuit breakers, and relays, shall not be located in the enclosure or compartment housing a vented battery, nor shall the enclosure or compartment vent into closed spaces where such parts are located. For purposes of this requirement, fuses and connectors do not contain arcing parts. Battery or compartment monitoring sensors (such as temperature sensors and the like) may be located in the enclosure or compartment.

42.1.3 The interior of a metal compartment housing a lead-acid battery shall be protected against corrosion by two coats of acid resistant paint, two coats of enamel individually baked on, or the equivalent.

42.1.4 To reduce the risk of leakage of the electrolyte as a result of damage to the battery case by a battery mounting means, a battery mounting means shall not cause undue stress to the battery case. See 42.1.5 and 42.1.6.

42.1.5 A battery mounting means that consists of a bracket, strap, or the like that extends around the top and/or sides of the battery shall not cause undue compression to the walls of the battery. The types of brackets or straps indicated in (a) – (c) are considered acceptable. Other constructions may be accepted if they are determined to be equivalent:

a) A bracket or strap constructed of a non-rigid polymeric material; or

b) A metal bracket or strap with a flexible, foamed material or the like between the bracket or strap and the battery walls; or

c) A metal bracket, which when tightened as intended, provides a clearance, minimum not specified, between the bracket and the battery walls. See 42.1.6.

42.1.6 When determining the adequacy of the clearance for the mounting means described in 42.1.5(c), the following factors shall be taken into consideration:

a) Dimensional tolerances of the bracket and overall dimensions of the battery case;

b) The overall dimensions of the battery may increase slightly after use; and

c) The need for a restraining means for use during shipping if the clearance of the mounting means permits excessive movement of the battery.

42.1.7 A vented battery or a valve-regulated battery provided with a generator assembly or battery cabinet for energy storage purposes (other than engine starting) shall comply with the applicable requirements in the following applicable standards: CSA C22.2 No. 141 / UL 924, CSA C22.2 No. 60950-1 / UL 1989, or UL 1973.

42.1.8 Energy storage systems (other than for engine starting) shall comply with ANSI/CAN/UL 9540.

42.1.9 Energy storage systems specified for installation within or adjacent to buildings shall comply with ANSI/CAN/UL 9540A.

42.2 Battery enclosure ventilation

42.2.1 The requirements in 42.2.2 – 42.2.5 apply to units having vented batteries.

42.2.2 The enclosure or compartment housing a vented battery where gassing is possible during heavy discharge, overcharging, or similar type of usages shall be vented. The means of venting shall provide air flow throughout the compartment in order to reduce the risk of buildup of pressure or accumulation of a gas mixture, such as hydrogen-air, involving a risk of injury to persons.

42.2.3 The ventilation shall be provided by construction of the engine generator assembly or the enclosure in the manufacturer's installation instructions (See 97.1).

42.2.4 If the gas mixture is lighter than air (such as hydrogen-air), the requirement of 42.2.2 may necessitate locating additional ventilation openings in the uppermost portions of the battery enclosure or compartment where such a gas mixture may accumulate.

42.2.5 With reference to 42.2.4, the venting means shall prevent hydrogen concentrations in excess of 2 percent by volume. If the adequacy of the ventilation required in 42.2.2 is not obvious, a determination shall be made by measurement of gas concentration in accordance with Section 75, Battery Compartment Ventilation Test. A lead-acid battery at full charge, when most of the charging energy goes into gas, will generate approximately 0.028 m^3 (1 cubic foot) of hydrogen gas per cell for each 63 ampere-hours of input.

42.3 Battery placement

42.3.1 A metal case or container of a battery, such as an alkaline battery, shall be insulated or spaced away from contact with uninsulated live parts of the generator assembly if such contact may result in a short circuit.

42.3.2 An enclosure or compartment housing batteries employing metal containers or cases that are conductively connected to a battery electrode shall be such that the batteries are insulated or spaced from each other, or otherwise physically arranged, to prevent short-circuiting of part or all of the battery supply after installation in a generator assembly.

42.3.3 A battery that requires the addition of water shall employ a means to determine the fluid level.

42.4 Battery circuit overcurrent protection

42.4.1 A battery other than an engine starting battery shall be provided with overcurrent protection in accordance with Section 33, Overcurrent Protection.

42.5 Battery circuit isolation

42.5.1 A generator having an integral battery charging circuit rated 60 volts, dc – maximum rectifier output voltage – or less shall incorporate isolation as specified in Section 31, Transformers, between the input ac circuit and the battery circuit.

43 Protection of Service Personnel

43.1 The requirements in this Section apply only with regard 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 engine generator is in operation. The generator output leads shall be located within an enclosure, wireway, or electrical conduit in a service personnel accessible area. For requirements covering accessibility of live parts for protection of users, refer to Section 8, Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing. For medium voltage engine generator equipment, the generator output leads shall be enclosed in a wireway in a service personnel accessible area. The medium voltage equipment shall be provided with interlocking in accordance with 7.3.4 that prevents servicing the equipment while the medium voltage equipment is energized.

43.2 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.

43.3 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 service, or performing mechanical service functions that are performed with the equipment energized, such as lubricating a motor, adjusting the setting of a control with or without marked dial settings, resetting a trip mechanism, or operating a manual switch.

43.4 Live parts involving a risk of electric shock (See Table 9.1) 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.

43.5 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.

43.6 For an adjustment that is to be made with a screwdriver or similar tool when the unit is energized, 43.5 requires that protection be provided so that inadvertent contact with adjacent uninsulated hazardous live parts involving a risk of electric shock is reduced taking into consideration that misalignment of the tool with the adjustment means results when an adjustment is attempted. This protection shall be provided by:

a) Location of the adjustment means away from uninsulated hazardous live parts; or

b) A guard to reduce the risk of the tool from contacting uninsulated live parts.

43.7 A live heat sink for a solid-state component, a live relay frame, or similar device 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 94.4.

Exception: This requirement does not apply to a heat sink mounted on a printed-wiring board.

43.8 Moving parts that result in injury to persons and that must be in motion during service operations not involving the moving parts shall be located, guarded, or protected so that unintentional contact with the moving parts is minimized or be marked in accordance with 94.19.

44 Walk-in Generator Enclosures

44.1 Working space

44.1.1 Electrical enclosures, compartments or specific areas within the generator that are likely to require a service person to enter the enclosure or housing to wire, examine, adjust, or perform maintenance, shall comply with Article 110.26, Spaces About Electrical Equipment, of NFPA 70 and Rules 2-308 and 2-310 of the Canadian Electrical Code, Part I.

Exception: In special areas where the required working spaces cannot be provided (e.g. generator skin-tight (non-walk-in) enclosures, gas turbine engine modules, fuel tanks, engine cylinders, exhaust systems, etc.), special working procedures shall be provided to address worker safety, including consideration of the specific hazards within the special area, as well as the scope of the work. The special working procedures shall comply with local codes.

44.1.2 Areas within a generator enclosure that require a lockout provision for worker safety shall be provided with a disconnecting means for the generator that shall:

a) Be at the point of connection of electric power to the generator or the affected circuit;

b) Be readily accessible; and

c) Be capable of being locked in the open position.

44.2 Panelboards within walk-in enclosures

44.2.1 When a panelboard is provided as a part of an appliance, it shall comply with CSA C22.2 No. 29 / UL 67 and be installed in accordance with the following:

a) The panelboard shall be mounted vertically;

b) Any opening giving access to a panelboard shall be at least as wide and high as the deadfront of the panelboard;

c) No part of the appliance shall obstruct the space between the panelboard and any opening giving access to the panelboard;

Exception: A panelboard is not prohibited from being located behind a door or cover when the construction complies with Section 43, Protection of Service Personnel.

d) The panelboard shall be marked in accordance with Sections 93 and 94; and

e) The face of the panelboard shall be directed outward and shall not be recessed more than 150 mm (6 inches) behind the perimeter of the appliance.

Exception: This requirement does not apply when:

a) Accessibility for servicing of another part of the overall appliance would be impeded by locating the panelboard as specified;

b) The panelboard is located to provide access to the fuses and/or actuators in accordance with Section 43, Protection of Service Personnel, (for example, with the front of the panelboard located perpendicular to and immediately behind an access opening);

c) When the panelboard is provided with a door, the panelboard door is hinged on the side away from the direction of access;

d) At least one edge of the panelboard is located within 150 mm (6 inches) of the perimeter of the appliance in the direction of access; and

e) When the panelboard is located behind a door or cover, see Section 43, Protection of Service Personnel, at least one edge of the panelboard is located within 25 mm (1 inch) behind the plane created by the inside of the door or cover.

44.2.2 When a panelboard is located behind another door or cover:

a) The construction of the appliance shall permit at least a 90 degree opening of all doors and hinged panels which give access to the panelboard;

b) The opening giving access to the panelboard shall be at least as wide and high as the deadfront of the panelboard;

c) The door or cover shall be constructed so that the panelboard is accessible without the use of tools; and

d) The space between the door or cover and the face of the panelboard shall be open such that no part of the appliance is located within that space, and the cabinet or enclosure shall be constructed so that the space is restricted from use as a storage space.

44.2.3 Doors to the walk-in enclosure shall be designed to prevent persons from becoming trapped within the walk-in enclosure. Doors shall be able to be opened from inside the enclosure without use of a tool or key should they become closed). Where a door locks automatically upon closing, the door shall open in the direction of egress and be equipped with panic bars, pressure plates, or other devices that are normally latched but open under simple pressure. Personnel door(s) intended for entrance to, and egress from a walk-in enclosure, shall open in the direction of egress.

44.2.4 Egress doors shall be marked with the word "Exit" and the line-of-sight to an exit sign shall not be interrupted. Any doorway or passage that might be mistaken for an exit shall be marked "Not an Exit" or with an indication of its actual use.

44.2.5 Walk-in enclosures with one or more personnel doors shall be provided with a switch near each door to operate interior lighting.

Exception: A light switch is not required for doors or hatches provided only for emergency egress.

44.3 Walk-in enclosures for medium voltage generators

44.3.1 Medium voltage generators with walk-in enclosures shall comply with the requirements in this Section 44 and additionally:

a) Be constructed such that all medium voltage wiring and components are enclosed by grounded metal, so that persons entering the enclosure have no access to the medium voltage circuits.

b) Be provided with interlocking in accordance with 7.3.4 that prevents entering the enclosure when the generator is running or any medium voltage wiring or component is energized.

45 Illumination

45.1 Lighting shall comply with CSA C22.2 No. 250.0 / UL 1598 and be installed in accordance with the National Electrical Code, NFPA 70, Article 410, and the Canadian Electrical Code, Part 1, Section 30.

45.2 Low voltage lighting below 60 Vdc and 30 Vac shall comply with CSA C22.2 No. 250.0 / CSA C22.2 No. 9.0 / UL 2108 and be installed in accordance with the National Electrical Code, NFPA 70, Article 411, and the Canadian Electrical Code, Part I, Section 30.

45.3 Emergency Lighting shall comply with CSA C22.2 No. 141 / UL 924 and its installation shall comply with National Building Code of Canada – Emergency Lighting / NFPA 101.

45.4 Lighting equipment shall be rated for applicable environmental exposure within the conditions of use accounting for leaking and spraying of fluids.

46 Inverters, Converters, Power Production Controllers, and Interconnection System Programmable Controls for Generators

46.1 Engine generators and gas turbines that include inverters or converters in their power output shall comply with the applicable portions of CSA C22.2 No. 107.1 / UL 1741.

46.2 Engine generators and gas turbines with their associated programmable control systems intended for utility interactive operations shall comply with CSA C22.2 No. 107.1 / UL 1741. Engine generators and gas turbines with their associated programmable control systems that are evaluated for complete utility interactive operations shall be marked in accordance with 94.16.

Exception: When engine generators and gas turbines are provided with programmable control systems that include features intended to support operation in parallel with the utility grid and these features have not been evaluated for compliance with specific utility interconnection protection standards or requirements, the engine generator or gas turbines shall be marked in accordance with 94.17 and the instructions specified in 96.6.

47 Additional Requirements for Generator Switchgear Rated Above 1,000 V

47.1 General

47.1.1 The requirements in this Section are for generator switchgear rated greater than 1,000 V and supplement the general requirements in Sections 6 – 99.

47.1.2 Medium voltage metal enclosed switchgear, if provided, shall comply with the applicable requirements specified in CSA C22.2 No. 31 / IEEE 1247 / IEEE C37.20.3 / IEEE C37.20.4 / NEMA C37.54 / NEMA C37.57 / NEMA C37.58 and CSA C22.2 No. 253 / UL 347.

47.1.3 Utility interactive engine generators provided with switchgear panel field wiring compartments identified as "arc resistant" shall comply with the requirements of CSA C22.2 No. 0.22 / IEEE C37.20.7.

47.2 Isolating means interlocks

47.2.1 Switches or drawout assemblies used to isolate circuits shall be rated for making and breaking the maximum rated current of the circuit at the maximum rated voltage, or shall comply with 47.2.2 and 47.2.3.

47.2.2 When an isolating means is not rated for interrupting the rated maximum current of the circuit, interlocks shall be provided by mechanical means to prevent the isolating means from being opened or closed unless all power is removed from the circuit by another means. It shall also prevent the restoration of power, unless the isolating means is either in the closed position or separated by the isolating distance.

47.2.3 When the sum of the full load ratings of the CPT and any other connected transformers exceeds the interrupting capacity of the isolating means, electrical interlocks shall be provided to disconnect secondary loads of CPTs before the isolating means can be opened.

47.2.4 When a drawout assembly is used as an isolating means, it shall comply with the requirements for Drawout Element Interlocks, 5.11.202, of CSA C22.2 No. 253 / UL 347.

47.3 Performance

47.3.1 Generator field wiring compartments with spacings less than those specified in Table 25.1 shall be subjected to and comply with the Dielectric Test in addition to other performance requirements in this Standard to validate spacings.

47.3.2 Generator field-wiring compartments which use cast insulated busbars or cast insulating materials to allow for spacings less than those in Table 25.1 for ratings 1,000 V and greater shall be subjected to and comply with the Dielectric Test, the Impulse Test in Section 69, and the Partial Discharge (Corona) Test in Section 70, in addition to other performance requirements in this Standard to validate spacings.

Exception: UL 1004-4 compliant alternators maybe disconnected during this test.

CONSTRUCTION – FUEL SYSTEMS

48 Liquid Fuel Systems

48.1 General

48.1.1 A fuel confining part having internal threads made of drawn brass or machined from brass rod shall be capable of withstanding, without cracking, the 10-day Moist Ammonia-Air Stress Cracking Test, Section 66.

48.1.2 Enclosed engine generator assemblies shall have ventilation designed to minimize the possibility of hazardous accumulation of flammable vapors or gases during equipment operation or when shut down and the ventilation openings shall be arranged to minimize exhausted gasses or vapors from entering the combustion or cooling inlet air stream.

48.2 Tanks and fuel pumps

48.2.1 Fuel tanks provided as part of the engine generator assembly shall be constructed in accordance with NFPA 37, Chapter 6, UL 142A, or ULC-S601.

48.2.2 Fittings and fill pipe longer than 0.3 m (1 ft), where soldered, welded or bonded, shall be mechanically secured to the tank in addition to soldering, welding, or bonding.

48.2.3 When a tank is within or contiguous to the engine compartment the tank location and the facilities for filling shall be such that spillage or leakage drains to the ground and not onto the engine or exhaust-system parts. Spillage tests shall be conducted when required to determine compliance.

48.2.4 A fuel tank and fill fitting shall be so located as to reduce the possibility of damage to the tank or its fittings. The fill fitting and exhaust terminus shall be at least 0.9 m (3 feet) apart when installed in accordance with the manufacturer's instructions. The fuel fill shall not be located above the exhaust.

48.2.5 External fuel-confining parts of an electrically or mechanically operated fuel pump shall be of metal or nonmetallic material that meets the requirements of 48.4.1 and 48.4.2. Failure of operating parts shall not result in external leakage of fuel.

48.2.6 Electrically-operated fuel pumps shall comply with UL 558 / ULC/ORD-C558.

Exception: This requirement does not apply to electric fuel pumps that are supplied as part of and are integral to the engine, are submerged or mounted inside a non-vented container such that a pump leak cannot result in a fuel leak outside the container or tank.

48.2.7 An automatically operated positive shutoff shall be incorporated in the fuel line. This positive shutoff shall be a part of the carburetor, fuel pump, or similar device, or shall be a separate automatic safety shutoff valve for fuel, and shall prevent fuel from flooding the carburetor or similar device and spilling into the compartment when the engine generator is not operating. Where there are fuels that may include particulate matter, the fuel system shall be provided with filtering upstream of the positive shutoff to prevent degradation of fuel valves or similar device.

48.2.8 Fuel pumps that provide safety shutoff functionality shall comply with the Seat Leakage requirements and tests from ANSI Z21.21 / CSA 6.5 on the discharge side of the pump.

48.3 Fuel lines and fittings

48.3.1 Metallic fuel lines shall be of annealed seamless drawn aluminum or steel tubing. Flexible tubing or hose shall be used only where required to absorb vibration.

48.3.2 Aluminum tubing shall have a nominal wall thickness of not less than 0.76 mm (0.030 inch), 0.089 mm (0.0035 inch) minus tolerance. Steel tubing shall have a wall thickness of not less than 0.71 mm (0.028 inch) and shall have a corrosion-resistant exterior coating equivalent to that afforded by paint.

48.3.3 Flexible tubing or hose shall be marked to identify the manufacturer and model and shall be evaluated and found to comply with 48.4. Tubing and hose shall not pull off fittings or fail when subjected to a 89 N (20 pound-force) axial pull test applied over a 1 minute period. The test shall be conducted at ambient conditions of 21 ±5°C (70 ±9°F) with tubing or hose wetted with fuel. Hose shall be subjected to 70 hours at 100°C (212°F) aging and 48 hours of 3.175 mm (0.125 inch) amplitude vibration at 17 Hz before the pull test.

Exception: Flexible tubing or hose for use with higher pressure diesel fuel injected engines shall be of the type indicated in Table 48.1 which have been found to comply with 48.3.3.

Table 48.1
Types of flexible tubing or hose

Identification	Standard
SAE J30R13, SAE J30R7, SAE J30R9"	Standard for Fuel and Oil Hoses, SAE J30 – R7 – Low Pressure Synthetic Rubber Tube, R9 – Fuel Injection, Medium Pressure Synthetic Rubber Tube, R13 – Diesel or Biodiesel
SAE J517 100R1 Type AT	Standard for Hydraulic Hose, SAE J517
SAE J1402	Standard for Automotive Air Brake Hose and Hose Assemblies, SAE J1402
SAE 100R5-10/J1402	Standard for Automotive Air Brake Hose and Hose Assemblies, SAE J1402
SAE 100R1/EN 853-1SN	Standard for Hydraulic Hose, SAE J517
DIN 73379	Standard for Road Vehicles – Fuel Hoses, DIN 73379-1
ISO 19013-1	Rubber Hoses and Tubing for Fuel Circuits for Internal Combustion Engines; Specification Part 1: Diesel Fuels, ISO 19013
SAE J1597	Standard for Laboratory Testing of Vehicle and Industrial Heat Exchanges for Pressure Cycle Durability, J1597

48.3.4 Fuel-line tubing fittings shall be of the type conforming to the Standard for Automotive Tube Fittings, SAE J512, or the Standard for Cast Copper Alloy Fittings for Flared Copper Tubes, ASME B16.26, or the equivalent.

Exception: Pressed-in fittings are not prohibited from being used on gravity feed systems.

48.3.5 A body or fitting provided with tapered threads shall be threaded in accordance with the Standard for General Purpose Pipe Threads (Inch), ASME B1.20.1.

48.3.6 Fuel-line hose fittings shall be of the non-adjustable spring clamp or crimp-on type fittings complying with Dry Seal Pipe Threads, SAE J476 and Automotive Tube Fittings, SAE J512.

48.3.7 External fuel-confining parts of a filter, except a gasket or seal, shall be of metal. Glass filter bowls are not prohibited when they are located within a compartment in which the system is installed.

48.3.8 Fuel lines shall be supported to minimize chafing and to maintain at least a 51 mm (2 inch) clearance from bare exhaust components. Electrical wiring shall not be tied to fuel lines and shall be routed so that it maintains 12.7 mm (1/2 inch) clearance from fuel lines.

48.3.9 Fuel feed lines, valves, and fittings shall be located so that any leakage does not run off or drip on electrical- or exhaust-system parts.

48.3.10 Mechanical guarding shall be used where necessary to reduce the risk of access to a component or prevents the splashing, dripping or spraying fuel that has the potential of causing an electrical fire, fuel fire hazard, or injury to persons.

48.4 Nonmetallic parts

48.4.1 A synthetic-rubber or nonmetallic liquid fuel gasket or part, in contact with gasoline or diesel fuel shall not show excessive volume change or loss of weight when evaluated on the basis of its intended function, following immersion for 70 hours in the test liquid specified in Table 48.2 at the operating temperature, or it shall be subjected to the Volume Change Test of UL 157 or ASTM D471 and the test liquid specified in Table 48.2.

Table 48.2
Test liquids for nonmetallic materials

Liquid in contact with part	Test liquid
Gasoline	ASTM Reference Fuels A and C
E85	CE85a
Diesel	IRM 903 Oil
Biodiesel	B100a
Caustic, corrosive, toxic fluid, DEF	Fluid handled

48.4.2 A change in volume of not more than 25 percent swelling or 1 percent shrinkage, and a weight loss (extraction) of not more than 10 percent is considered as indicating compliance with 48.4.1.

48.4.3 A part made of synthetic rubber which is affected by aging shall not crack or show visible evidence of deterioration following exposure for 96 hours to oxygen at a pressure of 2.07 MPa (300 psi) and a temperature of 70°C (158°F).

48.5 Corrosion resistance

48.5.1 Where corrosion of a ferrous part interferes with the proper functioning of a part, the part shall be provided with a corrosion-resistant protective coating.

48.6 Carburetors

48.6.1 Where a side or updraft carburetor is used, it shall be located so that overflow of gasoline shall flow to ground or into a catch tank/reservoir, and it shall not contact electrical parts and exhaust system, or collect in an engine compartment. Nonmetallic drain hose, when used, shall comply with the fuel resistance, oil resistance, and dry-heat resistance tests of the Standard for Fuel and Oil Hose, SAE J30. A drain hose when used shall be routed away from surfaces exceeding 70°C (158°F).

48.6.2 A downdraft carburetor, when mounted over an engine and having an external float bowl vent opening, shall have a vent overflow tube to direct fuel away from the engine in case of fuel overflow.

49 Fuel Injection Systems

49.1 High pressure fuel injection systems [over 103 kPa (15 psi)] not provided as part of the engine shall be constructed of metallic pipes or tubing and have pipe threads, welded joints or metallic compression fittings or couplings. Compression fittings or couplings making use of polymeric sealing components shall comply with 48.4. Compression fittings and couplings making use of single use metallic crush or compression rings shall be identified in the service manual including the proper replacement procedure. Welded fuel containing components operating at pressures over 850 kPa (125 psi) shall be constructed using welding practices in accordance with ASME B31.3.

49.2 Fuel lines shall be supported to minimize chafing and to maintain at least a 51 mm (2 inch) clearance from bare exhaust components. Electrical wiring shall not be tied to fuel lines and shall be routed so that it maintains 12.7 mm (1/2 inch) clearance from fuel lines.

50 Liquid Fuel Flow Controls

50.1 No control shall be furnished on an engine generator assembly which allows, by manual operation, liquid fuel flow to the engine when it is shutdown for any reason.

Exception: Manually operated manual or electric priming fuel pumps shall be allowed for starting purposes only.

50.2 An automatic engine shutdown sensor shall be provided to detect when the engine is shutdown.

50.3 The automatic engine shutdown sensor shall cause the automatic safety shutoff valve to close in the event the engine is shutdown. Gas turbines liquid fuel systems shall be supplied by two automatic safety shutoff valves in series with positive shutoff indication. Compliance shall be verified through the application of the Fuel Valve Flow Control Test in Section 89.

50.4 An automatic safety shutoff valve (ASSV) shall:

a) Close upon shutdown or failure conditions, to automatically stop the flow of liquid fuel within less than two seconds. The valve shall close upon command from the automatic engine shutdown sensor or programmable control;

b) Be of the type that fails closed; and

c) Be 100,000 cycle endurance tested.

50.5 An automatic valve shall:

a) Operate each time there is a call for fuel;

b) Completely stop the flow of liquid fuel within 2 second of the engine shutting down for any reason;

c) Be of the type that fails closed; and

d) Be 100,000 cycle endurance tested.

A valve that meters or controls fuel flow may serve as the automatic valve if it complies with the requirements of CSA C22.2 No. 139 for Canada and one of the following for the US: UL 429, UL 428A, or UL 428B.

50.6 Where there are fuels that may include particulate matter, the fuel system shall be provided with filtering upstream of the positive shutoff to prevent degradation of fuel valves or similar device.

51 Diesel Exhaust Fluid (DEF)

51.1 DEF system components shall be suitable for exposure to the DEF agent, operating conditions, and the operating environment of the intended application.

51.2 DEF components shall not leak or spray DEF and wet critical electrical and or fuel containing, control or interrupt components. Synthetic-rubber or nonmetallic components relied on to contain the DEF from wetting critical electrical and or fuel containing, control or interrupt components shall comply with 48.4.2.

52 Liquefied Petroleum Gas

52.1 General

52.1.1 Where an LP-Gas fuel system is provided as part of the generator set, it shall include the complete fuel system installed at the factory, except as indicated in 52.1.2 and 52.1.3.

52.1.2 Products equipped to use a removable fuel container shall not be shipped without the fuel container unless a metal nameplate that identifies the correct fuel-container assembly to be used is attached adjacent to the container-mounting hardware.

52.1.3 A generator assembly arranged for LP-Gas fuel and intended for use with a remotely mounted tank not provided or part of the generator is not prohibited. Requirements concerning fuel containers do not apply to generator sets units of this type.

52.1.4 Non-ductile (regular gray iron) cast iron shall not be used for LP-Gas confining parts.

52.1.5 A body or fitting provided with tapered threads shall be threaded in accordance with ASME B1.20.1.

52.1.6 Vaporizers, regulators, valves, filters, and other fuel-system components subject to container pressure shall be of a type designed for use with LP-Gas at a working pressure not less than 1.75 MPa (250 psi).

52.1.7 All fuel-system components shall be secured to the unit to minimize the risk of loosening due to vibration.

52.2 LP Containers

52.2.1 A fuel container shall be a pressure vessel constructed, tested, and marked in accordance with:

a) CSA B51 / ASME Boiler and Pressure Vessel Code VIII Rules for Construction of Pressure Vessels, Division 1; or

b) The Specifications of the Department of Transportation (DOT) CFR Title 49, Part 178 for LP-Gas Containers.

52.2.2 A fuel container is not prohibited from being fixed to or removable from the generator set.

52.2.3 An ASME fuel container shall have a designed working pressure of 2.15, 2.36 or 2.60 MPa (312, 343, or 375 psi). It shall be marked with the ASME "U" symbol and the design working pressure.

52.2.4 A DOT fuel container shall be constructed, tested, and marked for a minimum service pressure of 1.65 MPa (240 psi). It shall bear the marking DOT-4B240, DOT-4BA240, DOT-4BW240, or DOT-4E240.

52.2.5 A fuel container shall be located so as to reduce the risk of damage to the container or its fittings. The fittings of a removable container shall be protected to minimize the possibility of damage during removal, filling, and replacement.

52.2.6 A fuel container shall be secured in place.

52.2.7 A removable fuel container shall be designed to engage a substantial positioning pin or an equivalent means for proper positioning of the container when reinstalled.

52.2.8 When a removable fuel container is used, means shall be provided in the fuel system to minimize the escape of fuel when the container is changed.

52.2.9 The use of a quick-closing coupling (a type closing in both directions when uncoupled) in the fuel line shall be determined as complying with the requirements of 52.2.8.

52.2.10 Welding, when required shall be made only on saddle plates, lugs, or brackets originally attached to the fuel container by the manufacturer and shall meet the requirements of CSA B51 / ASME B31.3.

52.2.11 A fuel container from which vapor only is to be withdrawn shall be installed and equipped with connections arranged to minimize the accidental withdrawal of liquid.

52.2.12 A fuel container shall be shielded, when required against direct heat radiation from the engine and exhaust system. See Table 58.2.

52.2.13 A removable-type container shall have the protection means for the fittings permanently attached to the container.

52.2.14 An excess-flow and a back-pressure check valve, when required, shall be located inside the container.

52.2.15 The filling connection shall be fitted with a double back-pressure check valve, or a hand-operated shutoff valve and a back-pressure check valve.

52.2.16 A removable container employing a hand-operated shutoff valve with an internal excess-flow check valve is not prohibited.

52.2.17 An accessible hand operated shutoff valve shall be provided on the container for each liquid or vapor fuel supply line.

52.2.18 An automatic excess flow check valve shall be provided in each container connection having an opening for the flow of gas in excess of a No. 54 drill size, 1.4 mm (0.055 inch); except those connections for filling and safety relief valves.

52.2.19 A metal plenum in the low pressure fuel circuit shall be located after the safety shutoff valves and shall comply ASTM A179 / A179M.

52.3 LP Gauges

52.3.1 A variable liquid-level gauge (such as a slip-tube or rotary type) which requires venting of fuel to the atmosphere shall not be used on a fuel container.

52.3.2 A fixed-tube gauge shall be employed on the fuel container, except as indicated in 52.3.3.

52.3.3 A removable container filled by weight only is not required to employ a fixed-tube gauge.

52.3.4 The length of a fixed-tube shall be such that, when the lower end touches the surface of the liquid in the container, the volume of the contents does not exceed 80 percent of the total container volume. This condition shall be met on a removable container regardless of whether the container is being filled in the horizontal or vertical position.

52.3.5 ASME containers shall have, permanently attached to the container, adjacent to the fixed liquid level gauge, or on the container nameplate, markings showing the percentage full that is indicated by the gauge.

52.3.6 Each container, whether constructed to ASME or DOT specifications, equipped with a fixed liquid level gauge for which the tube is not welded in place shall be permanently marked adjacent to such gauge or on the container nameplate as follows:

a) Containers designed to be filled in one position shall be marked with the letters "DT" followed by the vertical distance (to the nearest 2.5 mm (1/10 inch)) measured from the top center of the container boss or coupling into which the gauge is installed to the maximum filling level. The exterior of the removable dip tube gauging device shall bear a corresponding "DT" marking.

b) Portable universal type containers that are filled in either a vertical or horizontal position shall be marked as follows:

1) For Vertical Filling – With the letters "VDT" followed by the vertical distance (to the nearest 2.5 mm), measured from the top center of the container boss or coupling into which the gauge is installed to the maximum required filling level.

2) For Horizontal Filling – With the letters "HDT" followed by the vertical distance (to the nearest 2.5 mm), measured from the center line of the container boss or coupling opening into which the gauge is installed to the inside top of the container when in the horizontal position.

52.3.7 A non-venting, indicating-type liquid-level gauge (such as magnetic type) shall be provided on each container.

52.4 LP Fuel lines and fittings

52.4.1 All piping from a fuel container to the first-stage regulator shall be iron, steel (black), brass, or copper pipe; seamless copper or steel tubing; flexible metallic LP-Gas hose; or other equivalent piping means.

52.4.2 Steel tubing shall have a minimum wall thickness of 1.2 mm (0.049 inch) and shall have a corrosion-resistant exterior coating. Paint is considered to be a corrosion-resistant coating that meets the intent of this requirement. Copper tubing shall have a minimum wall thickness of 0.81 mm (0.032 inch) and shall be annealed. Aluminum piping or tubing shall not be used.

52.4.3 A length of flexible hose of a type designated for use with LP-Gas shall be employed between a removable container and any fixed fuel-system parts, and between any high-pressure parts on the frame and parts which are mounted on the engine.

52.4.4 Tubing fittings shall be of a type designed for use with LP-Gas.

52.4.5 Hose fittings shall be of a type for use with the LP-Gas hose employed.

52.4.6 Non-ductile cast fittings (such as but not limited to cast iron) shall not be employed for either piping or tubing.

52.4.7 Fuel lines shall be supported to reduce chafing and to maintain at least a 51 mm (2 inch) clearance from bare exhaust components. Electrical wiring shall not be tied to fuel lines and shall be routed so that it does not inadvertently contact fuel lines.

52.4.8 Flexible hose passing through sheet metal shall be installed to minimize hose abrasion, such as by use of clamps and grommets.

52.4.9 All pipe threaded fuel system fittings, including container fittings, shall be assembled using a pipe joint sealing compound designed for use with LP-Gas. All fuel-system connections, including the container with associated valves and fittings, shall be tested for leaks with a soap and water solution or equivalent while the system is under LP-Gas pressure of 1.5 times maximum rated operating pressure (for the fuel system under test) but not less than 103 kPa (15 psi).

Exception: Fuel systems with multiple operating pressures can be evaluated at the highest pressure or each fuel system section may be tested at 1.5 times the operating pressure of that portion of the fuel system.

52.4.10 The fuel container and associated valves and fittings are not prohibited from being tested separately using air pressure of not less than 621 kPa (90 psi).

52.4.11 Nonmetallic low pressure propane flexible hoses and fittings shall be subjected to the Volume Change and Extraction Test, Section 85, the Vibration Test, Section 86, Aerostatic Leakage Test, Section 87, and the Hydrostatic Strength Test, Section 88.

52.5 LP Vaporizers

52.5.1 Each vaporizer shall have a valve or plug which can completely drain the vaporizer in the section occupied by the water or other heating medium. Where the engine cooling system drain is so located that it is able to serve as a vaporizer drain, a separate vaporizer drain valve or plug is not required.

52.5.2 Each vaporizer shall be marked with the design working pressure in kPa (pounds per square inch) gauge and with the water capacity of the fuel-containing portion in kg (pounds).

52.5.3 Engine exhaust gases shall not be used as a direct means of heat supply for the vaporization of fuel unless the materials used for parts of the vaporizer in contact with the exhaust gases are resistant to the corrosion action of exhaust gases and the vaporizer system is designed to prevent excessive pressure.

52.5.4 Vaporizers shall not be equipped with fusible plugs.

52.6 LP Safety control and relief devices

52.6.1 A spring loaded internal-type safety relief valve with proper start-to-discharge setting and flow capacity, as detailed in 52.6.2 – 52.6.7, shall be provided on the fuel container.

52.6.2 A safety relief valve to be used on an ASME container shall be set, sealed, and marked with a start-to-discharge pressure not higher than the marked design working pressure of the container, and not less than 88 percent of the marked design working pressure of the container.

52.6.3 A safety relief valve on an ASME container shall be marked with its discharge capacity in cubic meters (cubic feet) per minute of air in accordance with Table 52.1 which relates the minimum required flow capacity to the outside surface area of the container.

Table 52.1
Safety relief valve capacity

Container surface area		Minimum flow rate of air	
m^2	($feet^2$)	M^3/m	(CFM)
1.86	(20 or less)	17.73	(626)
2.32	(25)	21.27	(751)
2.79	(30)	24.69	(872)
3.25	(35)	28.03	(990)
3.72	(40)	31.15	(1100)

52.6.4 A safety relief valve on a DOT container shall be set for a start-to-discharge pressure of 2.60 MPa (375 psi) and shall comply with the DOT regulations.

52.6.5 A safety relief valve shall have direct communication with the vapor space of the container.

52.6.6 The outlet from a container safety relief device shall discharge to the outside of enclosed spaces and as far as practicable from possible sources of ignition. A loose-fitting rain cap shall be provided on the end of discharge outlet piping. The cap shall be attached to prevent its being lost.

52.6.7 When a discharge line from the container safety relief device is used, it shall be of metal (other than aluminum) sized, and located so as not to restrict the required flow of gas from the safety relief device. Such a discharge line shall be so constructed and installed as to reduce the risk of its being dislodged by the discharge from the safety relief device and shall be directed upward within 45 degrees of the vertical.

52.6.8 An automatic shutoff valve shall be provided in the fuel system at some point ahead of the inlet of the first-stage regulator, designed to prevent flow of fuel when the ignition is off and the engine not running or when the engine stops. This device shall permit the back flow of fuel from the vaporizer in the event of a pressure build-up in the vaporizer. The device shall be of a type designed for use with LP-Gas at a working pressure of not less than 1.72 MPa (250 psig).

52.6.9 An automatic switch, such as an oil-pressure switch or vacuum switch, provided to control the automatic shutoff valve shall be rated for the load controlled and shall be of a type which is designed for the intended use.

52.6.10 A hydrostatic relief valve shall be installed between the container shutoff valve and the automatic shutoff valve of a liquid withdrawal system. The relief valve shall be set to discharge at not higher than the lowest pressure rating of the components in that portion of the fuel system. The valve discharge shall be arranged to vent outside of the system enclosure.

52.6.11 Automatic pressure-reducing equipment incorporating an automatic shutoff means to prevent the passage of fuel when the engine is not running shall be employed.

52.7 LP Nonmetallic parts

52.7.1 A synthetic-rubber part in contact with LP-Gas shall not show excessive volume change or loss of weight, when evaluated on the basis of its intended function, following immersion for 70 hours in hexane at 23.0 ±2.0°C.

52.7.2 A change in volume of not more than 25 percent swelling or 1 percent shrinkage, and a weight loss (extraction) of not more than 10 percent indicates compliance with 52.7.1.

52.7.3 A part made of synthetic rubber which is affected by aging shall not crack or show visible evidence of deterioration following exposure for 96 hours to oxygen at a pressure of 2.07 MPa (300 psig) and a temperature of 70°C (158°F).

52.7.4 Rigid (not rubber or synthetic rubber) polymeric components relied upon for gas containment that are located within, between, or upstream from the safety shutoff valves shall be made of materials rated for the operating conditions including: temperature (mechanical RTI accounting for worst case operating conditions), water exposure, and UV exposure (if exposed to UV).

52.7.5 Polymeric parts described in 52.7.4 shall be subjected to the following test sequence:

a) Fuel Compatibility Test of UL 1337;

b) Vibration Test of UL 1337; and

c) Leakage Test of UL 1337.

Intentionally moveable rigid polymeric fuel containing parts, such as but not limited to fuel type flow restrictors, shall be subjected to a preconditioning of 6000 mechanical cycles prior to the test sequence.

52.8 LP Corrosion resistance

52.8.1 When corrosion of a ferrous part interferes with the proper function of a part, the part shall be provided with a corrosion-resistant protective coating. When the corrosion resistance properties of the metal are not known, a sample shall be subjected to the Salt Spray Test, Section 67.

Exception: This requirement does not apply to a part made of stainless steel.

52.8.2 A part made of drawn brass or machined from brass rod shall withstand, without cracking, the 10-Day Moist Ammonia Air Stress Cracking Test, Section 66, for copper and copper alloys.

53 High Pressure and Low Pressure Natural Gas

53.1 General

53.1.1 Steel pipe (black) employed as low pressure gas conduit on an engine generator system pressure equal to or less than 850 kPa (125 psi) shall comply with NFPA 54 / ANSI Z223.1 and shall comply dimensionally with the Standard for Welded and Seamless Wrought Steel Pipe, ASME B36.10M.

53.1.2 Enclosed engine generator assemblies shall have ventilation designed to minimize the possibility of hazardous accumulation of flammable vapors or gases during equipment operation or when shut down and the ventilation openings shall be arranged to minimize exhausted gasses or vapors from entering the combustion or cooling inlet air stream.

53.1.3 High pressure fuel lines operating at pressures greater than 103 kPa (15 psi) shall be made of metallic piping and tubing or metallic flexible hose suitable for the intended use and capable of withstanding a 510°C (950°F) melt temperature. Flexible nonmetallic hose with fire sleeve may be used with other than gas turbine applications if found to be equivalent after additional investigation. Stainless steel piping and tubing employed as high pressure gas conduit system with a pressure of 850 kPa (125 psi) and greater shall comply with CSA B51 / ASME B31.3. Metallic flexible piping shall comply with ISO 10380, ASTM F1120, or ULC/ORD-C536 / UL 536 and be capable of withstanding pressure equivalent to five times its maximum rated pressure for 1 minute. The enclosed area where the high pressure gas fuel system is located shall be ventilated from a clean source of air.

53.1.4 Tapped holes for gas valves, pilots or other branch supply lines shall carry not less than 3-1/2 taper pipe threads in accordance with ASME B1.20.1.

53.1.5 Formed supply piping shall have all bends smoothly made without any appreciable reduction in the cross-sectional area, shall reveal no imperfections occasioned by the forming process, shall be annealed where required to remove internal stresses, and shall be thoroughly cleaned inside to remove loose particles.

53.1.6 Ends of piping and tubing shall be carefully reamed to remove obstructions and burrs.

53.1.7 Copper tubing or tubing with internal copper surfaces, when used for conveying low pressure fuel gas, shall be internally tinned or equivalently treated to resist sulphur corrosion.

53.1.8 Fuel lines subjected to vibration and movement shall be provided with flexible fuel line or flexible coupling to prevent damage to the line or connected components. If flexible steel tubing, piping hoses, and connectors are used to connect the engine to the natural gas fuel supply system, it shall be constructed of (316/316L Stainless Steel).

In the United States, if a rubber flexible coupling is used to connect the low pressure natural gas supply (less than 1 psi) to the engine it shall comply with UL 21.

In Canada, CSA B149.1 requires the use of metal flexible connections for this application.

53.1.9 Non-ferrous tubing employed as low pressure gas conduit shall have a wall thickness in accordance with Table 53.1.

53.1.10 Nonmetallic low pressure natural gas flexible hoses and fittings shall be subjected to the Volume Change and Extraction Test, Section 85, the Vibration Test, Section 86, Aerostatic Leakage Test, Section 87, and the Hydrostatic Strength Test, Section 88.

Table 53.1
Minimum wall thicknesses for nonferrous tubing

Outside diameter		Minimum wall thickness	
mm	(Inch)	mm	(Inch)
3.2	(1/8)	0.51	(0.020)
4.8	(3/16)	0.64	(0.025)
6.4	(1/4)	0.74	(0.029)
7.9	(5/16)	0.74	(0.029)
9.5	(3/8)	0.81	(0.032)
11.1	(7/16)	0.81	(0.032)
12.7	(1/2)	0.97	(0.038)
14.3	(9/16)	0.97	(0.038)
15.9	(5/8)	0.97	(0.038)
19.1	(3/4)	1.14	(0.045)
22.2	(7/8)	1.14	(0.045)

53.1.11 Gas supply piping shall be rigidly supported.

53.1.12 Compounds used on threaded joints of gas piping shall be resistant to the action of liquefied petroleum gases.

53.1.13 Unions in gas lines shall be of the ground-joint or flanged-joint type including a gasket resistant to the natural gas and intended for the temperature to which it is exposed. High pressure fuel systems are constructed of metallic pipes, tubes or elements such as Bourdon tubes within a gauge, bellows or spirals, with joints not subject to disconnection during routine maintenance and made with pipe threads, welding, or metallic compression fittings shall be considered to have no normal fuel release but limited abnormal fuel release.

53.1.14 A 3.175 mm (1/8 inch) N.P.T plugged tapping, accessible for test gauge connection, shall be furnished for measuring inlet gas pressure to the unit. The plug used shall not be of the slotted head type.

53.1.15 Aluminum tubing shall not be:

a) Exposed to condensate;

b) Used if it passes through insulating material of other than neutral reaction, unless the tubing is protected from the insulation; or

c) Used for water connections.

53.2 Synthetic rubber material parts

53.2.1 A synthetic-rubber part, in contact with gas fuel shall not show excessive volume change or loss of weight when evaluated on the basis of its intended function, following immersion for 70 hours in the test liquid specified in Table 53.2.

Table 53.2
Test fluids for synthetic rubber materials

Fuel gas in contact with part	Test liquid
Manufactured, natural fuel gases, and LP-Gas	IRM Oil No. 903 (ASTM D471) and n-Hexane
Caustic, corrosive, toxic (biogas), digester/landfill gas	2% vol. fraction H_2S/5%vol. fraction CO_2/93%vol. fraction CH_4
Caustic, corrosive, toxic (wellhead gas)	5% vol. fraction H_2S/5%vol. fraction CO_2/90%vol. fraction CH_4
Caustic, corrosive, toxic fluid (Diesel Exhaust Fluid, DEF)	Fluid handled

53.2.2 A change in volume of not more than 25 percent swelling or 1 percent shrinkage, and a weight loss (extraction) of not more than 10 percent is considered as indicating compliance with 53.2.1.

53.2.3 A part made of synthetic rubber which is affected by aging shall not crack or show visible evidence of deterioration following exposure for 96 hours to oxygen at a pressure of 2.07 MPa (300 psi) and a temperature of 70°C (158°F).

53.3 Natural gas boosters

53.3.1 Natural gas booster pump components shall be suitable for the intended application.

53.3.2 Natural gas booster pumps shall be protected against the effects of normal vibration in service, shall not be rigidly connected to the gas supply piping at the inlet and outlet by flexible metallic piping which shall comply with CSA B51 / ASME B31.3. Metallic flexible hose shall comply with ISO 10380, ASTM F1120, or ULC/ORD-C536 / UL 536 and capable of withstanding pressure equivalent to five times its maximum rated pressure for 1 minute.

53.4 Gas flow controls

53.4.1 General

53.4.1.1 No control shall be furnished on an engine generator assembly which allows, by manual operation, gas flow to the engine when it is shutdown.

53.4.1.2 An automatic engine shutdown sensor and/or programmable control shall be provided to detect when the engine is shutdown.

53.4.1.3 The automatic engine shutdown sensor and/or programmable control shall cause the automatic safety shutoff valve to close in the event the engine is shutdown or is required to shut down in a fault condition.

53.4.1.4 The automatic engine shutdown sensor and or programmable control operation shall be evaluated to Section 89, Fuel Valve Position Flow Control Test.

53.4.2 Automatic valves and automatic safety shutoff valves (ASSV)

53.4.2.1 All gas to the engine shall pass through at least one automatic valve and one automatic safety shutoff valve. The valves shall be in series and may be in a single control body and shall be located upstream of any flexible connectors in the fuel system within the generator assembly. Where there are fuels that may include particulate matter, the fuel system shall be provided with filtering upstream of the safety shutoff valve to prevent degradation of fuel valves.

53.4.2.2 Automatic safety shutoff valve (ASSV):

a) Shall close upon shutdown or failure conditions, to automatically stop the flow of gas within less than 2 seconds. The valve closes upon command from the automatic engine shutdown sensor or programmable control.

b) Shall be of the type that fails closed.

c) Shall be 100,000 cycle endurance tested.

53.4.2.3 An automatic valve shall:

a) Operate each time there is a call for fuel;

b) Completely stop the flow of gas within less than 2 seconds of the engine shutting down for any reason;

c) Be of the type that fails closed; and

d) Be 100,000 cycle endurance tested.

A zero governor regulator may serve as the automatic valve if they are found compliant with the reference requirements in 53.4.2.4.

53.4.2.4 Automatic valves and automatic safety shutoff valves shall comply with the applicable requirements in ANSI Z21.21 / CSA 6.5 or CSA C22.2 No. 139 / UL 429 / UL 428A / UL 428B including the following:

a) Normally closed electrically/pneumatically operated automatic safety shutoff valves shall close upon zero current flow;

b) Normally closed gas operated automatic safety shutoff valves shall close upon pressure failure to the valve operator;

c) Shall be 100,000 cycle endurance tested; and

d) The valve shall not utilize inlet fuel gas pressure/flow through the valve or an external power source for closure.

53.4.3 Gas appliance pressure regulators

53.4.3.1 A gas appliance pressure regulator shall be supplied with each engine generator.

53.4.3.2 Gas appliance pressure regulators, including vent limiters when so equipped, shall comply with the applicable provisions of ANSI Z21.18 / CSA 6.3, UL 252, ULC-C252, UL 1337, or ANSI/AGA NGV3.1/CGA NGV 12.3.

53.4.4 Bleeds and vents

53.4.4.1 The gas appliance pressure regulator shall be equipped with either a vent line or a vent limiter.

53.4.4.2 A diaphragm type automatic valve incorporating an external bleed shall be equipped with a bleed line.

53.4.4.3 An automatic safety vent valve shall comply with 53.4.2 and the requirements of ANSI Z21.21 / CSA 6.5 or CSA C22.2 No. 139 / UL 429.

53.5 Natural gas pressurized containers/receivers

53.5.1 A fuel container/receiver shall be a pressure vessel constructed, tested, and or marked in accordance with:

a) The ASME Boiler and Pressure Vessel Code, Section VIII; or

b) The construction shall meet the following requirements of the Specifications of the Department of Transportation (DOT) CFR Title 49, Part 571.304 for compressed natural gas fuel container integrity:

1) The burst pressure shall not be less than 2.25 times the service pressure for non-welded containers;

2) Shall not be less than 3.5 times the service pressure for welded containers and shall comply with CSA B51 / ASME B31.3; and

3) The burst test pressure shall be maintained for a minimum of 10 seconds

c) ASME receivers, if used, shall be stamped that they have been designed, constructed, and tested as required by Section VIII, Division 1, “Pressure Vessels,” of the ANSI/ASME Boiler and Pressure Vessel Code.

53.5.2 A fuel container is not prohibited from being fixed to or removable from the generator set.

53.5.3 An ASME fuel container shall have a designed working pressure of 2.15, 2.36 or 2.60 MPa (312, 343, or 375 psi). It shall be marked with the ASME "U" symbol and the design working pressure.

53.5.4 A metal plenum in the low pressure fuel circuit shall be located after the safety shutoff valves and shall comply ASTM A179 / A179M.

54 Bio-Gas and Well-Head Gas

54.1 Bio-gas and well-head gas flow controls shall comply with 53.4.

54.2 Steel pipe and fittings employed as gas conduit on an engine generator shall comply dimensionally with ASME B36.19M and ASME B31.11 and be constructed of 316 or 316L stainless steel as require by ANSI/CSA B149.6.

54.3 Formed supply piping shall have all relaxed bends smoothly made without reduction in the cross-sectional area smaller than 85 percent of the unbent area. The bends shall reveal no imperfections occasioned by the forming process, shall be annealed following the bending process to remove internal stresses, and shall be thoroughly cleaned inside to remove loose particles.

54.4 Ends of piping and tubing shall be free of obstructions and burrs.

54.5 Piping and tubing subjected to vibration in service shall not be directly connected to fuel supply systems. Flexible steel (316/316L SS) tubing/hoses shall be used to connect the engine to the fuel supply system in accordance with 54.6.

54.6 Type 316 stainless steel flexible metallic hoses and connectors compliant with 53.1.3 shall be used to protect against damage caused by corrosion, settlement, vibration, expansion, and contraction. Non-flexible fuel piping and tubing shall be supported adjacent to flexible metallic hoses.

54.7 Gas supply piping shall be rigidly supported.

54.8 Nonmetallic gas fuel gaskets, fluid housings, and hoses shall be:

a) Resistant to the intended fuel as specified in Table 53.2 at the operating temperature; or

b) Subjected to the Volume Change Test of UL 157 or ASTM D471.

54.9 Gas appliance pressure regulators, including vent limiters shall comply with the applicable provisions of UL 252, ANSI Z21.21, ANSI Z21.18 / CSA 6.3 or ANSI Z21.80 / CSA 6.22, and shall additionally comply with Table 53.2.

54.10 The gas appliance pressure regulator shall be equipped with either a vent line or a vent limiter.

54.11 A diaphragm type automatic valve incorporating an external bleed shall be equipped with a bleed line.

54.12 Automatic valves used in vents shall comply with UL 429 / CSA 6.3.

55 Multi-Fuel Systems

55.1 Units that are rated to operate with multiple fuel types shall comply with the requirements for each of the rated fuel types and shall comply with the applicable requirements of Section 48, Fuel Systems, and NFPA 37.

56 Exhaust Systems

56.1 The exhaust system shall be supported at least 76.2 mm (3 inches) clear of flammable materials, excluding flexible mountings, and at least 50.8 mm (2 inches) clear of fuel and electrical-system parts and shall not be subject to drippage of fuel, oil, or grease. Reduced spacings (minimum 12.7 mm) are evaluated for compliance during the Temperature Test, Section 58.

56.2 When an engine generator is rated for one or more of the following fuel types: gasoline, liquified propane (LP), and/or natural gas (NG), its exhaust system and muffler if provided shall conform with the test requirements in Section 64, Muffler Tests.

56.3 When a unit is provided with a partially installed or incomplete exhaust system, the information in 96.4(t) shall be provided.

56.4 Exhaust systems and components that are intended to be run through building structures shall comply with ULC/ORD-C959 / UL 2561 or ULC-S629 / UL 103.

56.5 Exhaust systems and engine exhaust hot sections that incorporate thermal insulation blanket/barrier component materials shall comply with the thermal insulation 20-mm (3/4-inch) flame test of 103.4.

PERFORMANCE

57 General

57.1 A generator assembly shall comply with the applicable requirements when tested as described herein. A generator of a type not described specifically in this Standard shall be tested in accordance with the intent of these requirements. When any indications are observed during the test procedures that a generator does not continue to meet the requirements in intended usage, such supplementary tests shall be conducted as applicable.

57.2 A representative sample of a unit shall be subjected to the tests described in Sections 58 – 84.

57.3 A unit marked with one frequency rating is to 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 are to be conducted at the worst case frequency or frequency at which highest rated current is produced.

Exception: For a unit marked with a dual frequency rating or a frequency range, the Temperature Test of Section 58, is to be conducted at the worst case frequency.

57.4 In preparation for testing, the unit is to be connected to the fuel supply and electrical input and output circuits as defined in the product ratings and installation instructions.

58 Temperature Test

58.1 The generator assembly is to be tested at full rated load. Parts shall not attain a temperature that damages required corrosion protection, adversely affects operation of safety controls, impairs the value of required thermal or electrical insulation, or results in creeping, distortion, sagging, or similar damage where such damage to the material or part results in a risk of fire or personal injury. The measured temperatures at specific points, corrected when applicable in accordance with 58.3 and with 58.8, shall not be greater than those specified in Table 58.1 and Table 58.2 unless otherwise indicated.

Table 58.1
Surface temperature limits

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

Table 58.1 Continued on Next Page

Table 58.1 Continued

Location	Composition of surface[a]			
	Metal		Nonmetallic	
	°C	(°F)	°C	(°F)
Lighting Fixture and heating elements located in areas that may be subjected to contact with leaking, dripping or spraying flammable fluids or gasses.	200	(392)	200	(392)

[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 the Exception to 58.3.

Table 58.2 Temperature limits

Insulation class, materials and components	°C	(°F)
A. Generator, alternator, and motor		
1. Class A (105) insulation systems on coil windings of alternators and generators:		
Thermocouple method	105[a]	(221[a])
Resistance method	115	(239)
2. Class E (120) insulation systems on coil windings of alternators and generators:		
Thermocouple method	115[a]	(239[a])
Resistance method	125	(257)
3. Class B (130) insulation systems on coil windings of alternators and generators:		
Thermocouple method	125[a]	(257[a])
Resistance method	135	(275)
4. Class F (155) insulation on coil windings of alternators and generators:		
Thermocouple method	150	(302)
Resistance method	160	(320)
5. Class H (180) insulation on coil windings of alternators and generators:		
Thermocouple method	165	(329)
Resistance method	175	(347)
6. Class N (200) insulation on coil windings of alternators and generators:		
Thermocouple method	180	(356)
Resistance method	190	(374)
7. Class R (220) insulation on coil windings of alternators and generators:		
Thermocouple method	195	(383)
Resistance method	205	(401)
B. 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])

Table 58.2 Continued on Next Page

Table 58.2 Continued

Insulation class, materials and components	°C	(°F)
3. Vulcanized fiber employed as electric insulation	90	(194)
4. Plated bus bar	105[d]	(221[d])
5. Unplated bus bar and a joint	75[d]	(167[d])
6. Transformer, relay, contactor, valve solenoids, and similar components 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)
7. 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])
8. Wood and other combustible material	90	(194)
9. Rubber- or thermoplastic-insulated wire and cord	60[e,f]	(140[e,f])
10. Other types of insulated wires	g	g
11. A surface upon which a generator is to be mounted in service, and surfaces that are adjacent to the generator when so mounted	90	(194)
12. Any point on or within a terminal box or compartment of a generator on which field-installed conductors rest	60[c]	(140[c])
13. Thermoplastic sealing compound	h	h
14. Selenium rectifier	75[i,e]	(167[i,e])
15. Power semiconductor	j	j
16. Printed-wiring board	k	k
17. Fuel		
a. Gasoline or diesel fuel in a fuel tank	75	(167)
b. LP-gas in a fuel tank	l	l
18. Sealing compound	340°C (140°F) less than melting point	

[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 specified.

Table 58.2 Continued on Next Page

Table 58.2 Continued

Insulation class, materials and components	°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 field wiring compartment of a generator shall not attain a temperature higher than the field wiring temperature marking required in 96.4 (m) and (n). Bus bar field wiring terminals will be based upon the field wiring insulation temperature marking as required by Table 96.3.		
[d] For a low voltage generator output bus bar having a current density in accordance with 23.5.2, it is not required to measure the temperature since it has characteristics which result in temperatures not exceeding the indicated values. The maximum temperature is determined by the temperature limit of the busbar support material, busbar insulating material, adjacent part material, or 100°C (212°F) temperature rise for plated busbar material and 75°C (167°F) for unplated busbar, whichever is lower.		
[e] The temperature limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has been investigated and found to have the required heat-resistant properties.		
[f] A short length of rubber- or thermoplastic-insulated cord inside the generator is not prohibited from being exposed to a temperature of more than 60°C (140°F) when supplementary insulation intended for the measured temperature and of adequate dielectric properties is employed on each individual conductor.		
[g] The maximum temperature is not to exceed the temperature limit of the wire except as noted in footnote 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) is not prohibited when the stack assembly is insulated with phenolic composition or other insulating material intended for a temperature of 150°C (302°F).		
[j] For a power-switching semiconductor or similar device, 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.		
[l] Temperature shall not exceed that which raises the pressure within an LP-gas container to more than 80 percent of the design working pressure of an ASME container or 120 percent of the minimum service pressure of a DOT fuel container.		

58.2 A temperature is determined to be constant when 3 consecutive readings taken at intervals of 10 percent of the previously elapsed duration of the test, and not less than 15 minutes, indicate no increase greater than 2°C (4°F).

58.3 During the Temperature Test, the temperature of a surface that is capable of being contacted by the user shall not be more than the value specified in Table 58.1. When the test is conducted at a room temperature of other than 25°C (77°F), the results are to be corrected to that temperature.

Exception: A unit is not prohibited from exceeding the temperature limits specified for surfaces subject to casual contact in Table 58.1 when it is:

a) A fixed unit so that the risk of contact by people is reduced;

b) Marked as required by 94.5; and

c) Provided with instructions as specified in 96.4(i).

58.4 With reference to 58.1, the test conditions for a generator having a 120/240 volt, single-phase output shall include maximum unbalanced load capability of the unit in accordance with the marking described in 91.2(b).

58.5 A thermocouple junction and the adjacent thermocouple lead wires are to be held securely in thermal contact with the surface of which the temperature is being measured.

58.6 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, or by the resistance method. In a generator, the thermocouple is to be mounted on the integrally applied insulation of the coil wire.

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

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

In which:

T is the temperature of the winding in degrees 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 degrees C at the beginning of the test

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.

58.8 All temperature limit values in Table 58.2 are based on an ambient air temperature of 25°C (77°F). However, tests are not prohibited from being conducted in other ambients as described in Table 58.3 when measured temperatures are corrected by subtracting the test ambient, and then adding the rated ambient for compliance, to the measured temperatures. Low voltage bus bars shall comply with note (d) of Table 58.2.

Table 58.3
Permitted test ambient

Ambient air temperature rating of unit	Test ambient air temperature
1. 25°C (77°F)	Range of 10 – 40°C (50 – 104°F)
2. Range of 25 – 40°C (77 – 104°F)	Range of 20 – 40°C (68 – 104°F)
3. Above 40°C (104°F)	Rated ambient[a]

[a] Allowable tolerances are as follows:

Minus – not less than 5°C (9°F) below rated ambient.

Plus – not specified.

58.9 When a unit is rated for an ambient air temperature higher than 25° C (77° F), the rating shall be indicated in the instruction manual in accordance with 96.4(j).

58.10 Thermocouples are to 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 is to be used wherever reference temperature measurements by thermocouples are required. The thermocouples and related instruments are to be accurate and calibrated in accordance with standard laboratory practice. The thermocouple wire is to conform with the requirements listed in the Tolerances on Initial Values of EMF versus Temperature tables in ASTM E230.

58.11 Measuring the temperatures of components or conductors operating at medium voltage using thermocouples is inherently dangerous. Other methods may be employed to reduce the hazards, such as testing the medium voltage circuits and equipment with the same current but at a lower voltage or use of temperature measurement equipment not affected by the medium voltage.

59 Dielectric Voltage-Withstand Test

59.1 The test potential specified in 59.4 is to be obtained from any convenient source having a capacity of at least 500 volt-amperes. The capacity is not prohibited from being lower 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 is to be continuously adjustable. Starting at zero, the applied potential is to be increased at a rate of 200 volts per second until the required test value is reached.

59.2 Direct-current potential is to be used for an ac circuit. A test potential of 1.414 times the applicable rms value of alternating-current voltage specified in 59.4 is to be applied.

59.3 Printed-wiring assemblies and other electronic-circuit components that are damaged by application of the test potential or that short-circuit the test potential are to be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand tests are made. Testing a representative subassembly instead of an entire unit is not prohibited. Individually shunting the semiconductor devices in the unit before the test is made to avoid destroying them in the case of a malfunction elsewhere in the secondary circuits is not prohibited.

59.4 While at operating temperature, the low voltage ac and when provided, dc power circuits shall withstand without breakdown the application of a sinusoidal potential of 1000 plus twice rated voltage (see 59.5) at a frequency in the range of 40 – 70 hertz applied for 1 minute between output (including generator) current carrying parts and dead metal parts.

Exception: For a dc circuit, either an alternating-current or a direct-current potential is to be used. When an alternating current potential is used, the potential is to be the value indicated above, divided by 1.414.

59.5 With reference to 59.4, the test potential between ac power circuits and dead metal parts is to be based on the phase-to-ground voltage rating. The test potential for other points involving the ac power circuit is to be based on the phase-to-phase voltage rating or the voltage rating of the other circuit, whichever is greater.

Exception: This test does not apply when the voltage potential is less than 30 volts (RMS).

59.6 The test potential for medium voltage circuits shall be the appropriate test potential from Table 69.1, or the rated dielectric voltage rating, whichever is higher.

60 Harmonic Distortion Test

60.1 When tested as described in 60.2, the total rms of the harmonic voltages, excluding the fundamental, delivered by a generator shall not exceed 5 percent of the fundamental rms output voltage rating, for Class I circuits, 20 percent for Class 2 circuits and 30 percent for Class 3 circuits and the rms voltage of any single harmonic shall not exceed 15 percent of the nominal fundamental rms output voltage rating for Class 3 circuits.

60.2 With reference to the requirement in 60.1, the generator is to be connected to a linear load having an adjustable impedance so the generator is able to deliver power at rated power factor. The measurements are to be made at open circuit and with the generator delivering 50 and 100 percent of rated power.

60.3 Exceeding the output voltage distortion levels of 60.1 is not prohibited when the unit is intended for use with a specific load device and is so marked in accordance with 93.19. The Temperature Test, Section

58, shall be conducted using the specified load. The temperature on the load shall not exceed the intended values applicable to the load equipment involved.

60.4 Exceeding the output voltage distortion levels of 60.1 is not prohibited when the unit is intended for use with a specific type of device and is so marked in accordance with 93.19. The instruction manual shall contain the information described in 96.4(r) when a specific type of device is used.

60.5 Exceeding the output voltage distortion levels of 60.1 is not prohibited when the temperatures measured on loads supplied by the non-sinusoidal waveform do not exceed the temperatures measured using the sinusoidal waveform by more than 5°C (9°F) and do not exceed the intended values applicable to the load equipment involved.

61 Output Voltage And Frequency Fluctuation Test

61.1 When tested as described in 61.2, the output voltage shall be within 90 to 110 percent of the nominal output voltage rating and the frequency shall be within 91 to 108 percent nominal output frequency rating.

61.2 With reference to the requirement in 61.1, the generator is to be connected to a linear load having an adjustable impedance so the generator is able to deliver power at rated power factor. With the generator in a steady state condition, fluctuation measurements are to be made at open circuit and with the generator delivering 50 and 100 percent of rated power.

62 Blocked Inlet Test

62.1 The generator assembly shall be arranged for testing as described for the Temperature Test, Section 58. When operating at maximum rated capacity, the circulator air flow is to be gradually restricted. This is to be accomplished by gradually blocking the circulating air inlet openings; first to one half of their open area, and then to complete blockage of the inlet grill area. The test is to be continued, under each of the restrictions, until equilibrium conditions are attained, the product shuts down or for 5 minutes after the alarm is activated. There shall be no burning, charring, smoke, or other evidence of damage to the product or enclosure which creates a risk of fire or personal injury with continued use. The product is not required to be operable following the test.

Exception: This test is not required for open type generator assemblies.

63 Intake Air Filter and Intake Backfire-Deflector Test

63.1 Electrical and or mechanical failures of an engine can result in intake backfire conditions. Backfires can occur on reciprocating four cycle engines. An air filter and backfire deflector under backfire conditions shall contain a visible flame front within its confines and shall not be displaced, physically damaged or distorted or show evidence of burning or smoldering of internal parts.

Exception: This test is not required for generator assemblies that employ diesel engines and gas turbine engines.

63.2 A backfire test shall be performed on a representative engine intake assembly including the backfire deflector and combustion air filter, oil-treated or dry-element type, connecting hoses, and fittings. Backfires in the intake system shall be created and verified. During this test, the intensity of the backfire and the issuance and extent of the accompanying flame are to be noted.

NOTE: Intake backfires can be created by causing ignition sparks to occur before the intake valve closes.

63.3 The backfire deflector and combustion air filter are then to be installed on the engine in the intended location.

63.4 The engine is then to be operated in the several manners determined in the preliminary test to provide for the most severe backfire conditions. At least ten and not more than twenty severe backfires are to be produced.

63.5 Observation for containment of flame are to be made under semi-darkened conditions by a minimum of two observers. No visible flame is to be in evidence at any time during the tests.

63.6 A dry-type filter element is to be tested in the above manner and a separate sample is to be subjected to a flame source of an intensity that results in the media burning or glowing. When the flame source is removed, a filter media shall not continue to burn or smolder.

Exception: This test is not required for filter elements used on engines that do not backfire when tested as described in 63.2.

64 Muffler Tests

64.1 As required by 56.2, a complete engine exhaust assembly is to be used for this test.

64.2 The engine is to be continuously operated until the engine is in a heated state. This state is assumed to have been reached when the exhaust manifold has been heated to approximately 315°C (600°F).

Exception: If the exhaust manifold temperature of 315°C (600°F) is not reached, the engine shall be operated for no less than 10 minutes.

64.3 Ten exhaust backfires are to be created for this test. Some methods of achieving exhaust backfires include:

a) Disabling the ignition system while the engine is running so as to fill the exhaust with an air fuel mixture, then re-enabling the ignition to ignite the fuel in the exhaust system; or

b) Altering spark ignition timing or similarly creating a condition allowing uncombusted fuel to enter the exhaust system and energizing an auxiliary spark plug in the exhaust system to ignite the fuel.

64.4 As a result of the ten exhaust backfires, the muffler and exhaust piping of the engine generator assembly shall not rupture.

65 Neutral to Ground Potential Measurement Test

65.1 In accordance with 19.1.7, a generator having a lead or terminal identified as a grounded circuit that is not grounded at the unit itself is to be subjected to this test. The generator is to:

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 (see Section 9, Electric Shock).

66 10-Day Moist Ammonia-Air Stress Cracking Test

66.1 After being subjected to the conditions described in 66.2 – 66.5, fuel-confining brass parts containing more than 15 percent zinc shall show no evidence of cracking when examined using 25X magnification.

66.2 A test sample shall be subjected to the physical stresses normally imposed on or within a part as the result of assembly with other components or with tubing or piping. Such stresses shall be applied to the sample prior to and maintained during the test.

66.3 Female pipe-threaded ends are to be engaged with brass plugs or fittings tightened to prevent leakage.

66.4 Three samples are to be degreased and then continuously exposed in a set position for 10 days to a moist ammonia-air mixture maintained in a glass chamber 305 by 305 by 305 mm (12 by 12 by 12 inches) having a glass cover.

66.5 A 600 ml (20 fluid ounces) of aqueous ammonia having a specific gravity of 0.94 is maintained to be at the bottom of the glass chamber below the samples. The samples are to be positioned 38.1 mm (1-1/2 inch) above the aqueous ammonia solution and supported by an inert tray. The moist ammonia air mixture in the chamber is to be maintained at atmospheric pressure and at a temperature of 34 ±2°C (93 ±3.6°F).

67 Salt Spray Test

67.1 The corrosion resistance of a metallic material is to be determined in accordance with 67.2. The samples shall show no signs of deterioration or corrosion.

67.2 Specimens of the material are to be supported vertically and exposed to salt spray (fog) for 50 hours in accordance with ASTM B117.

68 LP-Gas Container Load Tests

68.1 An LP-Gas fuel container shall be secured in place on the product in a manner capable of withstanding loadings in any direction equal to four times the filled weight of the container.

68.2 For this test, the container is to be empty of fuel and is to be so secured in the manner covered by the manufacturer's instructions. Loadings are to be applied in any convenient manner capable of being measured by gauges or weights.

69 Impulse Withstand Tests

69.1 General

69.1.1 This Section shall be applied as referenced or required by other portions of this Standard. This test shall be performed for each generator construction considering: distribution of charge, including location of any ground plane; changes in proximity of medium-voltage parts to grounded parts, other medium-voltage parts or low-voltage parts and shape of busbars and other medium-voltage parts.

NOTE: The results of this test are typically affected by the distribution of charge, location of any ground plane and shape of live parts. Sharp points such as corners and edges of busbars, bolts, screws, or other hardware commonly affect the results of this test.

69.1.2 The Impulse Withstand Test is a design test intended to evaluate the rated insulation level (impulse voltage withstand, or basic insulation level [BIL]) rating of a given generator field-wiring compartment assembly design. The medium-voltage circuits of a previously untested generator field-wiring compartment assembly shall be capable of withstanding voltage impulses using a full-wave 1.2 × 50 microsecond impulse in accordance with IEEE 4 and having a crest value equal to or greater than the rated impulse voltage of the equipment.

69.1.3 The test sample shall be subjected to a sequence of tests in accordance with 69.1.4 using one of the following test methods:

a) Method 1 (3 × 9 test procedure): This method is preferred for new tests. In each of these tests, three positive and three negative impulses shall be applied to each phase individually without causing a disruptive discharge, except as noted in 69.2.

b) Method 2 (2 × 15 test procedure): This method is an alternate preferred test method for new tests. In each of these tests, fifteen positive and fifteen negative impulses shall be applied to each phase individually without causing a disruptive discharge, except as noted in 69.2.

Some insulating materials retain a charge after an impulse test, and for these cases care should be taken when reversing the polarity. To allow the discharge of insulating materials, the use of appropriate methods, such as the application of 3 impulses at about 80 percent of the test voltage in the reverse polarity before the test, is recommended.

69.1.4 The sequence of tests shall be as follows:

a) For Test 1, the isolating means is to be closed, all medium-voltage fuses and control circuit fuses are to be in place, and the test voltage is to be applied between the medium voltage terminals and ground. For this test, all the input terminals are to be connected together, and all low voltage circuits are to be connected to ground during the test.

b) For Test 2, the isolating means is to be open and an impulse voltage of 110 percent of the rated impulse withstand voltage is to be applied in each phase individually between the contacts of the isolating means across the isolating gap. If the isolation means has provision for automatically grounding its load side when in the fully opened position, the test voltage is to be value specified under Test 1.

69.2 Evaluation

69.2.1 The generator assembly shall be considered to have passed the test if no disruptive discharge on non-self-restoring insulation occurs. A discharge that occurs through an integrally connected surge arrester is acceptable.

69.2.2 Test method 1, 3 × 9 test procedure: If a disruptive discharge occurs on only one test during any group of three consecutive tests, nine more tests shall be made. If the equipment successfully withstands all nine of the second group of tests, the flashover in the first group shall be considered a random flashover, and the generator assembly shall be considered as having successfully completed the test.

69.2.3 Test method 2, 2 × 15 test procedure: The generator assembly shall be considered as having successfully completed the test if the following conditions are fulfilled:

a) Each group has at least 15 tests;

b) The number of disruptive discharges does not exceed two for each complete group; and

c) No disruptive discharges on non-self-restoring insulation occur. This is to be confirmed by 5 consecutive impulse withstands following the last disruptive discharge. This procedure leads to a maximum possible number of 25 impulses per group.

Table 69.1
Rated insulation levels for rated voltages

Rated line-to-line voltage, U_r V_{rms}	Dielectric withstand voltage, U_d V_{rms} Test voltage Common value	Rated lightning impulse withstand voltage, U_p kV (peak value) Test voltage	WYE connection Minimum CEV[a] kV_{rms}	Delta connection Minimum CEV[a] kV_{rms} kV_{rms}
Column 1	Column 2	Column 3	Column 4	Column 5
0 – 750	1,000 V + (2 × rated voltage)	Not applicable	Not applicable	Not applicable
751 – 1,500	b	30	0.9	1.6
1,501 – 2,400	b	45	1.8	3.1
2,401 – 4,200	b	60	3.5	6.1
4,201 – 7,200	b	75	5.5	9.5
7,201 – 12,000	b	85	8.5	14.7
12,001 – 13,800	b	95	10.5	18.2
13,801 – 18,000	b	110	14	24.2
18,001 – 28,000	b	125	19	32.9
28,001 – 34,000	b	150	26.4	45.9
34,001 – 46,000	b	200	34	58.8

[a] Corona-extinction voltage

[b] The test voltage shall be the rated dielectric withstand voltage assigned by the manufacturer, or 2000 V + (2.25 x rated voltage of the generator), whichever is greater.

70 Partial Discharge (Corona) Test

70.1 Generators with rated maximum voltages (U_r) greater than 15 kV and having reduced spacing based on the use of insulation shall be subjected to the Partial Discharge Test.

70.2 The generator having reduced spacing used for the partial discharge test shall have been previously subjected to the Dielectric Voltage-Withstand Test, Section 59, and the Impulse Withstand Tests, Section 69. The Partial Discharge Test may be combined with the Dielectric Voltage-Withstand Test if all the parameters for both applicable tests are met.

70.3 With the generator field-wiring compartments installed and the isolating means closed, the test voltage shall be applied between each phase and ground with the other phases grounded. The impulse withstand or dielectric voltage-withstand test voltage shall first be raised to the rated short-duration test voltage across the isolating distance of the isolating means value shown in Table 69.1 and held for no less than 10 seconds. The voltage shall then be reduced to the minimum CEV (corona extinction voltage) shown in Table 69.1 and held for one minute.

70.4 At the end of the one minute period, if the measured partial discharge level is 100 pC (picocoulombs) or less, the equipment is considered to have passed the test.

71 Abnormal Tests

71.1 General

71.1.1 A generator assembly shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons (see 71.1.3) when subjected to the tests specified in 71.1.2 – 71.5.1. Using separate samples for conducting these tests is not prohibited.

71.1.2 Following each test, the Dielectric Voltage-Withstand Test, Section 59, is to be conducted. The potential is to be applied across the points indicated in 59.4.

Exception: Conducting more than one abnormal test on a sample, or conducting the Dielectric Voltage-Withstand Test after completion of all abnormal tests is not prohibited.

71.1.3 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 generator as evidenced by ignition, glowing, or charring of the cheesecloth, untreated cotton, or tissue paper;

b) The insulation breaks down when tested in accordance with 71.1.2 or live parts are made accessible (see Section 8, Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing);

c) Cracking, rupturing, or bursting of the battery case or cover, when 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.

71.1.4 During these tests, on enclosed type generator assemblies, all ventilating openings of the generator assembly are to be covered with a single layer of cheesecloth or untreated cotton loosely over the entire enclosure. The cheesecloth is to be untreated cotton cloth running 28 – 30 m^2/kg (14 – 15 yards per pound), and having, for any 6.45 cm^2 (1 square inch), a count of 32 threads in one direction and 28 in the other direction.

71.1.5 The enclosure of the unit is to be connected directly to ground.

71.1.6 Each test is to be continued until further change, as a result of the test condition, does not occur. When an automatically reset protector functions during a test, the test is to be continued for 7 hours. When a manual reset protector functions during a test, the test is to be continued until the protector operates for 10 cycles using the minimum resetting time, and not at a faster rate than 10 cycles of operation per minute. Termination of the test occurs when:

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

b) Opening of the overcurrent protection device; or

c) Opening of an internal fuse.

Exception No. 1: When the manually reset protector is a circuit breaker that complies with CSA C22.2 No. 5 / UL 489, it is to be operated for 3 cycles using the minimum resetting time and not at a rate faster than 10 cycles of operation per minute.

Exception No. 2: A manual reset protector that becomes inoperative in the open condition shall be operated between 10 cycles and 3 cycles.

71.2 Overspeed test

71.2.1 The product prime mover shall be arranged for operation in its intended manner and is to be operated under normal conditions with little or no external electrical load. An overspeed condition is to be attempted. Common methods to introduce an overspeed include electrically or manually opening the throttle valve. Compliant results, speed of the engine with no overspeed protection if the engine failure does not expel/eject fragments based on the manufactures risk assessment. When overspeed protection, such as an electronic or mechanical cut off switch (other than an electronic speed controller and throttle governor actuator) is provided, the test shall be run at the maximum speed controlled by the overspeed device. The test is to be conducted for a period of 1 minute. Alternatively the test for engines that expel/eject fragments shall take into account protective measures during this test or the over speed failure shall be a simulated fault signal injection input to the controls.

71.2.2 For units provided with electronic speed controllers for overspeed protection, this test shall be performed with the electronic speed controller throttle governor actuator in the failed position or defeated. Alternatively, the test for engines that expel/eject fragments shall take into account protective measures during this test or the over speed failure shall be a simulated fault signal injection input to the controller.

71.2.3 There shall be no evidence of fire or risk of personal injury as a result of this test.

71.3 Output overload test

71.3.1 Generator winding temperatures shall not exceed the temperature limits in Table 53.2. This test is to be conducted after thermal stabilization is reached during the mode of operation that has output power. While delivering maximum rated output power to an adjustable resistive load connected to the output ac circuit, the generator is to be subjected to the overload test described in 71.3.2.

71.3.2 The ac load is to be increased in increments of 10 percent of the maximum output rating and held for 1/2 hour at each increment until:

a) Further change as a result of the test condition does not occur; or

b) The unit shuts down.

Thermal stabilization is obtained with a load adjusted to result in maximum obtainable output power without causing operation of overcurrent protective devices, followed by increased incremental loading as described above. The maximum overload magnitude and time duration are to be recorded.

71.4 AC output short circuit test

71.4.1 The generator is to be connected and operated as in the normal temperature test. While operating, the AC output is to be shorted using an appropriately rated switch or contactor. Shorting is to include from line to line and line to neutral. The short circuit application time, maximum fault current peak and system response time duration are to be measured and recorded.

Exception: This test is not required to be conducted when the overcurrent protection device is rated no more than 125 percent of the rated output circuit current and having a short-circuit interruption rating not less than the maximum fault current available from the generator output tested.

71.4.2 If equipped with bus bars on the output, there shall be no damage to the bus bar mounting supports during the AC output short circuit test.

71.5 Component short- and open-circuit test

71.5.1 A component, such as a capacitor, diode, solid state device, or similar component connected in the input and output alternating current and direct current power circuits are to be short- or open-circuited, any two terminals one at a time, during any condition of operation including startup.

Exception: This test is not required where circuit analysis indicates that no other component or portion of the circuit is overloaded.

71.6 DC output short circuit test

71.6.1 This test is to be conducted on generator assemblies:

a) That have an integral battery charging circuit;

b) Whose direct current output of the generator is intended to be used with a remote battery supply; or

c) Direct current power circuit of a remote battery supply/cabinet assembly for use with a generator and investigated under the requirements of this Standard.

71.6.2 The test shall be conducted in accordance with the requirements for DC circuits in CSA C22.2 No. 107.3 / UL 1778.

71.6.3 During the tests described by 71.6.1 (a) and (c), batteries intended to be used with the generator shall be fully charged. During the test described by 71.6.1(b), batteries are not to be connected. The tests specified in 71.6.1 (b) and (c) are not prohibited from being combined into one test with the batteries connected.

Exception No. 1: A battery supply complies with the requirements when it complies with the following:

a) An overcurrent protection device is employed having a short-circuit interrupting rating not less than the maximum fault current available from the battery supply; and

b) The maximum current from the battery supply during the reserve mode – see 71.1 – does not exceed the ampacity rating of the conductors connected to the batteries. Table 310.15(B)(16) of the National Electrical Code, NFPA 70, and the Canadian Electrical Code, CSA C22.1, requirements are to be used for determining conductor ampacity.

Exception No. 2: This test is not required when the overcurrent protection device is rated not more than 125 percent of the rated output circuit current and having a short-circuit interruption rating not less than the maximum fault current available from the generator output tested.

72 Over-Temperature Protection – Overload and Endurance Operation Tests

72.1 When incorporated in the generator assembly, a protective device shall comply with 72.2 when subjected to:

a) An Overload Test consisting of making and breaking for 50 cycles of operation, at a rate of 6 cycles per minute, a current of 150 percent of rated value, at the rated voltage and power factor.

b) An Endurance Test consisting of making and breaking rated current, voltage, and power factor for 1,000 cycles for a manual reset protector or 6,000 cycles for an automatic reset protector, at a rate of 6 cycles per minute when the nature of the device allows this rate of operation.

72.2 There shall be no electrical or mechanical failure of the device, nor undue burning or pitting of the contacts.

72.3 The rate of operation indicated in 72.1 is not prohibited from being less than 6 cycles per minute when the nature of the device does not permit faster cycling.

73 Grounding Impedance Test

73.1 In accordance with 21.8, when penetration of nonconductive coatings is not determined by examination, a measurement of the grounding path resistance is to 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 73.2. The resistance of the equipment grounding conductor of a power supply cord shall not be included in the resistance measurement.

73.2 Compliance with 73.1 is to 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:

a) The equipment grounding connection; and

b) The metal part in question.

74 Overcurrent Protection Calibration Test

74.1 A fuse, or circuit protective device, provided for protection of secondary circuits in accordance with 26.9 shall meet the requirements for the Maximum Input Test in UL 1310 and the requirements of CSA C22.2 No. 223.

75 Battery Compartment Ventilation Test

75.1 If a measurement is needed to determine if a battery compartment complies with 42.2.5, the battery is to be subjected to the overcharge test in 75.2. During and at the conclusion of the test, the maximum hydrogen gas concentration shall not be more than 2 percent by volume. Measurements are to be made by sampling the atmosphere inside the battery compartment at periods of approximately 2, 4, 6, and 7 hours during the test. Samples of the atmosphere within the battery compartment are to be taken at the location where the greatest concentration of hydrogen gas is likely, using an aspirator bulb provided with the concentration measurement equipment, or other equivalent means.

75.2 A charging circuit adjusted to 106 percent of the maximum battery charge voltage is to be connected to a battery and be subjected to 7 hours of overcharging using a fully charged battery. Any user adjustable controls associated with the charger or charging circuit are to be adjusted for the most severe charging rate.

Exception: This requirement does not apply to a battery charger provided with a regulating circuit preventing an increase in battery charging current when the ac input voltage is increased from rated value to 106 percent of rated value.

75.3 The most severe charging rate referred to in 75.2 is the maximum charging rate that does not cause a thermal or overcurrent protective device to open.

75.4 Batteries other than lead acid shall comply with the referenced standard identified in Section 42, Batteries.

76 Strength of Terminal Insulating Base and Support Test

76.1 In accordance with the requirement in 17.1.13, 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 17.1.8, are torqued to

110 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 76.2.

Exception: 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.

76.2 With reference to 76.1, damage has occurred when the base insulating material cracks or rotates; bosses, recesses, or deforms in some way to prevent turning; does not perform its 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.

77 Cycling Test

77.1 In accordance with 17.4.1, an enclosure door, cover, or hood that is positioned or moved in normal use shall be subjected to 1000 cycles of operation and then be subjected to the tests in Section 101 for Outdoor-Use Units.

77.2 The enclosure door, cover, or hood shall not crack, deform, or allow wetting of live parts or the entrance of water.

78 Evaluation of Reduced Spacings on Printed-Wiring Boards

78.1 General

78.1.1 In accordance with (a) in Exception No. 3 to 25.1.1, printed-wiring board traces of different potential having reduced spacings are judged by conducting:

a) A Dielectric Voltage-Withstand Test described in 78.2; or

b) A Shorted Trace Test described in 78.3 for a generator investigated for use in either a controlled or general environment.

78.1.2 The requirements of this Section do not apply to medium voltage circuits on printed-wiring boards.

78.2 Dielectric voltage-withstand test

78.2.1 A printed-wiring board as specified in 78.1.1 shall withstand for 1 minute without breakdown the application of a dielectric withstand potential between the traces having reduced spacings in accordance with 59.1 and 59.2 as applicable.

78.2.2 Power-dissipating component parts, electronic devices, and capacitors connected between traces having reduced spacings are to be removed or disconnected in such a manner that the spacings and insulations, rather than these component parts, are subjected to the full dielectric voltage-withstand test potential.

78.3 Shorted trace test

78.3.1 Printed-wiring board traces specified in 78.1.1 are to be short-circuited, one location at a time, and the test is to be conducted as described in 71.1.1 – 71.1.3, 71.1.5, and 71.1.6. As a result of this test:

a) The overcurrent protection associated with the branch circuit to the rotary generator 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, the test is to be repeated twice using new components, as required.

Exception: Opening of an internal overcurrent protective device meets the intent of the requirement, and the test is not required to be repeated.

79 Bonding Conductor Test

79.1 A bonding conductor that does not comply with 21.9 (a) or (b) does comply 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 79.1; and

b) Three samples are subjected to a limited-short-circuit test using a test current as specified in Table 79.2 while connected in series with a nonrenewable fuse having a rating equal to the intended branch-circuit overcurrent-protective device.

Exception: When a fuse that is 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, then 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 79.1
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 79.2
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

79.2 The test circuit described in 79.1(b) is to have a power factor of 0.9 – 1.0 and a closed-circuit test voltage as specified in 57.2. The open-circuit voltage is to be 100 – 105 percent of the closed-circuit voltage. Each test is to be performed on each of the three samples.

80 Impact Tests

80.1 General

80.1.1 Plastic enclosures or plastic components required to be impact tested by the requirements or references in this Standard shall also be subjected to the cold impact in UL 746C if they are used as part of generators or generator assemblies rated for outdoor installation.

80.2 Impact on glass covered openings

80.2.1 With reference to 7.7.1(b), a glass covered opening shall withstand a 3.38 J (2-1/2 foot-pound) impact without cracking or breaking to the extent that a piece is released or dropped from its normal position.

80.2.2 The impact specified in 80.2.1 is to be applied by means of a smooth, solid steel sphere 50.8 mm (2 inches) in diameter and having 535 g (1.18 pounds) mass. The sphere is to fall freely from rest through a vertical distance of 63.5 cm (25 inches).

80.3 Polymeric material guards over moving parts

80.3.1 In accordance with 6.3, a part of a unit as described in 6.1 and 6.2 is to 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 6.8 J (5-foot-pound) impact. For surfaces other than the top, the steel sphere is to be suspended by a cord and to swing as a pendulum, dropping through a vertical distance of 1.29 m (51 inches) to strike the surface.

80.3.2 A unit is to be subjected to the impact test described in 80.3.1 with or without any attachment specified by the manufacturer so as to result in the most severe test.

80.3.3 When a part as specified in 6.1 is made of a polymeric material, the impact test is to be first conducted on a sample or samples in the as-received condition. The test is then to be repeated on a different sample or samples that have 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). While being conditioned, a part is to be supported in the same manner in which it is supported on the generator set.

80.3.4 Upon being removed from the oven specified in 80.3.3 and before being subjected to the impact test, no sample shall show signs of checking, cracking, or other deleterious effects from the oven conditioning, and no sample shall be distorted so as to result in a risk of injury to persons.

80.3.5 After the impact test required by 80.3.1, any openings resulting from the test shall comply with the accessibility requirements described in Section 8, Protection of Users – Accessibility of Uninsulated Live Parts and Moving Parts – and User Servicing.

81 Mechanical Tests of Viewing Panes for Medium Voltage Compartments

81.1 General

81.1.1 Viewing panes for medium voltage compartments shall not shatter, crack, or become dislodged when subjected to the impact and pressure tests described in 81.2 and 81.3.

81.1.2 The impact and pressure tests shall be applied to the outside surface of the viewing pane. The inside surface of the viewing pane need not be tested. Separate samples may be used for each of the tests.

81.2 Pressure test

81.2.1 A force of 890 N (200 lbf) shall be exerted perpendicular to the surface in which the viewing pane is mounted. This force shall be evenly distributed over an area of 0.010 m^2 (16 in^2), as nearly square as possible and as near the geometric center of the viewing pane as possible. If the viewing pane has an area less than 0.010 m^2 (16 in^2), a force of 86 kPa (12.5 psi) shall be evenly distributed over the entire viewing area. The force shall be sustained for a period of 1 min.

81.3 Impact test

81.3.1 The viewing pane shall be subjected to an impact of 6.8 N·m (5 ft-lbf) using a steel ball weighing approximately 0.535 kg (1.18 lb) and approximately 50 mm (2 inches) in diameter.

81.3.2 If the viewing panes are provided with a pivoting or hinged protective cover, which by design is always in place except when performing thermal inspections, this test may be performed with the cover in place. When a protective cover is provided, this test will be considered passed if the protective cover is not dislodged and does not shatter or crack, even though the viewing pane may be shattered, cracked, or dislodged.

82 Heat Sink Temperature Cycling Test

82.1 Where required by Exception No. 2 to 23.7.1, a current-carrying, aluminum heat sink shall be subjected to the test described in 82.2 and 82.3.

82.2 Three samples of the heat sink/solid state component assemblies are to be subjected to this test. After completion of the 500th cycle described in 82.3, 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.

82.3 The samples are to be subjected to 500 cycles of current-on and current-off operations. During the current-on time, the samples are to 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.

83 Ignition Test Through Bottom-Panel Openings

83.1 In accordance with Exception No. 3 to 7.10.1, a ventilated, bottom-panel construction shall be evaluated by conducting the tests described in 83.2 – 83.5.

83.2 Openings in a bottom panel shall be so arranged and small in size and few in number that hot, flaming No. 2 fuel oil (see 83.4) poured three times onto the openings from a position above the panel is extinguished as it passes through the openings.

83.3 A sample of the complete, finished bottom panel is to be supported in a horizontal position a short distance above a horizontal surface under a hood or in another area that is ventilated and free from drafts. Bleached cheesecloth running 28 – 30 m^2/kg mass (14 – 15 square yards to the pound) and having, for any 6.4 cm^2 (1 square inch), 32 threads in one direction and 28 in the other, is to be draped in one layer over a shallow, flat-bottomed pan that is of a size and shape to cover completely the pattern of openings in the panel and is not large enough to catch any of the oil that runs over the edge of the panel or otherwise does not pass through the openings. The pan is to be positioned with its center under the center of the pattern of openings in the panel. The center of the cheesecloth is to be 50.8 mm (2 inches) below the openings. Use of a metal screen or wired-glass enclosure surrounding the test area is a way to reduce the risk of splattering oil, causing injury to persons.

83.4 A small metal ladle no more than 63.5 mm (2-1/2 inches) in diameter, with a pouring lip and a long handle whose longitudinal axis remains horizontal during pouring, is to be partially filled with 10 cubic centimeters of No. 2 fuel oil, which is a medium-volatile distillate having a minimum API gravity of 30 degrees, a flash point of 43.3 – 87.7° C (110 – 190° F), and an average calorific value of 38.2 MJ/L (136,900 Btu per gallon) (see the American Society for Testing and Materials Specification for Fuel Oils, ASTM D396). The ladle containing the oil is to be heated and the oil is to be ignited. The oil is to flame for 1 minute and then is to be poured at the rate of, and no less than, 1 cubic centimeter per second in a steady stream onto the center of the pattern of openings from a position 102 mm (4 inches) above the openings. It is to be observed whether the oil ignites the cheesecloth.

83.5 Five minutes after completion of the pouring of the oil, the cheesecloth is to be replaced with a clean piece and a second 10 cubic centimeter of hot, flaming oil is to be poured from the ladle onto the openings, and it is again to be observed whether the cheesecloth is ignited. Five minutes later, a third identical pouring is to be made. The cheesecloth shall not ignite in any of the three pourings.

84 Bus Bar Tests

84.1 An aluminum bus bar employing a coating specified in Exception No. 3 of 23.2.1 or a bus bar that has a clamped joint construction described in Exception No. 2 and Exception No. 4 of 23.2.1, respectively, shall be subjected to the tests described in 84.2 – 84.4.

84.2 The temperature of the bus bar joint shall be measured during the temperature test described in Temperature Test, Section 58, and comply with the maximum temperature requirements specified in Table 58.2.

84.3 The temperature rise at the joint during the five hundredth cycle shall not be more than 15°C (27°F) higher than the temperature rise at the end of the twenty-fifth cycle.

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

Exception: The length of the bus bar is not prohibited from being less than 609 mm (2 feet) with the concurrence of those concerned.

85 Volume Change and Extraction Test

85.1 General

85.1.1 The Volume Change and Extraction Test is a sequence of tests. The test sequence is a Pull Test on three samples of the hose assembly in the as-received condition to obtain a pull out force for the samples. Three samples of the hose assembly are then to be conditioned during the Aging Test and followed by a Pull Test. The pull force of the as-received samples shall be compared to the pull force of the conditioned samples.

85.1.2 Nonmetallic low pressure propane and natural gas flexible hoses and fittings shall be subjected to the tests specified in 85.2 – 85.4.

Exception: This test sequence is not conducted on low pressure propane and natural gas non-metallic hoses evaluated to CSA 8.3 / CGA-8.1 / UL 569 and UL 536 for metal flexible fuel piping.

85.2 Pull test – as-received

85.2.1 The samples shall withstand a 267 N (60 pound-force) pull.

85.2.2 Three samples of the fuel hose assembly (hose and end fittings) are to be tested. Each sample is to be mounted in a tensile strength testing machine and operated with a rate of travel of 12.7 mm/minute (0.5 inch/minute) until the specified pull force has been reached.

85.3 Aging test

85.3.1 The samples shall not show visual signs of deterioration or loss of flexibility after aging.

85.3.2 Three representative samples of the fuel hose assembly are to be subjected to 70 hours in an air-circulating oven maintained at a temperature of 100°C (212°F). The samples are to be subjected to a Pull Test after temperature conditioning.

85.4 Pull test – after the aging test

85.4.1 The samples shall maintain at least 70 percent [187 N (42 pounds)] of their longitudinal pull force.

85.4.2 The three samples of the fuel line assembly (fuel line and end fittings), which were subjected to the Aging Test, are to be used for this test. Each sample is to be mounted in a tensile strength testing machine and operated with a rate of travel of 12.7 mm/minute (0.5 inch/minute) until:

a) The hose or fitting breaks, cracks, splits;

b) The fitting separates from the hose; or

c) The minimum pull force has been obtained.

86 Vibration Test

86.1 During and following this test, the hose assembly samples shall withstand the vibration without showing signs of degradation or leakage.

86.2 Two samples of the hose assembly are to be subjected to vibration while pressurized to normal operating pressure. The two samples are to be prepared one in the horizontal position, the other in the vertical, and both with one end fixed. They are to be mounted on the vibration machine and subjected to 48 hours vibration of 3.175 mm (0.125 inch) amplitude at a frequency of 17 Hz.

87 Aerostatic Leakage Test

87.1 To determine compliance with this test, the hose assemblies shall not leak.

87.2 Three samples of 457 mm (18 inch) long flexible hose assemblies are to be subjected to this test. Each sample is to have one end of the assembly plugged and the other hose end aerostatically pressurized to 1.5 times operating pressure for 5 minutes. The hose assemblies shall be checked for leakage by being immersed in water or an equivalent method.

88 Hydrostatic Strength Test

88.1 To determine compliance with this test, the hose assemblies shall not leak.

88.2 Three samples of 457 mm (18 inch) long flexible fuel line assemblies are to be subjected to this test. Each sample is to have one end plugged and the other hose end is to be hydrostatically pressurized to 4 times operating pressure for 1 minute and checked for leakage. The fuel line assemblies shall be checked for leakage by being immersed in water or an equivalent method.

89 Fuel Valve Flow Control Test

89.1 The fuel flow control system shall identify a fault condition and take action to close the fuel valves following a failure event as defined in Table 89.1 and as required by the tests in this Section. The valve closing feature may be performed in the complete product or may be separately tested as a fuel subsystem such as an evaluation of the controller and or the fuel valve component. The failure events defined above include loss of rotation, loss of combustion, and critical turbine failures. [Examples of programmable fuel control features are normal shutdown valve state, abnormal shutdown valve state and time (engine or engine control system failure such as overspeed, loss of ignition, or flame out) and the state of fuel flow and stop time.]

Table 89.1
Maximum generator fault fuel cessation time

Engine type	Maximum time between fault and fuel cessation time in seconds
Reciprocating	2
Turbine	5
NOTE 1: The time specified in this table is a sum of: a) the control time to identify the failure, b) the control action to close the valve, and c) the valve closing time.	
NOTE 2: Some fuel valves close in 2 seconds, therefore the combinations of valves, fuel flow/metering components, and control system must be tested and verified for compliance with these requirements.	

89.2 Compliance is demonstrated if at least one of the automatic valves closes within the specified time of the failure event.

89.3 The compliance time for this test is measured between the fault injection time and the valve closure.

NOTE: This test may be performed on a bench with signal generation for some types of engines and fuel flow control systems.

89.4 If the evaluation of the system is performed on individual control system assembly without the valve, the specific valve closing time shall be added to the time between the fault application and the valve closing signal.

89.5 A safety shutoff rated zero governor regulator or similar valve shall stop gas flow when a vacuum is not present at the outlet, the closing time shall be measured.

89.6 The following describes the test method:

a) The engine is to be operated under normal conditions. A fault condition is to be introduced and the fuel system control is required to close/stop fuel flow in accordance with 89.1 and Table 89.1.

b) The solenoid coil voltage or valve position state is to be observed and recorded.

c) For zero governor valve configurations, the vacuum pressure on the outlet line of the zero governor to the engine intake manifold is to be measured.

d) Measure and record the time of the above inputs per the system configuration of the product concurrently. The measurement device shall be capable of recording at a minimum of 10 millisecond increments.

e) A flame out condition or simulated flame out fault condition may be used to initiate a combustion failure condition.

89.7 The results of the test shall demonstrate that the control system including the valve closure complies with the values in Table 89.1.

90 Rod Entry Test

90.1 This test shall be conducted to determine acceptability of ventilation openings in medium voltage compartments.

90.2 When live parts are less than 102 mm (4 inches) from an opening, this test shall be made by attempting to insert a rod having a diameter of 12.7 mm (0.5 inch).

90.3 When live parts are 102 mm (4 inches) or more from an opening, this test shall be made by attempting to insert a rod having a diameter of 19 mm (0.75 inch).

90.4 The equipment complies with these requirements if the rod cannot enter the opening.

RATINGS

91 Details

91.1 The unit shall be marked with the following ac output ratings:

a) Voltage;

b) Frequency;

c) Number of phases except for a unit intended for single-phase only;

d) Amperes, volt-amperes, kilovolt-amperes, watts, or kilowatts;

e) Power factor, when less than unity unless the rating is expressed in: