UL 458

STANDARD FOR SAFETY

Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts

UL Standard for Safety for Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts, UL 458

Sixth Edition, Dated September 2, 2015

Summary of Topics

This revision of ANSI/UL 458 dated January 11, 2021 includes the following changes in requirements:

- ***Revision to polarity color coding; 58.2***
- ***Revision to scope; 1.1, 1.2, 1.4, 1.5, Table 32.1, Table 35.1 and 48.2.5***
- ***Revision to production line test conditions; Table 54.1***
- ***Revision to address charging lithium batteries; 1.3, Section 14A, 58.26 and 59.5***

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated July 31, 2020 and October 2, 2020.

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SEPTEMBER 2, 2015
(Title Page Reprinted: January 11, 2021)

UL 458

Standard for Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts

The first, second, and third editions were titled Power Converters and Power-Converter Systems for Recreational Vehicles.

First Edition – February, 1977
Second Edition – May, 1986
Third Edition – November, 1991
Fourth Edition – December, 1993
Fifth Edition – April, 2006

Sixth Edition

September 2, 2015

This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through January 11, 2021.

The most recent designation of ANSI/UL 458 as an American National Standard (ANSI) occurred on December 8, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover fixed and stationary power converters, power-converter systems, and accessories having a rated nominal input of 120, 120/240, or 240 V, alternating current and a nominal output of 60 V or less, direct current. Additionally, a power converter may have a rated nominal input of 12 – 60 V, direct current. These converters are intended for use within land vehicles where not directly exposed to outdoor conditions and are intended to be employed in accordance with the National Electrical Code, NFPA 70.

1.2 These requirements also cover fixed, stationary and portable power inverters and power-inverter systems having a dc input and a 120 or 240 V ac single phase output or up to 600Y/346V three-phase output. These inverters are intended for use within land vehicles where not directly exposed to outdoor conditions and are intended to be employed in accordance with the National Electrical Code, NFPA 70.

1.3 These requirements also cover converters/inverters that are additionally intended to charge batteries. Batteries intended for use with these systems are lead acid batteries or lithium based batteries, and the batteries are intended to comply with applicable battery standards and be provided with protective measures for discharging and charging. These products are not intended to provide protection to these batteries unless specifically included and evaluated as part of a system.

1.4 Power converters supplied by AC circuits covered by Part I of this standard are intended for connection to established 15- and 20-A branch circuits within a recreational vehicle.

1.5 Power-inverters and converters supplied by DC circuits covered by Part I of this standard are intended for connection to a nominal 12 to 60 V dc battery supply.

1.6 Converters and inverters incorporating provisions for the connection of less than three line-voltage branch circuits are investigated under the requirements in Part I of this standard.

1.7 A power-converter or power-inverter system is intended for direct connection to a power-supply assembly. A system for connection of three or less line-voltage branch circuits, not including the main disconnect, may optionally be evaluated in accordance with the requirements in Part II of this standard, or with the applicable requirements for a Class CTL panelboard in the Standard for Panelboards, UL 67. Power converter systems and power inverter systems also employ circuitry as described in 1.4 and 1.5.

1.8 A power-converter or power-inverter system provided with more than three line-voltage branch circuits, not including the main disconnect, is investigated to the applicable requirements for a Class CTL panelboard in the Standard for Panelboards, UL 67.

1.9 Converters and inverters incorporating provisions for the connection of more than three line-voltage branch circuits are judged under the requirements in Part I of this standard and the applicable requirements for a Class CTL panelboard in accordance with the Standard for Panelboards, UL 67.

1.10 Each pole of a multiple-pole circuit breaker is a separate circuit.

2 Glossary

2.1 For the purpose of this standard the following definitions apply.

2.2 ACCESSIBLE PART – A part located so that it can be contacted by a person, either directly or by means of a probe or tool during user servicing, or that is not recessed the required distance behind an opening.

2.3 BARRIER – A partition for the insulation or isolation of electric circuits, for the isolation of electric arcs, or for isolation of moving parts or hot surfaces. In this respect, a barrier may serve as a portion of an enclosure or as a functional part.

2.4 BRANCH CIRCUIT – That portion of the wiring system beyond the final overcurrent protecting device on the power-distribution panel protecting the circuit to the output.

2.5 CIGARETTE LIGHTER CONNECTOR – The male connector provided as part of a vehicle battery adapter for insertion into a cigarette lighter receptacle or a power outlet.

2.6 CLASS 2 TRANSFORMER – A step-down, isolation type transformer having a secondary voltage of not more than 30 Vrms (42.4 peak) under any condition of loading including open circuit and complying with the applicable requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1 and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

2.7 CONTROL CIRCUIT – A circuit that carries electric signals directing the performance of a controller that, in turn, governs power delivered to a motor or other load in the equipment. A control circuit does not carry main power current.

2.8 ENCLOSURE – That portion of a unit that reduces the accessibility and unintentional contact of a part that may involve a risk of fire, electric shock or injury to persons, or reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

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

2.10 FIELD-WIRING TERMINAL – Any terminal to which a supply or other wire is intended to be connected by an installer in the field is a field-wiring terminal unless the wire is provided as part of the product and a pressure terminal, connector, soldering lug, soldered loop, crimped eyelet, or other means for making the connection is factory-assembled to the wire.

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

2.12 FLUSH-WALL-MOUNTED UNITS – Units that are intended to be recessed in a wall.

2.13 LIMITED-ENERGY CIRCUIT – A circuit having a voltage not exceeding 1000 V and the energy limited to 100 VA by a secondary winding of a transformer, or a fixed impedance.

2.14 LIVE PART – Denotes metal or conductive parts that, during intended use, have a potential difference with respect to ground or any other conductive part.

2.15 LOW-VOLTAGE, LIMITED ENERGY CIRCUIT – A circuit involving an alternating voltage of not more than 30 Vrms (42.4 Vpeak) or a direct voltage of not more than 60 V and supplied by:

a) An inherently limiting Class 2 transformer;

b) A non-inherently limiting 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) Not readily interchangeable with a device of a different rating;

c) A combination of an isolated transformer secondary winding and a fixed impedance that complies with all the performance requirements for an energy-limiting Class 2 transformer or power source;

d) A dry-cell battery that is isolated from the primary circuit and having output characteristics no greater than those of an energy-limiting Class 2 transformer or power source; or

e) A combination of a rechargeable battery and a fixed impedance that complies with all of the performance requirements for an energy-limiting Class 2 transformer or power source.

2.16 PORTABLE POWER INVERTER – A power inverter that has no provisions for permanent mounting or wiring, and can be easily carried or conveyed by hand.

2.17 POWER-CONVERTER OR POWER-INVERTER SYSTEM – An integral combination of a converter or inverter, power-supply assembly, branch-circuit breakers, grounding bar, marking, and the like, that are necessary for a complete installation.

2.18 POWER SUPPLY ASSEMBLY – Conductors, including grounding conductors insulated from each other, connectors, attachment plugs, and all other fittings, grommets, or devices installed for the purpose of delivering energy from a source of supply to a power-converter or inverter system of a land vehicle or marine craft.

2.19 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. A pressure terminal connector may be the barrel and set screw type, crimp type barrel, or clamping plate and screw type.

2.20 PRIMARY CIRCUIT – Wiring and components that are conductively connected to a branch circuit or an alternating-current motor generator set installed separately from, or included as, a part of a power-converter or power-inverter system.

2.21 PRINTED WIRING BOARD – The finished combination of a pattern of conductive paths either on, in, or both on and in (multilayer) a sheet of insulating material, including printed components, and the base material.

2.22 PROTECTED ENVIRONMENT – Areas internal to the equipment that are resistant to entry of carbon dust, or other conductive contaminants, and the like.

2.23 PROTECTED ENVIRONMENT ENCLOSURE – A part or total enclosure of an appliance that is constructed as defined in Section 8, Enclosures Used for Protected Environments, so as to maintain a protected environment.

2.24 RISK OF ELECTRICAL ENERGY – HIGH CURRENT LEVELS – The capability for damage to property or injury to persons, other than by electric shock, from available electrical energy is considered to exist, if 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 an available continuous power level of 240 VA or more, or a reactive energy level of 20 J or more. For example, a tool, or other metal short circuiting a component may cause a burn or a fire if enough energy is available at the component to vaporize, melt, or more than warm the metal.

2.25 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist at any part if the potential between the part and earth ground or any other accessible part is greater than 42.4 Vpeak ac or 60 V dc, and the continuous current flow through a 1500 Ω resistor connected across the potential exceeds 5 mA.

2.26 RISK OF FIRE – A risk of fire is considered to exist at any component unless an investigation of the supply delivering power to that component complies with the criteria in Section 7, Frame and Enclosure.

2.27 RISK OF INJURY TO PERSONS – A condition that exists when stationary parts (such as sharp metal edges and projections), moving parts (such as gears, chains, or linkages), falling objects, inadequate mechanical strength of material, or the physical instability of the equipment are such that injury to persons may result.

2.28 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 considered to be a safety circuit.

2.29 SECONDARY CIRCUIT – A circuit conductively connected to the secondary winding of an isolating power supply transformer.

2.30 SERVICE PERSONNEL – Trained persons having familiarity with the construction and operation of the equipment, and the risks involved, who may periodically open an appliance to repair or maintain electrical or mechanical components.

2.31 STAND ALONE UNITS – Units that are intended to be permanently mounted in place but not recessed in the wall.

2.32 STATIONARY UNIT – Cord- and plug-connected units that are not fixed and are not movable. A stationary unit may have provision for attachment in accordance with this standard.

2.33 POWER SUPPLY CORD – A separable cord set or a length of flexible cord or cable, with one end connected to the primary-circuit wiring of the unit and the other end connected to the attachment plug for connection to branch circuit power.

2.34 SWITCH, TRANSFER – An automatic or nonautomatic device for transferring load conductor connections from one power source to another. May be referred to as transfer switch/mechanism.

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

2.36 TRIP – Denotes automatic interruption of the electric circuit to the load.

2.37 UNIT – For the purposes of this standard, a converter, inverter, converter system, or inverter system, unless specified otherwise.

2.38 USER SERVICING – Any form of servicing that can be performed by personnel other than those who are trained to maintain the unit. Some examples of user servicing are:

a) The installation of accessories by means of attachment plugs and receptacles, or by means of separable connectors.

b) The replacement of lamps and fuses, or the resetting of circuit breakers located in a user access area unless they are marked to indicate replacement or resetting by qualified personnel only.

c) The making of routine operating adjustments necessary to adapt the unit for different intended functions.

d) Routine cleaning.

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by the standard.

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

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

b) Is superseded by a requirement in this standard.

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

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

4 Units of Measurement

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

5 Undated References

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

PART I – POWER CONVERTERS AND INVERTERS

CONSTRUCTION

6 General

6.1 A unit shall employ materials that are acceptable for the intended use.

7 Frame and Enclosure

7.1 A unit shall be so formed and assembled that it will have the strength and rigidity necessary to resist the abuses to which it may be subjected without increasing the risk of fire, electric shock, or injury to persons due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other serious defects.

7.2 A unit shall be provided with an enclosure acceptable for the intended application that shall house all parts other than the power-supply cord or primary connector and the output leads or terminals that may increase the risk of fire, electric shock, or injury to persons under normal conditions of use.

7.3 A cast- or sheet-metal section of the enclosure shall have a thickness not less than that specified in Table 7.1.

Table 7.1
Minimum acceptable thicknesses of enclosure metal

Metal	At small, flat, unreinforced surfaces and at surfaces of a shape or size to ensure adequate mechanical strength,		At surfaces to which a wiring system is to be connected in the field,		At relatively large unreinforced flat surfaces,	
	in	(mm)	in	(mm)	in	(mm)
Die-cast metal	3/64	(1.2)	–		5/64	(2.0)
Cast malleable iron	1/16	(1.6)	–		3/32	(2.4)
Other cast metal	3/32	(2.4)	–		1/8	(3.2)
Uncoated sheet steel	0.026	(0.66)	0.032	(0.81)	0.026	(0.66)
Galvanized sheet steel	0.029	(0.74)	0.034	(0.86)	0.029	(0.74)
Nonferrous sheet metal other than copper	0.036	(0.91)	0.045	(1.14)	0.036	(0.91)
Sheet copper	0.033	(0.84)	0.043	(1.09)	0.033	(0.84)

7.4 A polymeric enclosure or polymeric part of an enclosure shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: A polymeric enclosure or polymeric part of an enclosure in accordance with 7.6 need not comply with this requirement.

7.5 If the dimensional integrity of nonmetallic material employed for a part is depended upon to maintain continuity of a grounding system, the material is to be investigated with respect to:

a) Dimensional stability;

b) Mechanical strength; and

c) Resistance to creeping and distortion at temperatures to which the material may be subjected under conditions of intended use.

The material shall not display a loss of these properties beyond the minimum acceptable level as a result of aging.

7.6 A nonmetallic part (such as a reset knob, a lever, or a button) protruding through a hole in the enclosure, shall be made of a material classed as V-0, V-1, or V-2 in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, if the area of the hole is 0.6 in^2 (387.1 mm^2) or less. Nonmetallic parts protruding through a hole having an area larger than 0.6 in^2 shall be made of materials that comply with the requirement in 7.4.

Exception No. 1: A part of a component need not be classed V-0, V-1, or V-2 if it complies with the flammability requirements applicable to the component.

Exception No. 2: A part need not be classed V-0, V-1, or V-2 if, when removed, there are no live parts or moving parts accessible to the user as determined by the requirements in Section 9, Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts.

7.7 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 the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: If flaking or peeling of the coating will 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 UL 746C.

7.8 Overtemperature and overcurrent protection shall be located within the unit enclosure. See 21.2.1 – 21.2.3.

Exception: The operating handle of a circuit breaker, the operating button of a manually-operable protector, the capped portion of an extractor-type fuseholder, or a similar part may project outside the enclosure.

7.9 A door or cover of an enclosure shall be hinged or attached in an equivalent manner if it provides access to an overload-protective device the normal functioning of which requires renewal, or if it is necessary to open the cover in connection with normal operation of the protective device. A door or cover providing access to a fuseholder shall be tight-fitting and shall be positively held closed.

7.10 A unit shall be provided with means for securely mounting the unit in its intended operating position. Bolts, screws, or other parts used for mounting the unit shall be independent of those used for securing components.

7.11 If 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: An electrical instrument connected in a secondary circuit need not comply with this requirement if damage to or deterioration of the materials of which the housing is made will not result in a risk of electric shock or fire.

7.12 Material supporting terminals or used as internal electrical insulation of an electrical instrument shall comply with the requirements in Section 17, Insulating Materials.

Exception: An electrical instrument connected in a secondary circuit need not comply with this requirement if damage to or deterioration of the materials will not result in a risk of electric shock or fire.

7.13 Supporting feet of a unit that form part of the enclosure or are needed for ventilation shall be reliably secured and the resistance to aging, physical properties, and resistance to combustion of the material shall be investigated.

7.14 A compartment or part of an enclosure that will contain field-wiring splices in other than a Class 2 circuit shall not be provided with ventilating openings.

7.15 The enclosure of a unit shall be such as to prevent molten metal, burning insulation, flaming particles, or the like from falling on combustible materials, including the surface upon which the unit is supported. See Section 50, Burnout Test.

7.16 If a screen is needed in the bottom of an enclosure to comply with the requirements in 7.18 and 7.19, it shall be 14 mesh steel with a minimum wire diameter of 0.018 in (0.46 mm) and shall be mechanically secured in position.

7.17 For a unit having holes in the bottom of the enclosure, the requirements in 7.15 will necessitate the use of:

a) Internal wiring insulated with neoprene, thermoplastic, or glass fiber, or an equally fire-retardant material.

b) An individually enclosed fuse, such as an extractor type. Consideration will be given to a fuse enclosed with a transformer winding.

7.18 A component having a magnetic winding or coil, such as a relay or a solenoid, shall be individually and completely enclosed, or subjected to the burnout tests described in 50.1.1 and 50.2.1.

7.19 Arcing parts of a switch or relay located in an enclosure having ventilating openings in the bottom shall be individually and completely enclosed, or the switch or relay shall be subjected to the arcing overload test described in 50.3.4.

8 Enclosures Used For Protected Environments

8.1 A protected environment enclosure provided for compliance with 29.1.1 shall be constructed so as to protect the internal parts of the appliance against conductive contaminants and shall comply with the Atomized Water Test, Section 52.

Exception: A part that is uniformly coated or completely encapsulated need not be subjected to the Atomized Water Test.

8.2 A protected environment enclosure may be provided by means of an enclosure that is:

a) Hermetically sealed;

b) Provided with gasketed, tight fitting joints and doors or covers;

c) Welded, sonically welded, solvent cemented, or provided with tongue and groove joints and seams; or

d) Encapsulated (potted); or

e) Conformally coated with a compound that complies with the Standard for Polymeric Materials – Use in Electrical Evaluations, UL 746C, and with the intended application.

8.3 All openings used for cords, leads, bushings, connectors, and the like shall be constructed to preclude entry of dust or other contaminants.

8.4 Gaskets intended to provide tight fitting joints, doors, and covers for a protected environment enclosure shall comply with the Gasket Tests, Section 50.

8.5 Potting shall be used within its temperature rating. Prior to potting, all parts shall be mechanically secured.

9 Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts

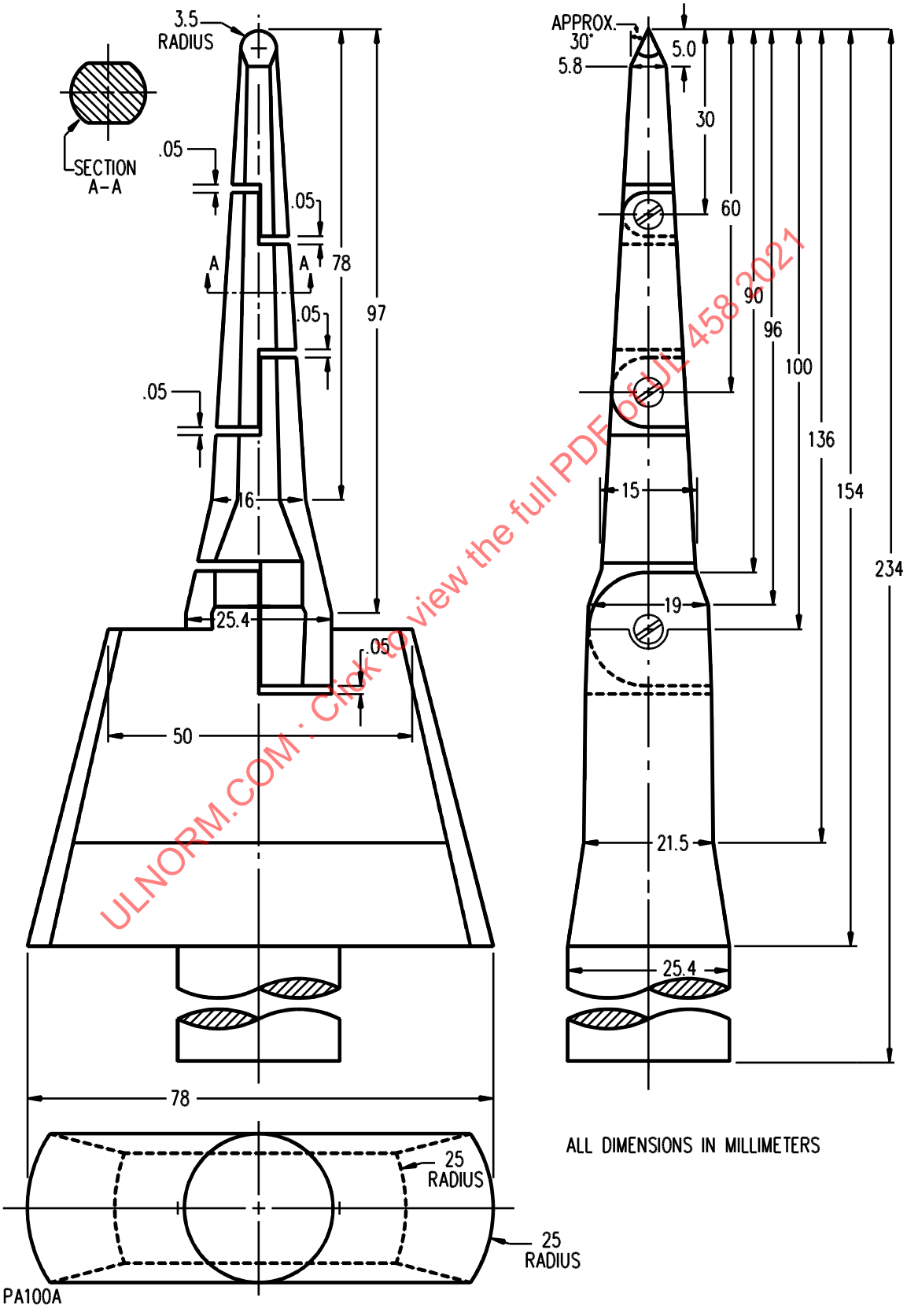
9.1 General

9.1.1 An uninsulated live part, film-coated wire, or moving part, that could result in a risk of electric shock or injury to persons shall be located or enclosed so that unintentional contact is precluded.

9.1.2 An opening in the enclosure of a unit that will not permit entrance of a 3/4-in (19.1-mm) diameter rod is acceptable if a probe as illustrated in Figure 9.1 cannot be made to touch any uninsulated live part, film-coated wire, and moving part, that could result in a risk of electric shock when inserted through the opening.

Figure 9.1

Accessibility probe



9.1.3 Perforated sheet metal shall not be less than 0.042-in (1.07-mm) thick if the perforations are 1/2 in^2 (3.2 cm^2) or less in area, and shall not be less than 0.080-in (2.03-mm) thick for larger openings.

Exception: Perforated sheet metal not less than 0.020-in (0.51-mm) thick may be used where the indentation of a guard or enclosure will not affect the clearance between uninsulated live parts, film-coated wire, or moving parts and grounded metal.

9.1.4 A door or cover that provides access to a live part, film-coated wire, or moving part, that may result in a risk of electric shock, shall be securely held in place so that it can be opened or removed only by using a tool.

9.2 User servicing

9.2.1 Live parts, film-coated wire, and moving parts shall be arranged and covers located so as to reduce the likelihood of a risk of electric shock while covers are being removed and replaced if it is necessary to do so to perform a servicing function as indicated in the operator's instruction manual accompanying the unit.

9.2.2 Live parts, film-coated wire, and moving parts shall be:

a) Recessed at least 1/8 in (3.2 mm) from the plane of the front of the fixed portion of an enclosure; or

b) Recessed at least 1/8 in (3.2 mm) from the front edge of a wiring compartment, in the case of a device mounted to the face of a wiring compartment; or

c) Afforded equivalent protection by projections or guards.

To determine whether such live parts, film-coated wire, and moving parts comply with the requirement in 9.2.1, the cover is to be removed and replaced. Contact of either persons or a conductive cover with live parts, film-coated wire, or moving parts is unacceptable.

9.2.3 Operations and adjustments that are considered to subject parts to contact by the user include those made at the time of installation or during normal use, and operations such as relamping, replacing a fuse, and resetting an overload device.

9.2.4 A part on the back of a component mounting panel and a part located so as to require major disassembly by using a tool are not considered to be exposed to the user, and are not considered to be exposed to the serviceman unless it is likely that servicing will be done while the parts are energized after disassembly.

9.3 Serviceman servicing

9.3.1 An electrical component that may require adjustment, servicing, or maintenance not specified in the operator's manual shall be located and mounted with respect to other components and with respect to grounded metal parts so that it is accessible for electrical service functions without subjecting the serviceman to the likelihood of electric shock or injury to persons. Access to components for servicing shall not be impeded by other components or by wiring in the direction of access.

9.3.2 The electrical components mentioned in 9.3.1 include a fuse and an adjustable control.

9.3.3 All conductive internal parts that are accessible to service personnel and that are usually expected to be at ground potential (heatsinks and the like), but are energized and involve a risk of electric shock, shall be marked in accordance with 58.22.

10 Assembly

10.1 An uninsulated live part shall be secured to the base or surface so that it will be prevented from rotating or shifting in position as the result of normal stresses if such movement might result in a reduction of spacings below the minimum acceptable values. See Section 29, Spacings.

10.2 A component such as a rectifier element, control switch, lampholder, attachment plug receptacle, or plug connector shall be mounted securely and shall be prevented from turning by means other than friction between surfaces.

Exception No. 1: A switch, if the following conditions are met:

a) The switch is a plunger or other type that does not tend to rotate when operated–a toggle switch is considered to be subject to forces that tend to turn the switch;

b) The means for mounting the switch makes it unlikely that operation of the switch will loosen it;

c) Spacings are not reduced below the minimum acceptable values if the switch rotates; and

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

Exception No. 2: A lampholder of the type in which the lamp cannot be replaced, such as a sealed neon pilot or indicator light, if rotation cannot reduce spacings below the minimum acceptable value.

10.3 A small stem-mounted device having a single-hole mounting means may be prevented from rotating by a lock washer properly applied.

10.4 If a switch or circuit breaker is mounted such that movement of the operating handle, either linearly or rotationally, between the on and off positions results in one position being above the other position, then the upper position shall be the on position. This requirement does not apply to a switching device having two on positions such as a double throw switch.

11 Protection Against Corrosion

11.1 Iron and steel parts shall be protected against corrosion by enameling, painting, galvanizing, plating, or an equivalent means.

Exception No. 1: Bearings, laminations, other parts of iron or steel such as washers and screws, need not comply with this requirement.

Exception No. 2: A part the corrosion of which would not result in a risk of fire, electric shock, or injury to persons need not comply with this requirement.

12 Supply Connections

12.1 Permanently-connected converters or inverters

12.1.1 General

12.1.1.1 A unit intended for permanent connection to the source of supply shall have provision for the connection of one of the wiring systems that is acceptable for the unit.

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

12.1.1.3 A knockout shall be surrounded by a flat surface adequate for seating of a conduit bushing or locknut of the appropriate size and shall be located so that installation of a bushing at any knockout likely to be used during installation will not result in spacing between an uninsulated live part and the bushing to be less than that specified in Spacings, Section 29.

12.1.1.3.1 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as mentioned in 12.1.1.3, it is to be assumed that a bushing having the dimensions specified in Table 12.1 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

Table 12.1
Knockout or hole sizes and dimensions of bushings

Trade size of conduit	Knockout or hole diameter		Bushing dimensions			
			Overall diameter		Height	
in	in	(mm)	in	(mm)	in	(mm)
1/2	7/8	(22.2)	1	(25.4)	3/8	(9.5)
3/4	1-3/32	(27.8)	1-15/16	(31.4)	27/64	(10.7)
1	1-23/64	(34.5)	1-19/32	(40.5)	33/64	(13.1)
1-1/4	1-23/32	(43.7)	1-15/16	(49.2)	9/16	(14.3)
1-1/2	1-31/32	(50.0)	2-13/64	(56.0)	19/32	(15.1)
2	2-15/32	(62.7)	2-45/64	(68.7)	5/8	(15.9)
2-1/2	3	(76.2)	3-7/32	(81.8)	3/4	(19.1)
3	3-5/8	(92.1)	3-7/8	(98.4)	13/16	(20.6)
3-1/2	4-1/8	(104.8)	4-7/16	(112.7)	15/16	(23.8)
4	4-5/8	(117.5)	4-31/32	(126.2)	1	(25.4)
4-1/2	5-1/8	(130.2)	5-35/64	(140.9)	1-1/16	(27.0)
5	5-5/8	(142.9)	6-7/32	(158.0)	1-3/16	(30.2)
6	6-3/4	(171.5)	7-7/32	(183.4)	1-1/4	(31.8)

12.1.1.4 A field-wiring compartment in which power-supply connections are to be made shall be located so that the connections may be readily inspected after the unit is installed as intended.

12.1.1.5 Wire connections in a flush-mounted unit may be accessible upon removal of a front panel from the base of the enclosure.

12.1.1.6 A field-wiring compartment intended for connection of a wiring system shall be attached to the unit so that it will be prevented from turning.

12.1.1.7 If a separate field-wiring compartment is not provided, space for field-wiring connections shall be located near the connecting means and shall permit routing of the wiring away from live parts and rough metal. See 12.1.1.4.

12.1.1.8 A field-wiring compartment shall be constructed so that wiring is protected from:

a) Sharp edges, including screw threads, burrs, fins, and the like that may abrade the insulation on conductors or otherwise damage the wiring;

b) Terminals; and

c) Other live parts.

12.1.1.9 To determine whether wiring is prevented from being forced against live parts or sharp edges, a trial installation is to be made using only ordinary care. The system used for the test is to be representative of the various constructions and installation methods that may be employed.

12.1.2 Wiring terminals and leads

12.1.2.1 A field-wiring terminal is considered to be a terminal to which power supply or other permanent connections will be made in the field when the unit is installed.

12.1.2.2 The field-wiring terminals or leads shall be acceptable for the connection of conductors having an ampacity acceptable for the rating of the unit.

12.1.2.3 A wiring terminal shall be provided with a soldering lug or pressure terminal connector securely fastened in place, for example, firmly bolted or held by a screw. A wire-binding screw may be employed at a wiring terminal intended for connection of a 10 AWG or smaller conductor if upturned lugs or the equivalent are provided to hold the wire in position.

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

12.1.2.5 A wire-binding screw at a field-wiring terminal shall not be smaller than No. 10.

Exception No. 1: A No. 8 screw may be used at a terminal intended only for the connection of a 14 AWG conductor.

Exception No. 2: A No. 6 screw may be used for the connection of a 16 AWG or 18 AWG control-circuit conductor.

12.1.2.6 A wire-binding screw shall thread into metal.

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

Exception: A plate not less than 0.030-in (0.76-mm) thick is acceptable if the tapped threads have adequate mechanical strength.

12.1.2.8 There shall be two or more full threads in the metal of a terminal plate. The metal may be extruded at the tapped hole to provide at least two full threads.

12.1.2.9 Upturned lugs, a cupped washer, or the equivalent shall be capable of retaining a conductor of the size specified in 12.1.2.2 under the head of the screw or washer.

12.1.2.10 The free length of a lead inside an outlet box or wiring compartment shall be 6 in (152 mm) or more if the lead is intended for field connection to an external circuit.

Exception: A lead may be less than 6-in long if it is evident that the use of a longer lead might result in a risk of fire or electric shock.

12.1.2.11 A lead in a wiring compartment intended for field connection shall be provided with strain relief complying with 43.3 so that stress on the lead will not be transmitted to terminals, splices, or interior wiring.

12.1.2.12 A terminal intended for connection of a grounded power-supply conductor shall be made of or plated with metal substantially white in color and shall be readily distinguishable from other terminals; or proper identification of that terminal shall be clearly identified in some other manner, such as on an attached wiring diagram.

12.1.2.13 The surface of a lead for the connection of a grounded power-supply conductor shall have a white or gray color and shall be readily distinguishable from other leads.

12.1.2.14 For a device having components intended to be mounted on a cover of an outlet box or similar enclosure, wiring terminals or other live parts and sharp-edged grounded or dead metal parts shall be located or protected so that they will not be forced against wiring in the box during installation or servicing.

12.1.2.15 With reference to the requirements in 12.1.2.14, back wiring terminals may be employed if they are recessed or are protected by close-fitting barriers of insulating material or the equivalent that will prevent contact with wiring installed in the box. Terminals that do not project into the box beyond the plane of the front edge of the box are acceptable.

12.1.2.16 With reference to 12.1.2.15, guards provided along the sides of terminals and extending not less than 1/4 in (6.4 mm) beyond the terminals before wiring, with a corresponding guard between double-pole switching mechanisms, are acceptable.

12.1.2.17 To determine whether a construction other than that described in 12.1.2.16 will prevent wiring in the box from being forced against live parts or sharp edges, a trial installation is to be made, using only ordinary care and employing Type NM cable or supply cord of the sizes having ampacities in accordance with the rating of the device. The wire is to extend 6 in (152 mm) inside the box from its point of entrance into the box.

12.2 Cord connection

12.2.1 General

12.2.1.1 Other than a flush-wall mounted unit or a unit for which specific installation instructions are required, a unit requiring provision for connection to a source of supply that will facilitate the interchange of equipment to maintain continuous service or otherwise meet special conditions of use may employ Type S, SE, SEOO, SO, ST, STO, SJ, SJE, SJEOO, SJO, SJT, SJTO, SP-3, or SPT-3 flexible cord with a grounding conductor.

12.2.1.2 The current and voltage ratings of a flexible supply cord and attachment plug for a unit shall not be less than the input rating of the unit. The loads drawn by a single or duplex receptacle shall be included in determining the input rating as described in 56.4.

12.2.1.3 The length of supply cord external to the unit shall not be more than 3 ft (914 mm) measured from the face of the attachment plug to the point of entry.

12.2.1.4 A power supply cord shall terminate in a grounding-type attachment plug.

12.2.1.5 The ampacity of the attachment plug shall not be less than 125% of the marked input rating of the unit.

12.2.1.6 A cord-connected unit shall not have more than one single or duplex enclosure-mounted grounding-type receptacle for general use and there shall be no provision for remotely wired line-voltage circuits.

12.2.2 Strain relief

12.2.2.1 Strain relief shall be provided to prevent stress on the supply cord or output cord from being transmitted to terminals, splices, or interior wiring. See 43.1.

12.2.2.2 A metal strain-relief clamp or band is acceptable without supplementary protection on a Type S, SE, SEOO, SO, ST, STO, SJ, SJE, SJEOO, SJT, or SJTO cord. A metal strain-relief clamp or band is acceptable on a Type SP-3 or SPT-3 cord only if adequate supplementary nonconductive mechanical protection is provided over the cord.

12.2.2.3 If a knot in a flexible cord serves as strain relief, the surfaces that the knot may touch shall be free from burrs, fins, sharp edges, and projections that can damage the cord.

12.2.2.4 Means shall be provided to prevent the flexible cord from being pushed into the unit enclosure through the cord-entry hole if such displacement might result in mechanical damage to the cord, expose the cord to a temperature higher than that for which it is acceptable, or reduce spacings, such as to a metal strain-relief clamp, below the minimum acceptable values.

12.3 Bushings

12.3.1 A bushing or the equivalent shall be provided at a point where a flexible cord passes through an opening in a wall, barrier, or enclosing case. The bushing shall be substantial, reliably secured in place, and shall have a smooth, rounded surface against which the cord may bear. If Type SP-3 or SPT-3 cord is employed, the wall or barrier is of metal, and the construction is such that the cord may be subjected to stress or motion, the bushing shall be an insulating bushing.

Exception: For a cord hole in wood, porcelain, phenolic composition, or other acceptable nonconductive material, a smooth, rounded surface is considered to be the equivalent of an insulating bushing.

12.3.2 Ceramic materials and some molded compositions are acceptable for insulating bushings.

12.3.3 Vulcanized fiber may be employed if the bushing is not less than 3/64-in (1.2-mm) thick, and if so formed and secured in place that it will not be affected adversely by conditions of ordinary moisture.

12.3.4 An insulating bushing molded integrally with the supply cord is acceptable on a Type SP-3 or heavier cord provided the built-up section is not less than 1/16-in (1.6-mm) thick where the cord passes through the enclosure.

12.3.5 An insulated metal grommet is acceptable as an insulating bushing if the insulating material is not less than 1/32-in (0.8-mm) thick and completely fills the space between the grommet and the metal in which it is mounted.

13 Low-Voltage DC Connections and Wiring

13.1 General

13.1.1 A unit shall have one of the following provisions for output connections:

a) A wiring compartment and terminals complying with the requirements in 13.1.2 – 13.1.5,

b) A receptacle or attachment plug complying with the requirements in 13.1.6 – 13.1.12,

c) Unenclosed individual leads complying with the requirements in 13.1.13 – 13.1.15.

13.1.2 An opening in a wiring compartment for output connections shall be an opening or knockout for a standard trade size conduit, or an opening of unspecified size provided with an acceptable insulating bushing.

13.1.3 Leads provided in the wiring compartment shall be provided with strain relief so that stress on the leads will not be transmitted to terminals, splices, or interior wiring.

13.1.4 Terminal assemblies provided for the connection of low-voltage external circuits shall comply with the requirements for line-voltage circuits.

13.1.5 A field-wiring terminal assembly provided as part of a transfer mechanism shall comply with the requirements in 12.1.2.1 – 12.1.2.10, and shall be of such size as to accommodate a load based on 1.25 times the output current rating of the unit. A lead provided for this purpose shall be capable of carrying the same current without exceeding its temperature rating.

13.1.6 A receptacle or attachment plug for output connection shall not accept a mating part having a standard configuration complying with the Standard for Attachment Plugs and Receptacles, UL 498.

13.1.7 An attachment plug shall be a locking type to reduce the likelihood of loosening under conditions of transit or shall be investigated for secureness.

13.1.8 An attachment plug or a receptacle other than as mentioned in 13.1.9 shall be secured to the enclosure or to another rigid part of the unit.

13.1.9 Both mating parts of a battery-type attachment plug or a receptacle provided for connection of wiring to a storage battery shall have recessed contacts. The receptacle shall be mounted to a rigid part of the unit unless it is intended to be rigidly attached to the recreational vehicle, in which case the attachment plug shall terminate in an output cord not longer than 3 ft (914 mm). The cord shall comply with the requirements for strain-relief specified in Section 43, Strain Relief Test.

13.1.10 An attachment-plug receptacle shall have recessed contacts.

13.1.11 If a matching attachment plug or receptacle is used on a unit, the unit shall be marked in accordance with 58.18.

13.1.12 Unless a receptacle and its attachment plug have been investigated for current interruption, the unit shall be marked in accordance with 58.19.

13.1.13 Unenclosed individual leads intended for connection external to the unit shall employ insulated copper conductors. A positive lead shall extend outside the unit not more than 18 in (457 mm). The insulation may be 0.030-in (0.76-mm) thick thermoplastic or the equivalent.

13.1.14 Unenclosed individual leads intended for connection external to the unit shall comply with the requirements in Section 43, Strain Relief Test.

13.1.15 The conductors of unenclosed individual leads for output connections shall be protected by overcurrent devices unless the ampacity of the conductors of such leads is not less than the output rating of the circuit. Ampacities are to be based on the values for low-voltage circuits.

13.1.16 Each secondary-output branch circuit shall be marked in accordance with 58.4 to indicate the corresponding branch-circuit protection provided for each secondary-output connection.

13.2 Cigarette lighter inputs

13.2.1 A unit intended to be connected to the cigarette lighter or power outlet of a vehicle, while delivering its normal output load, shall not exceed 12 A at the cigarette lighter outlet.

13.2.2 A unit provided with cigarette lighter connector with a flexible cord, the cord shall be type SP-2, SPE-2, SPT-2, SV, SVE, SVT, S, SE, SO, SP-3, SPT-3, ST, STO, SJ, SJE, SJO, SJT, or SJTO. The length of cord external to the unit and including the cigarette lighter connector shall not be less than 3 ft (0.9 m) as measured from the end of the cigarette lighter connector to the point of attachment or entry. Cord AWG size shall be in accordance with Table 13.1.

Exception No. 1: Output wiring for Class 2 or Low Voltage Limited Energy circuits may be parallel cord insulated with rubber, neoprene, or thermoplastic having a wall thickness of not less than 0.013 in (0.33 mm).

Exception No. 2: For units rated 10 A or less, an equivalent style appliance wiring material (AWM) may be employed.

Table 13.1
Cord sizes

Adapter input fuse rating A	Minimum cord conductor size AWG (mm^2)
10 and less	18[a] (0.82)
12	17 (1.04)
13	16 (1.31)
18	14 (2.08)
20	12 (3.31)

[a] Size not specified for conductors in Class 2 or Low Voltage Limited Energy Circuits.

14 Secondary Circuits

14.1 A metal enclosure of a unit shall not be used as a current-carrying part of an output circuit. Secondary circuits may be connected to the frame of a unit; however, the frame shall not be used to carry current during intended operation.

14.2 All secondary circuits other than as specified in 14.3 – 14.11, are to be investigated as primary circuits. In addition, all safety circuits shall be investigated using the requirements for primary circuits.

14.3 Except as noted in 29.1.13, printed-wiring assemblies and associated circuitry used in low-voltage, limited energy circuits need not be investigated. However, components such as wire connectors, bus bars, printed-wiring receptacles, connectors and the like, motors, printed wiring boards, and insulated wire used in such circuits shall be investigated.

14.4 A circuit supplied from a Class 2 transformer need not be investigated. However, printed-wiring boards and insulated wire used in such circuits shall be investigated with respect to the temperature and voltage, exposure to oil or grease, and other conditions of service to which the wiring and printed-wiring boards can be subjected.

14.5 Except as noted in 29.1.13 and 29.1.14, a circuit that does not extend out of the unit need not be investigated if the open-circuit potential or no-load output of the supply, when measured in accordance with 37.1 and 37.2, is:

a) Not more than 42.4 Vpeak ac or 60 Vdc; and

b) The energy available at 1 min of operation is limited to:

1) 8 A for 0-42.4 Vpeak ac or 0-30 Vdc; or

2) 150/Vmax A for 30-60 Vdc.

14.6 The power supply of a circuit as mentioned in 14.5 that is not limited to available energy in accordance with 14.5(b), but the circuit includes either one or more resistors, a fuse, a non-adjustable manual-reset circuit protective device, or a regulating network – see 14.9 – need not be investigated if the current is limited in accordance with 14.7, 14.8 or 14.9.

14.7 A fuse or non-adjustable manual reset circuit protective device provided in the secondary circuit that is used to limit the current in accordance with 14.6 shall be rated or set at not more than the values specified in Table 14.1.

Table 14.1
Rating for secondary fuse or circuit protector

Circuit voltage (V rms)	Maximum overcurrent protection (A)
20 or less	5
More than 20 but less than 60	100/V[a]
[a] V is the maximum output voltage, regardless of load, with the primary energized in accordance with 32.1.	

14.8 A fuse or circuit protective device may be connected in the primary of the transformer to limit the current in accordance with 14.6 provided that the protection is equivalent to that specified in 14.7 as determined by the Overcurrent Protection Calibration Test, Section 45.

14.9 One or more resistors or a regulating network used to limit the current in accordance with 14.6 shall be such that the current under any condition of loading including short circuit does not exceed 8 A measured at 1 min of operation.

14.10 If a regulating network is used to limit the voltage or current in accordance with 14.5 – 14.9, each component of the regulating network should be short circuited or open circuited separately to determine that the voltage or current does not exceed the maximum allowable values with the components faulted.

14.11 In a circuit of the type described in 14.6, the secondary winding of the transformer, one or more resistors, a fuse or a non-adjustable manual reset circuit-protective device, or a regulating network, and all wiring up to the point at which the current, voltage or both are limited shall be judged as primary circuits.

14A Batteries

14A.1 Lead acid batteries provided as part of the system shall comply with the Standard for Standby Batteries, UL 1989.

14A.2 Lithium based batteries that are provided as part of the system shall comply with the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications, UL 1973.

14A.3 If the battery is not provided as part of the system, the inverter/converter charging function shall be designed and evaluated such that is capable of safely charging a battery that complies with 14A.1 or 14A.2.

15 Live Parts

15.1 A current-carrying part shall be of silver, copper, a copper alloy, or other material acceptable for the application.

15.2 Plated iron or steel may be used for a current-carrying part if acceptable in accordance with 3.1, or in a secondary circuit rated 30 Vrms (42.4 Vpeak) or less; but unplated iron or steel is not acceptable. Stainless steel and other corrosion-resistant alloys may be used for current-carrying parts.

15.3 An uninsulated live part shall be secured to an insulating base or mounting surface so that it will be prevented from turning or shifting in position if such motion might result in a reduction of spacings below the minimum acceptable values.

15.4 Friction between surfaces is not acceptable as a means to prevent shifting or turning of a live part, but a lock washer properly applied is acceptable.

16 Internal Wiring

16.1 General

16.1.1 The internal wiring of a unit shall be of a type and size acceptable for the application as specified in this section. Other types of wiring may be acceptable based on temperature, voltage, and the need for mechanical protection.

16.1.2 The thickness of insulation on wiring shall not be less than 3/64 in (1.2 mm) for unbraided neoprene-insulated wire, 1/32 in (0.8 mm) for thermoplastic-insulated wire, and 1/32 in for rubber-insulated wire with an impregnated braid.

16.1.3 Unless a unit includes a resistor or other heat-producing component and wire is subjected to a temperature of more than 80°C (176°F), or other need is demonstrated, Type AF or CF wire shall not be employed.

16.1.4 The length of the power-supply cord inside a unit shall not be more than the need for the electrical connections.

16.1.5 The jacket of a flexible cord inside the enclosure shall not be stripped to expose the individual conductors unless:

a) The insulation on the individual conductors is equivalent to that required by 16.1.2;

b) The individual conductors are supported in a manner positively separating them from live parts and dead metal parts; or

c) Supplementary insulation equivalent to that required by 16.1.2 is reliably secured on each individual conductor.

16.2 Tubing

16.2.1 Insulation of internal wiring consisting of coated fabric, thermoplastic, or other types of tubing is to be considered with respect to electrical, mechanical, and flammability properties of the material.

16.2.2 If the use of a short length of insulated conductor, such as a short coil lead, is not practical, electrical insulating tubing may be used on each conductor. The tubing shall not be subjected to sharp bends, tension, compression, or repeated flexing, or to contact with sharp edges, projections, or corners.

Except as noted in 16.2.3, the wall thickness shall comply with the requirements for the tubing as a component.

16.2.3 Polyvinyl chloride tubing shall not be less than 0.017-in (0.43-mm) thick at any point. The thickness of insulating tubing of other types, shall provide mechanical strength, flame resistance, dielectric properties, and heat- and moisture-resistant characteristics, and the like that are at least equivalent to those of 0.017-in thick polyvinyl chloride tubing.

16.3 Protection of wiring

16.3.1 Internal wiring shall be protected if, when judged in accordance with 9.1.2, it is accessible.

Exception: Internal wiring need not be protected if it is located and secured within the enclosure so that it is not likely to be subjected to stress or mechanical damage.

16.3.2 Wires within an enclosure, compartment, raceway, or the like shall be located or protected to prevent contact with any sharp edge, burr, fin, moving part, or the like that can damage the conductor insulation.

16.3.3 A hole through which insulated wires pass in a sheet metal wall within the overall enclosure of a unit shall be provided with smooth, rounded surfaces upon which the wires may bear, to prevent abrasion of the insulation.

16.3.4 Internal wiring within an enclosure or compartment shall be located or protected from surfaces so that the temperature rating of the conductors will not be exceeded under normal operating conditions.

16.3.5 Mounting screws and nuts shall be designed or located so that sharp edges will not damage wiring. A screw shall have a flat or blunt end. The end of the screw shall not have burrs, fins, or sharp edges that might abrade wire insulation, and shall not project more than 3/16 in (4.8 mm) into a wireway.

16.4 Electrical connections

16.4.1 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for interconnection between current-carrying parts or in a component winding, shall be terminated at each end by a method suitable for the combination of metals involved at the points of connection.

16.4.2 With reference to 16.4.1, a wire-binding screw or a pressure wire connector used as a terminating device shall be suitable for use with aluminum under the conditions involved, for example, temperature, heat cycling, vibration, and the like.

16.4.3 All splices and connections shall be mechanically secure and shall make reliable electrical contact.

16.4.4 A soldered connection shall be mechanically secured before being soldered.

Exception: A wave- or lap-solder connection to a printed-circuit board where components are properly inserted or secured (as in a surface mounted component) is considered acceptable without any further mechanical security.

16.4.5 A splice shall be provided with insulation equivalent to that of the wires involved if permanent spacing may not be maintained between the splice and other metal parts.

16.4.6 When determining whether splice insulation consisting of coated-fabric, thermoplastic, or other tubing is acceptable, consideration is to be given to such factors as dielectric properties, heat-resistant and moisture-resistant characteristics, and the like. Thermoplastic tape wrapped over a sharp edge is not acceptable. An insulated splicing device is acceptable within the limits of voltage and temperature ratings of the device.

16.4.7 The means of connecting stranded internal wiring to a wire-binding screw shall prevent loose strands of wire from contacting other live parts not always of the same polarity as the wire, and from contacting dead metal parts. This may be accomplished by the use of a pressure terminal connector, a soldering lug, a crimped eyelet, soldering of all strands together, or other reliable means.

16.5 Separation of circuits

16.5.1 Unless provided with insulation acceptable for the highest of the circuit voltages, factory-installed insulated conductors of different circuits within a unit including wires in a terminal box or compartment, shall be separated by barriers or shall be segregated and shall be so separated or segregated from uninsulated live parts connected to different circuits.

16.5.2 Segregation of factory installed insulated conductors may be accomplished by clamping, routing, or an equivalent means that will maintain permanent separation from insulated and uninsulated live parts and from conductors of a different circuit.

16.5.3 Field-installed conductors of a circuit shall be segregated (see 16.5.4) or separated by barriers (see 16.6.1 – 16.6.4) from:

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

b) An insulated live part of another circuit.

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

16.5.4 Segregation of a field-installed conductor from another field-installed or factory-installed conductor or from an uninsulated live part connected to another circuit can be accomplished by locating an opening in the enclosure for the conductor opposite to the conductor terminal so that, when the installation is complete, the conductors and parts of different circuits will be separated by a minimum of 1/4 in (6.4 mm). In determining if a device with such openings complies with this requirement, it is to be wired as in service including 6 in (152 mm) of slack in each conductor within the enclosure. No more than average care is to be exercised in routing the wiring and stowing the conductor slack into the wiring compartment.

16.6 Barriers

16.6.1 A barrier used to separate or segregate internal wiring shall have adequate mechanical strength, and shall be reliably held in place.

16.6.2 A barrier of metal shall be at least as thick as specified in 7.3. A barrier of insulating material shall not be less than 0.028-in (0.71-mm) thick and shall be supported so that it cannot be readily deformed to defeat its purpose.

16.6.3 A barrier used to provide separation between field wiring of one circuit and wiring or uninsulated live parts of another circuit shall be spaced not more than 1/16 in (1.6 mm) from the enclosure walls and interior mechanisms, component-mounting panels, and other parts that serve to provide segregated compartments.

16.6.4 With reference to 16.6.3, a hole provided for routing leads from a component compartment into a field-wiring compartment shall have smooth rounded edges or be provided with an insulating bushing. The size of the hole shall not be greater than necessary for passage of the conductors.

17 Insulating Materials

17.1 An insulating washer, a bushing, or the like, and a base or a support for mounting a live part, shall be moisture-resistant material that will not be adversely affected by the temperatures and stresses to which it will be subjected under conditions of use.

17.2 Insulating material is to be judged with respect to its acceptability for the particular application. Materials such as mica, ceramic, and some molded compounds are usually acceptable for the sole support of live parts. If an investigation is necessary to determine whether a material is acceptable, consideration is to be given to:

a) Its mechanical strength, resistance to ignition, dielectric strength, insulation resistance, and heat-resistance qualities in both the aged and unaged conditions;

b) The degree to which it is enclosed; and

c) Any other feature affecting the risk of fire, electric shock, or injury to persons.

All factors are to be considered with respect to conditions of service.

18 Transformers

18.1 General

18.1.1 A transformer used to supply a Class 2 circuit, that extends from the unit to a remote panel, status panel or the like shall have its primary windings electrically isolated from all other windings and shall be constructed as specified in 18.1.2 – 18.2.3 so that there is no electrical connection – under normal and overload conditions – between the primary and secondary windings, between the primary winding and the core, or between separate adjacent secondary windings, if such connection may result in a risk of fire or electric shock.

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

18.1.3 A thermal cutoff or other device employed to reduce the risk of fire or electric shock due to overheating of a transformer during abnormal operation shall comply with the requirements applicable to such a device in addition to the applicable requirements in this standard. For example, a thermal cutoff shall comply with the applicable requirements in this standard and those in the Standard for Thermal-Links – Requirements and Application Guide, UL 60691.

18.2 Coil insulation

18.2.1 A transformer winding, including the start, all taps, finish, and crossover leads up to the point where insulated leads, if used, are provided, shall be constructed as specified in Table 18.1.

Table 18.1
Transformer insulation

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

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

[b] A thermoplastic or thermostat coil form not less than 0.028-in (0.71-mm) thick.

[c] A material having a thickness less than 0.028 (0.71 mm) in may be used provided that it is equivalent to Note (a) or (b) and the material has a minimum dielectric breakdown strength of 5000 V for the thickness used when tested as specified in Testing on Transformer Insulating Materials, Section 42.

[d] Spacings specified in Table 18.2 may be used in place of the specified insulation. Spacings in Table 29.2, if applicable, may be used.

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

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

[g] A material having a thickness less than that specified in Notes (e) and (f) may be used, provided that it is equivalent to Notes (e) and (f) and the material has a minimum dielectric breakdown strength of 2500 V for the thickness used for Note (e) and 5000 V for the thickness used for Note (f) when tested as specified in Testing on Transformer Insulating Materials, Section 42.

[h] Any type and thickness of insulation in addition to the magnet wire coating, or a through air spacing less than that specified in Table 18.2 may be used between a crossover lead and the winding to which it is connected if the construction complies with either of the following:

1. The coil withstands the appropriate dielectric voltage withstand potential described in 40.1 and 40.2. The potential is to be applied between the coil leads with the crossover lead cut at the point where it enters the inner layer.

2. The coil withstands the induced potential described in 41.1 – 41.4.

Table 18.2
Spacings within a transformer

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

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

18.2.2 Insulating material, such as outer-wrap and crossover-lead insulation, employed to reduce the risk of live parts from becoming accessible through openings in the outer enclosure in accordance with Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 9, shall comply with Note (a) or (c) of Table 18.1.

18.2.3 A flanged bobbin-wound transformer shall be constructed so as to maintain physical separation between the primary and secondary windings. Physical separation may be accomplished by employing a 3-flange bobbin for winding the primary and secondary windings adjacent to each other. As an alternative,

a telescoping bobbin construction, with each section containing an individual winding may be used where the primary winding is wound over the secondary winding, or the secondary winding is wound over the primary winding. The bobbin insulation shall comply with Notes (a), (b), (c) or (d) of Table 18.1.

Exception: A 2-flange bobbin having the primary winding wound over the secondary winding, or the secondary winding wound over the primary winding with the primary winding insulated from the secondary winding by means of tape insulation is acceptable if:

a) The tape insulation complies with Note (a) or (c) of Table 18.1,

b) The tape insulation provides a continuous overlap on the bobbin flanges,

c) The transformer complies with the tests described in the flanged bobbin transformer abnormal operation test as specified in 48.10.1 – 48.10.13.

d) The transformer complies with the induced potential tests specified in 41.1 – 41.4.

18.2.4 With reference to (c) of the Exception to 18.2.3, the flanged bobbin transformer abnormal operation test is not required if the transformer is supplied from a low-voltage, limited energy circuit in accordance with 2.15 or a limited energy circuit in accordance with 2.13.

19 Resistors

19.1 A resistor shall be reliably supported and the assembly shall be prevented from loosening or rotating by a means other than friction between surfaces.

19.2 The use of a lock washer is considered to comply with the requirement in 18.1.

20 Switches and Controllers

20.1 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 as intended.

20.2 A primary-circuit switch that controls an inductive load having a power factor less than 75%, such as a transformer or some ballasts, and does not have an acceptable inductive rating, shall be rated not less than twice the full-load current rating of the load, or the switch shall be investigated for the particular application.

20.3 A switch that controls a tungsten-filament lamp shall have a tungsten-filament-lamp current rating not less than the maximum current it will control.

Exception: A switch not having an acceptable tungsten-filament-lamp current rating and rated 3 A or more may be used to control a 15 W or smaller lamp.

20.4 Solid state switches shall comply with the requirements in this standard, others are per the applicable Standard, the most commonly used are referenced in Appendix A.

20.5 A means used to transfer the load directly from one source to an alternate source operating at voltages greater than 42.4 Vpeak ac or 60 V dc, shall comply with requirements in the Standard for Transfer Switch Equipment, UL 1008.

21 Overload-Protective Devices

21.1 General

21.1.1 A protective device, such as a fuse or manually operable protector, the normal functioning of which requires renewal, resetting, or replacement, shall be in a readily accessible location when the unit is installed in accordance with manufacturer's installation instructions.

21.1.2 If more than two circuit breakers are employed, a means shall be provided for disconnecting all conductors in a recreational vehicle from the power-supply assembly.

21.1.3 When circuit analysis or test results indicate that single component failure affects the ability of an electronic or solid-state circuit to perform its back-up, limiting, or other function intended to reduce the risk of fire, electric shock, or injury to persons, the circuit shall comply with the requirements in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, including environmental and stress tests applicable to the intended usage of the end-product. When such circuits employ a microprocessor executing software to perform the safety-related function, the software shall comply with the Standard for Software in Programmable Components, UL 1998.

21.1.4 With reference to 21.1.3, the components are to be subjected to the following test in accordance with the methods described in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991:

a) Transient Overvoltage Test;

b) Ramp Voltage Test;

c) Electromagnetic Susceptibility Tests;

d) Electrostatic Discharge Test;

e) Thermally Cycling Tests;

f) Humidity Test; and

g) Effects of Shipping and Storage Test.

21.2 Overcurrent-overtemperature protection

21.2.1 Integral overtemperature or overcurrent protection for all secondary circuits shall be provided. See 7.6 – 7.7.

21.2.2 An automatically reset protective device installed in a secondary circuit shall comply with the requirements for such devices and shall have a current and voltage rating acceptable for its intended use. The voltage rating shall be direct-current rating.

21.2.3 If secondary output overcurrent protection is provided, the overcurrent-protective devices shall be fuses or manually reset circuit breakers. The protective devices for alternating current output circuits of recreational vehicle inverters shall be suitable for branch circuit protection. See 7.8 – 7.9.

Exception No. 1: An appliance protector complying with the requirements in the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077, may be used in the output circuit of a unit supplied by a transformer in lieu of a branch circuit protection fuse or circuit breaker when all of the following are met:

a) The protector is an overcurrent type or a shunt trip overcurrent type;

b) The protector tripping current rating is not greater than 135% of the protector amp rating;

c) The protector complies with the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077 short-circuit test conducted without series overcurrent protection;

d) The protector complies with the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077 recalibration test following short-circuit testing;

e) The protector short circuit current rating is not less than the maximum fault current available; and

f) The instruction manual per 59.4, shall include an instruction indicating that branch rated overcurrent protection is to be provided by others to comply with the National Electrical Code, NFPA 70.

Exception No. 2: A fuse having a short-circuit interrupting rating not less than the maximum fault current available from the unit and complying with the requirements in the Standard for Low-Voltage Fuses – Part 14: Supplemental Fuses, UL 248-14, may be used in the output circuit of a unit supplied by a transformer in lieu of a branch circuit protection fuse or circuit breaker.

Exception No. 3: Overcurrent protection is not required to be provided with a unit having provision for permanent wiring connection of the output circuit and provided with an instruction manual per 59.4, indicating that the overcurrent protection is to be provided by others.

21.2.4 If a circuit breaker is provided, it shall be connected to open all ungrounded conductors of the circuit. A multiple-pole circuit breaker shall be of the common-trip type.

Exception: A combination of single-pole circuit breakers and handle ties that complies with the applicable requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489, may be used as the protection for each ungrounded conductor supplying line-to-line connected loads of a unit rated for connection to one of the following circuits of a grounded system:

a) Single-phase circuit,

b) 3-wire direct-current circuit, or

c) Circuit that is connected to a 4-wire 3-phase, or 5-wire 2-phase system with a grounded neutral.

22 Fuses and Fuseholders

22.1 A fuse and fuseholder shall have voltage and current ratings acceptable for the circuit in which they are connected.

22.2 A fuse and fuseholder connected in a primary circuit of a power unit shall comply with the requirements for line-voltage fuses and fuseholders.

22.3 A fuse and fuseholder connected in the input circuit of a power unit shall comply with the requirements for automotive type or line-voltage fuses and fuseholders.

22.4 A fuse connected in a secondary circuit of a power unit shall comply with the requirements for automotive or line-voltage fuses and fuseholders.

22.5 A fuse connected in an output circuit of a power unit shall comply with the requirements for line-voltage fuses and fuseholders.

22.6 An uninsulated live part of a fuseholder that can result in a risk of electric shock, other than the screw shell or clips, shall not be exposed to contact by a person removing or replacing the fuse.

22.7 The screw shell of a plug-type fuseholder and the upper terminal of an extractor-type fuseholder shall be connected toward the load.

23 Receptacles

23.1 A 15- or 20-A attachment plug receptacle shall be of the grounding type. The grounding contact of the receptacle shall be reliably electrically connected to the grounding means of the unit.

24 Inverter Output Circuits

24.1 A unit having output circuits for supplying 120 V, 60 Hz, 2-wire with ground or 120/240 V, 60 Hz, 3-wire with ground to vehicles and recreational vehicle wiring systems shall have the output circuits protected by integral ground-fault circuit-interrupters intended for the current involved.

Exception No. 1: A unit that does not have an integral output receptacle, and that has a wiring compartment with pigtail leads, wiring terminals, or other equivalent means for output field-wiring connections need not be provided with integral output circuit ground-fault circuit-interrupter protection if:

a) The unit is marked in accordance with 58.21, and

b) The installation and operating instructions manual for the unit comply with 59.1.

Exception No. 2: A portable unit need not be provided with integral ground-fault circuit-interrupter protection if the unit:

a) Is intended to be connected to the cigarette lighter outlet of a vehicle, and

b) Has no direct electrical connection between the input and output circuits.

25 Lampholders

25.1 The screw shell of an Edison-base lampholder in a unit shall be connected to a conductor that is intended to be connected to the grounded conductor of the power-supply circuit.

25.2 A lampholder shall be designed or installed so that uninsulated live parts, other than a screw shell, will not be exposed to contact by persons removing or replacing the lamp in normal service.

26 Capacitors

26.1 A capacitor connected across the line, such as a capacitor for radio-interference elimination or power-factor correction, shall be housed within an enclosure or container that will protect the plates against mechanical damage and will prevent the emission of flame or molten material resulting from breakdown of the capacitor.

26.2 The container of a capacitor shall be of metal providing strength and protection not less than that of uncoated steel having a minimum thickness of 0.020 in (0.51 mm).

Exception: The container may be of thinner sheet metal or may be of material other than metal, if the capacitor is mounted inside a unit having an enclosure that complies with the requirements in 7.1 – 7.4.

27 Transient Voltage Surge Suppressors

27.1 Transient voltage surge suppressors connected across a primary supply circuit or between primary circuits and ground shall comply with the applicable requirements in the Standard for Surge Protective Devices, UL 1449.

28 Printed Wiring

28.1 A printed circuit board shall comply with the Standard for Printed Wiring Boards, UL 796.

28.2 A resistor, capacitor, inductor, or other part that is mounted on a printed-circuit board to form a printed-circuit assembly shall be secured so that it cannot be displaced to result in a risk of electric shock or fire by a force likely to be exerted on it during assembly, normal operation, or servicing of the unit.

28.3 Consideration is to be given to a barrier or partition that is part of the unit assembly and that provides mechanical protection and electrical insulation for a component connected to a printed-circuit board.

29 Spacings

29.1 General

29.1.1 General environment spacings shall be as specified in Table 29.1. Protected environment spacings – see 8.1 – 8.5 – shall be as specified in Table 29.2. For the purpose of this requirement, a general environment is considered to be an environment other than a protected environment.

Exception No. 1: A unit complying with the requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, may have spacings less than that specified in Table 29.1 and Table 29.2. See 29.1.2 and 29.1.3.

Exception No. 2: Spacings may be as provided in 29.2.1 if liners and barriers are used.

Exception No. 3: Spacings may be as provided in 29.1.2, between adjacent foils on printed wiring boards provided with a conformal coating complying with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. See 29.1.2.

Exception No. 4: On printed wiring boards having a flammability classification of V-0 and constructed from a base material having a minimum Comparative Tracking Index (CTI) rating of 100 and 175 V for protected and general environments respectively, spacings (other than to ground, between primary and secondary circuits, and at field wiring terminals) are not specified between traces of different potential connected in the same circuit if the spacings comply with the requirements in Section 49, or an analysis of the circuit indicates that no more than 12.5 mA of current will flow between short-circuited traces having reduced spacings.

Exception No. 5: For multilayer printed wiring boards, the minimum spacing between adjacent internal foils of opposite polarity and between an internal foil and a plated-through hole is 1/32 in (0.8 mm). If these foils are in circuit described in 14.3 – 14.9, no spacing is specified.

Exception No. 6: The spacing requirements in Table 29.1 and Table 29.2 may not apply to inherent spacings of a component such as a switch, lampholder, or a motor. Such spacings are to comply with the

requirements for the component in question if the spacings are less than the values specified in Table 29.1 and Table 29.2. Spacings from such components to another component and to the enclosure shall comply with the appropriate spacings specified in this Standard.

Exception No. 7: Spacings between adjacent terminals of a power switching semiconductor device including the connection points of the terminals of the device are not specified.

Table 29.1
Spacings for a unit intended for use in a general environment

Involved in V RMS (peak)	Minimum spacings, in (mm)		
	Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[a]		Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[b], shortest distance
	Through air	Over surface	
0 – 50 (0 – 70.7)	1/16 (1.6)[c]	1/16 (1.6)[c]	1/16 (1.6)[c]
51 – 150 (70.7 – 212.1)	1/8 (3.2)[c]	1/4 (6.4)	1/4 (6.4)
151 – 300 (212.1 – 424.3)	1/4 (6.4)	3/8 (9.5)	1/2 (12.7)
301 – 600 (424.3 – 848.5)	3/8 (9.5)	1/2 (12.7)	1/2 (12.7)

[a] For printed wiring boards, see Exception Nos. 2 – 4 to 29.1.1.

[b] For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce spacings between the adjacent 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 1/4 in (6.4 mm).

Table 29.2
Spacings for a unit intended for use within a protected environment

Involved in V RMS (Peak)	Minimum spacings, in (mm)					
	Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[a, d]				Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[b], shortest distance	
	Through air		Over surface			
0 – 50 (0 – 70.7)	3/64	(1.2)[c]	3/64	(1.2)[c]	1/16	(1.6)[c]
51 –125 (70.8 – 176.8)	1/16	(1.6)[c, e]	1/16	(1.6)[c, e]	1/4	(6.4)
126 – 250 (176.9 – 353.5)	3/32	(2.4)[c, e]	3/32	(2.4)[c, e]	1/2	(12.7)
251 – 600 (353.6 – 848.5)	3/8	(9.5)	1/2	(12.7)	1/2	(12.7)

[a] For printed wiring boards, see Exception Nos. 2 – 4 of 29.1.1.

[b] For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce spacings between the adjacent metal piece and uninsulated live parts.

Table 29.2 Continued on Next Page

Table 29.2 Continued

Involved in V RMS (Peak)	Minimum spacings, in (mm)		
	Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[a, d]		Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[b], shortest distance
	Through air	Over surface	

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

[d] On printed wiring boards, their connectors and board-mounted components, wired on the load side of line filters or other similar-voltage-peak-reduction networks or components, or both, a minimum spacing of 0.023 in (0.58 mm) plus 0.0002 in (0.005 mm) per volt peak shall be maintained over surface and through air between uninsulated live parts and any other uninsulated conductive part (live or dead) not of the same polarity.

[e] At closed-in points only, such as a screw and washer construction of an insulated stud mounted in metal, a spacing of 3/64 in (1.2 mm) is acceptable.

29.1.2 With reference to Exception No. 1 to 29.1.1 and with reference to the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, reduced through-air spacings are based on the use of insulating materials that resist arc tracking and the degree of conductive pollution present in the environment of use. They are applicable to a unit in which the transient voltages are known and are controlled by a transient suppressive device and to a unit that withstands an impulse withstand voltage test. The spacing requirements of UL 840 shall not be used for field-wiring terminals and spacings to a dead metal enclosure.

29.1.3 A unit shall be considered overvoltage category II and/or overvoltage category I as defined in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

29.1.4 In order to apply Clearance B (controlled overvoltage) clearances as defined in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, controlled overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product.

29.1.5 All printed-wiring boards are considered to have a minimum comparative tracking index of 100 without further investigation.

29.1.6 With reference to Exception No. 1 to 29.1.1 and the pollution degree levels described in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, pollution degree 2 is considered applicable to a unit employing protected environment enclosure as described in Section 8, Enclosures Used for Protected Environments. Pollution degree 3 is considered applicable to a unit intended for use in a general environment.

29.1.7 With reference to Exception No. 2 to 29.1.1 concerning conformal coatings, minimum spacings of 1/32 in (0.8 mm) between adjacent foils shall be maintained. A conformal coating on printed wiring boards is not considered as insulation in lieu of spacings between a foil on a printed wiring board and uninsulated live-metal parts of opposite polarity or to uninsulated dead-metal parts.

29.1.8 If an uninsulated live part is not rigidly secured in position by means other than friction between surfaces, or if 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 acceptable spacings will be maintained.

Exception No. 1: The spacing requirements in Table 29.2 and Table 29.3 do not necessarily apply to the inherent spacings of a component of a unit, such as a switch, fuse, or attachment plug. Such spacings are

to comply with the requirements for the component in question if they are less than the values specified in Table 29.2 and Table 29.3.

Exception No. 2: As provided in 29.2.1.

Table 29.3
Minimum acceptable spacings between an uninsulated live part and a metal enclosure or other accessible dead metal part, including a fitting for conduit or armored cable

Potential involved, V	Minimum spacing through air and over surface	
	in	(mm)
50 or less	1/16	(1.6)
51 – 150	1/4	(6.4)
151 – 230	1/2	(12.7)

29.1.9 With reference to 29.1.8, a properly applied lock washer is considered an acceptable method of rigidly securing a part.

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

29.1.11 Film-coated wire is considered to be an uninsulated live part when determining spacings.

29.1.12 Spacings at field wiring terminals are to be measured with conductors installed in the terminals. The gauge of the conductors is to be based on the rating of the circuit containing the terminals.

29.1.13 Spacings between uninsulated live parts of different potential and between such parts and dead metal that may be grounded in service are not specified for parts of low-voltage limited energy circuits in accordance with 2.15. Spacings are determined by the applicable dielectric voltage withstand test specified in Section 40, Dielectric Voltage-Withstand Test.

29.1.14 Spacings between uninsulated live parts of different potential and between such parts and dead metal that are grounded in service are not specified for parts of isolated limited-energy circuits in accordance with 2.13. Spacings in circuits that exceed 30 V (42.4 peak) are to be investigated by the applicable dielectric voltage-withstand test specified in Section 40, Dielectric Voltage-Withstand Test.

Exception: A meter complying with the requirements in the Standard for Electrical Analog Instruments – Panelboard Type, UL 1437, need not be subjected to a dielectric voltage-withstand test.

29.1.15 All uninsulated live parts connected to different circuits shall be spaced from one another as if they were parts of opposite polarity and shall be judged on the basis of the highest voltage involved.

29.1.16 The acceptability of spacings between live and dead metal parts connected to the enclosure within an electrical instrument shall be determined by a dielectric voltage-withstand test in accordance with 40.1.

29.2 Insulation barriers

29.2.1 An insulating liner or barrier of material such as vulcanized fiber or thermoplastic employed in lieu of required spacings mentioned in Exception No. 1 to 29.1.1 shall not be less than 0.028-in (0.71-mm) thick and shall be so located or of such material that it will not be adversely affected by arcing.

Exception No. 1: Vulcanized fiber not less than 0.013-in (0.33-mm) thick may be used in conjunction with an air spacing of not less than 50% of the minimum acceptable through-air spacing and between a heat sink and a metal mounting surface, including the enclosure, of battery-charging circuits rated 50 Vrms or less.

Exception No. 2: Mica not less than 0.006-in (0.152-mm) thick may be used as insulation between a heat sink and a live case of a semiconductor device.

Exception No. 3: An insulating material having a thickness less than that specified in 29.2.1 may be used if, upon investigation, it is found to be acceptable for the particular application.

29.2.2 A wrap of thermoplastic tape, complying with the requirements in the Standard for Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape, UL 510, may be used in lieu of required spacings if all the following conditions are met:

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

b) The wrap is no less than 0.028-in (0.71-mm) thick when used with less than half the required through-air spacing.

c) Its temperature rating is no less than the maximum temperature observed during the Temperature Test, Section 38.

d) The tape is not subject to compression.

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

30 Grounding

30.1 A unit having a metal enclosure shall have a terminal or lead for connecting the metal enclosure and enclosure parts to ground.

Exception: This requirement does not apply to a portable unit:

a) Intended to be connected to the cigarette lighter outlet of a vehicle, and

b) Having no direct electrical connection between the input and output circuits.

30.2 With reference to 30.1, in a unit intended to be connected to the power supply by a metal-enclosed wiring system such as rigid metal conduit or armored cable, or intended to be connected indoors, by means other than a metal-enclosed wiring system such as nonmetallic-sheathed cable, all exposed dead metal parts and all dead metal parts inside the enclosure that are exposed to contact during normal operation or adjustment of the unit, or during any servicing operation, including maintenance and repair, and that are likely to become energized, shall be conductively connected to the grounding terminal or lead.

30.3 The surface of the insulation on a lead intended for the connection of a grounding conductor shall be green with or without one or more yellow stripes, and no other lead shall be so identified.

30.4 A wire-binding screw for the connection of a field-installed equipment grounding conductor shall have a green colored head. A pressure wire connector for connection of such conductor shall be plainly identified such as by being marked "G," "GR," "GND," "Ground," "Grounding," or the like; or by an acceptable marking on a wiring diagram attached to the unit.

30.5 The grounding connection shall be located so that it is unlikely to be removed during normal servicing of the unit.

30.6 A terminal solely for connection of an equipment grounding conductor shall secure a conductor of the size acceptable for the particular application.

30.7 A wiring terminal for connection of an equipment-grounding conductor shall comply with the requirements in 12.1.2.3 – 12.1.2.9.

30.8 The grounding conductor of a power-supply cord shall be connected to the grounding blade of a grounding attachment plug and shall be connected to dead metal parts within the frame or enclosure by means of a screw or by equivalent means that is not likely to be removed during any servicing operation not involving the power-supply cord. Solder alone shall not be used for securing the grounding conductor.

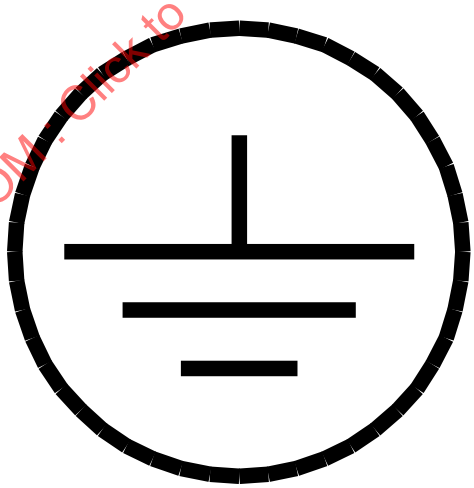
30.9 The surface of any insulation on the grounding conductor of a flexible cord shall be green with or without one or more yellow stripes and no other conductor shall be so identified.

30.10 A terminal shall be provided on the outside of a unit solely for connection of the enclosure to the chassis of a land vehicle. The terminal shall be of a size that will secure an 8 AWG copper bonding conductor, and shall be marked in accordance with Section 57, Details (plainly identified by being marked "Chassis Bonding Lug," or with the IEC Publication 417, Symbol 5019.) See Figure 30.1.

Exception: This requirement does not apply to marine crafts.

Figure 30.1

IEC Publication 417, Symbol 5019



30.11 The terminal mentioned in 30.10 shall not be secured to a part of the enclosure that is readily movable, such as a cover, hood, and the like.

31 Bonding of Internal Parts

31.1 General

31.1.1 An exposed dead metal part that is likely to become energized by an electrical fault shall be reliably bonded to the point of connection of the field-equipment-grounding means.

Exception: A dead metal part of a low-voltage component need not be bonded if it is:

a) Positively separated from line-voltage parts and wiring; or

b) Separated from live parts and wiring by an interposing barrier or part in such a manner that the interposed barrier or part will be the first to be subjected to an electrical fault. A metal barrier or part shall be grounded or bonded to the point of connection of the field equipment-grounding means.

31.1.2 An uninsulated metal part, such as a baffle, a barrier, a cover, an enclosure guard, a transformer core, or the like, shall be electrically bonded together if they might be contacted by the user or serviceman.

31.1.3 With reference to 31.1.2, internal parts that are painted or otherwise coated prior to assembly shall be secured in position by a fastening means that will reliably penetrate the surface coating.

31.1.3.1 The grounding connection and the output neutral of a unit that is intended to be connected to the cigarette lighter outlet of a vehicle shall be bonded to the inverter frame or enclosure. See 13.2.1.

31.1.4 Uninsulated live parts and wiring shall be separated from a moving or movable part, such as a relay or contactor magnet and armature, by clamping, positioning, or an equivalent means that will maintain permanent separation.

31.1.5 A metal part, such as an adhesive-attached metal marking plate, a screw, a handle, or the like, that is located on the outside of an enclosure or cabinet, need not be bonded if it is isolated from electrical components and wiring by a grounded metal part so that it is not likely to become energized, or separated from wiring and spaced from uninsulated live parts as if it were a grounded part. Other parts not required to be bonded are:

a) Small internal assembly screws, rivets, or other small fasteners;

b) A handle for a disconnect switch; and

c) A relay or contactor magnet and armature.

31.2 Bonding conductor

31.2.1 Bonding shall be accomplished by metal-to-metal contact between parts or by a separate bonding conductor as specified in 31.2.2 – 31.2.4.

31.2.2 A bonding conductor shall be copper, a copper alloy, or other acceptable material.

31.2.3 A splice shall not be employed in a bonding conductor.

31.2.4 A separate bonding conductor shall not be smaller than the conductors supplying a unit.

31.2.5 A separate bonding conductor for a unit shall have an ampacity rating equal to the total unit output.

PERFORMANCE

32 General

32.1 A representative sample of a unit shall be subjected to the tests described in Sections 33 – 53. Unless otherwise specified, all tests are to be conducted at not less than the rated voltage of the unit or the

highest of a rated voltage range, and an ambient temperature of 25°C (77°F) at rated frequency. See Table 32.1.

Table 32.1
Values of test voltages

Rated voltage	Test voltage
10.5 – 15.5	12.6
15.6 – 20.9	Rated voltage
21.0 – 31.0	25.2
31.1 – 41.9	37.8
42.0 – 60.0	50.4
110 – 115	120
Between 116 – 219	Rated voltage
220 – 230	240

32.2 The secondary current and voltage are to be measured by using an average-indicating meter.

32.3 Output-current measurements of either half-wave or full-wave rectifier circuits are to be based on the average current reading.

33 Leakage Current Test

33.1 The leakage current of a cord-connected unit rated for a nominal 120-V supply, when tested in accordance with 33.2 – 33.6 shall not be more than 0.75 mA.

33.2 All exposed conductive surfaces are to be tested for leakage currents. The leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one surface to another if simultaneously accessible. Parts are considered to be exposed surfaces unless protected against electric shock as defined in 9.1.2. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to output terminals operating at voltages less than 30 Vrms (42.4 Vpeak). If all accessible surfaces are bonded together and connected to the grounding conductor of the power-supply cord, the leakage current may be measured between the grounding conductor and the grounded supply conductor.

33.3 If a conductive surface other than metal is used for the enclosure or a part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 by 20 cm in contact with the surface. If the surface is less than 10 by 20 cm, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the unit.

33.4 The circuit for the leakage current measurement is to be as illustrated in Figure 32.1. The measurement instrument is defined in (a) – (d). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument. The meter used need not have all the attributes of the defined instrument.

a) The meter is to have an input impedance of 1500 Ω resistive shunted by a capacitance of 0.15 µF.

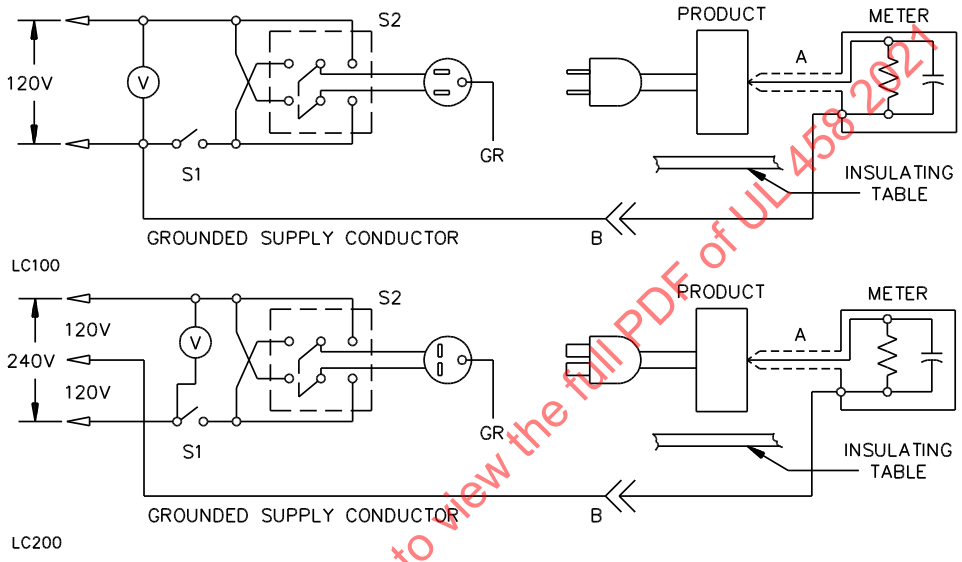
b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

c) Over a frequency range of 0 – 100 kHz, the measurement circuit is to have a frequency response – ratio of indicated to actual value of current – that is equal to the ratio of the impedance of a 1500-Ω resistor shunted by a 0.15-µF capacitor to 1500 Ω. At an indication of 0.75 mA, the measurement is to have an error of not more than 5% at 60 Hz.

d) Unless the meter is being used to measure leakage from one part of a unit to another, the meter is to be connected between an accessible part and the grounded supply conductor.

Figure 32.1

Leakage-current measurement circuit



33.5 A sample of the unit is to be tested for leakage current starting with the as-received condition – the as-received condition is to be without prior energization except as may occur as part of the production-line testing – but with the grounding conductor, if any, open at the attachment plug. The supply voltage is to be adjusted to 120 V. The test sequence, with reference to the measuring circuit, Figure 32.1, is as follows:

a) With switch S1 open, the unit is to be without load and connected to the measuring circuit. The leakage current is to be measured using both positions of switch S2 and with the unit switching devices in all their normal operating positions.

b) Switch S1 is then to be closed energizing the unit, and within a period of 5 s the leakage current is to be measured using both positions of switch S2 and with the unit switching devices in all their normal operating positions.

c) The leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in making this measurement. Thermal stabilization is considered to be obtained by operation of the unit as in the normal temperature test.

33.6 Normally, the complete leakage current test program as described in 33.5 is to be conducted without interruption for other tests. With the concurrence of those concerned, the leakage current tests may be interrupted to conduct other nondestructive tests.

34 Power Input Test

34.1 The input current to a unit shall be measured with the unit operating while connected to the maximum normal load, see 34.2 – 34.4. The current input shall not be more than 110% of the rated value.

34.2 Maximum normal load for a unit that does not incorporate an integral battery charger circuit is to be a resistive load adjusted to obtain rated output.

34.3 For a unit incorporating an integral battery-charger circuit, maximum normal load is to be obtained by:

a) Loading the charging circuit to its rated output current by means of an adjustable load consisting of a 100,000 µF capacitor in parallel with a resistor; and

b) Equally dividing – see 38.1.3 – among the secondary output-branch circuits a resistive load equal to the difference between the total secondary-output-current rating of the unit, and the output-current rating of the battery-charging circuit.

34.4 The maximum normal load for a unit designed for use with a floating battery – a battery that is connected to an electrical system including a charger and a load – is to be a 100,000 µF capacitor in parallel with a resistor adjusted to draw rated output current.

35 Output Voltage Measurement Test

35.1 The output voltage of a secondary circuit connected to a resistive load shall be within the value specified in Table 35.1.

Table 35.1
Output voltage of secondary circuits

Unit output rating, V	Minimum voltage at full rated output load, V	Maximum voltage at 5% of rated output load, V
12	10.5	15.5
24	21.0	31.0
36	31.5	46.5
48 – 60	42.0	60.0

36 Capacitor Voltage Measurement Test

36.1 The voltage applied to the terminals of a capacitor such as for filtering or in a resonating winding, shall not exceed the manufacturer's rating of the capacitor.

37 Output Voltage and Current Test

37.1 With respect to 14.5, the measurement is to be made with all loading circuits disconnected from the transformer or power supply being tested. Measurements may be made at the output terminals of the transformer or power supply.

37.2 The maximum current is to be measured under any condition of loading, including short circuit, using a resistor that is continuously re-adjusted during the 1-min period to maintain maximum load current.

38 Temperature Test

38.1 Normal

38.1.1 When tested on an open bench as described in 38.1.2 – 38.1.11, with the output load adjusted to deliver the maximum normal-load current, see 34.2 – 34.4, a unit shall not attain a temperature at any point high enough to constitute a risk of fire, adversely affect any material employed in the unit, or exceed the temperature limits specified in Table 38.1. See also 38.1.8.

Table 38.1
Maximum acceptable temperatures

	Material and component parts	°C	(°F)
1.	A surface upon which a unit may be mounted in service, and surfaces that may be adjacent to the unit when so mounted	90	(194)
2.	Any point on or within a terminal box or compartment of a fixed power unit on which field-installed conductors to be connected may rest	60	(140)
3.	Field wiring terminals	75	(167)
4.	Class 105 coil insulation systems of a relay, a solenoid, or the like		
	Thermocouple method	90[a]	(194)[a]
	Resistance method	110	(230)
5.	Class 130 coil insulation systems of a relay, a solenoid, or the like		
	Thermocouple method	110[a]	(230)[a]
	Resistance method	120	(248)

Table 38.1 Continued on Next Page

Table 38.1 Continued

Material and component parts		°C	(°F)
6.	Class 105 transformer insulation systems:		
	Thermocouple method	90[a]	(194)[a]
	Resistance method	95	(203)
7.	Class 130 transformer insulation systems		
	Thermocouple method	110[a]	(230)[a]
	Resistance method	120	(248)
8.	Class 155 transformer insulation systems		
	Thermocouple method	135	(275)
	Resistance method	145	(293)
9.	Class 180 transformer insulation systems		
	Thermocouple method	150	(302)
	Resistance method	(160)	(320)
10.	Class 200 transformer insulation systems		
	Thermocouple method	165	(329)
	Resistance method	175	(347)
11.	Class 220 transformer insulation systems		
	Thermocouple method	180	(356)
	Resistance method	190	(374)
12.	Class 2 transformer enclosure	85	(185)
13.	Class A motor coil insulation systems:		
	A. In an open motor:		
	Thermocouple method	90	(194)
	Resistance method	100	(212)
	B. In a totally enclosed motor:		
	Thermocouple method	95	(203)
	Resistance method	105	(221)
14.	Class B motor coil insulation systems:		
	A. In an open motor:		
	Thermocouple method	110	(230)
	Resistance method	120	(248)
	B. In a totally enclosed motor:		
	Thermocouple method	120	(248)
	Resistance method	125	(257)
15.	Varnished-cloth insulation	85	(185)
16.	Fiber employed as electrical insulation	90	(194)
17.	Phenolic composition employed as electrical insulation or as a part the deterioration of which would result in a risk of fire or electric shock.	150[b]	(302)[b]
18.	Wood or other combustible material	90	(194)
19.	Rubber- or thermoplastic-insulated wire and cord	60[b, c]	(140)[b, c]
20.	Other types of insulated wires	d	d
21.	Capacitor:		

Table 38.1 Continued on Next Page

Table 38.1 Continued

Material and component parts		°C	(°F)
	Electrolytic	65[e]	(149)[e]
	Other than electrolytic	90[e]	(194)[e]
22.	Sealing compound	f	f
23.	Selenium rectifier	75[g, h]	(167)[g, h]
24.	Silicon rectifier	100[h]	(212)[h]
25.	Power switching semiconductor device	100[h]	(212)[h]
26.	A handle or knob that is grasped for lifting, carrying, or holding		
	Metallic[i]	50	(122)
	Nonmetallic[i]	60	(140)
27.	A handle or knob that is contacted but does not involve lifting, carrying, or holding and other surfaces subject to contact in operation and user maintenance		
	Metallic[i]	60	(140)
	Nonmetallic[i]	85	(185)
28.	A surface subject to casual contact		
	Metallic	70[j]	(158)[j]
	Nonmetallic	95[j]	(203)[j]

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

[b] 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 acceptable heat-resistant properties.

[c] A short length of rubber- or thermoplastic-insulated flexible cord inside the power unit may be exposed to a temperature of more than 60°C (140°F) if supplementary insulation acceptable for the measured temperature and of adequate dielectric properties is employed on each individual conductor.

[d] The maximum allowable temperature shall not exceed the temperature limit of the wire except as noted in (d).

[e] 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 may be judged on the basis of its marked temperature limit.

[f] Unless a thermosetting compound, the maximum sealing compound temperature limit is 15°C (27°F) less than the softening point of the compound as determined in accordance with the Standard Test Methods for Softening Point of Resins Derived from Pine Chemicals and Hydrocarbons, by Ring-and-Ball Apparatus, ASTM E28.

[g] A temperature limit of 85°C (185°F) is acceptable if the stack assembly is insulated with phenolic composition or other insulating material suitable for a temperature of 150°C (302°F).

[h] A component that operates at a temperature of more than 100°C (212°F) shall be judged on the basis of the manufacturer's rating.

[i] A handle, knob, or the like made of a material other than metal, that is plated or clad with metal having a thickness of 0.005 in (0.13 mm) or less, shall be judged as a nonmetallic part.

[j] A power unit may exceed the temperature limits for surfaces subject to casual contact if all of the following conditions are met:

1) The power unit is intended to be permanently installed so that it is not likely to be contacted by people;

2) The power unit is marked as required by 58.25; and

3) The power unit is provided with instructions as specified in 59.2.

38.1.2 A protective device shall not operate during the normal temperature test.

38.1.3 With reference to 38.1.1, the load shall be subdivided between the output circuits so that at least one circuit of each rating is loaded to 80% of its rating and the remainder of the load is distributed equally among the other circuits.

38.1.4 A unit designed for mounting or support in more than one position shall be tested in a manner representing the most severe conditions.

38.1.5 Unless investigated and found acceptable – see 7.13 – a supporting means formed of soft rubber or rubberlike material is to be removed prior to the temperature test. If the supporting means has a metal insert, such as a screw or rivet, the test is to be conducted with the unit supported by the metal insert. At the request of the manufacturer, the test may be conducted without any means of support.

38.1.6 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, except the resistance method may be used for a coil that is inaccessible for mounting of these devices such as a coil:

a) Immersed in a sealing compound;

b) Wrapped with thermal insulation such as asbestos; or

c) Wrapped with more than two layers of material such as cotton, paper, or rayon more than 1/32-in (0.8-mm) thick.

In an alternating-current motor, the thermocouple is to be mounted on the integrally-applied insulation of the coil wire.

38.1.7 In using the resistance method, the windings are to be at room temperature at the start of the test. The temperature of a winding is to be calculated from the formula:

$$T_c = \frac{R}{r}(k + t\ 1) - k$$

in which:

Tc is the temperature of the winding at the end of the test in °C;

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

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

t1 is room temperature at the beginning of the test in °C; and

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum. Values of the constant k for other grades must be determined.

38.1.8 All temperature values in Table 38.1 are based on an assumed ambient temperature of 25° C (77°F). However, with correction of temperature measurements, tests may be conducted in other ambients as described in Table 38.2.

Table 38.2
Temperature measurement correction

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

Table 38.2 Continued on Next Page

Table 38.2 Continued

Ambient temperature rating of unit	Test ambient temperature	Correction of observed temperature
3. Above 40°C (104°F)	Rated ambient See note b	c

[a] Correction of temperature, as determined by item A or B below, shall not exceed the temperature limit specified in Table 38.1.

A. An observed temperature is to be corrected by addition if the test ambient temperature is lower then 25°C (77°F) or by subtraction if the test ambient temperature is higher than 25°C (77°F) of the difference between 25°C (77°F) and the test ambient temperature.

B. An observed temperature is to be corrected by addition (if the test ambient temperature is lower than the rated ambient temperature) or by subtraction (if the test ambient temperature is higher than the rated ambient temperature) of the difference between the rated ambient temperature and the test ambient temperature.

[b] Allowable tolerances are:

Minus – not less than 5°C (9°F) below rated ambient.

Plus – not specified.

[c] If the test ambient temperature equals rated ambient, no correction is to be made, and an observed temperature shall not exceed the temperature limit specified in Table 38.1. If the test ambient temperature is other than the rated ambient, correction is to be made as described in item B of note a.

38.1.9 Thermocouples shall consist of wires not larger than 24 AWG and not smaller than 30 AWG. When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer-type instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary. The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform with the requirements in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

38.1.10 A thermocouple junction and the adjacent thermocouple lead wires are to be held securely in good thermal contact with the surface of the material of which the temperature is being measured. Usually adequate thermal contact will result from securely taping or cementing the thermocouple in place but, if a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

38.1.11 A temperature is considered to be constant when three successive readings taken at intervals of 10% of the previously elapsed duration of the test, but not less than 15 min, indicate no further increase.

38.2 Maximum output without fan operation

38.2.1 A unit employing a cooling fan, the operation of which is controlled by a thermostat or other thermal sensing device or component, is to be operated under the conditions described in 38.1.1 – 38.1.11 except that the load is to be reduced to the maximum load it can carry without resulting in operation of the cooling fan. The unit shall comply with the temperature limits specified in Table 38.1 and Table 38.2.

38.3 Zero clearance

38.3.1 A unit mounted in a wooden enclosure as described in 38.3.2 and 38.3.3 shall comply with the requirements in 38.1.1 – 38.2.1. In addition, the surface temperatures on parts exposed to contact on a unit for flush-wall installation shall not exceed those specified in Table 38.3.

Exception No. 1: A protective device may cycle during the test.

Exception No. 2: A temperature rise may be 20°C (36°F) greater than that specified in Table 38.1.

Table 38.3
Maximum acceptable temperature limits

		°C	(°F)
A.	Surfaces		
	Bare or painted metal	67	(153)
	Porcelain enamel	71	(160)
	Glass	78	(172)
	Plastic[a]	83	(181)
B.	Handles and knobs		
	Bare or painted metal	55	(131)
	Glass	65	(149)
	Plastic[a]	75	(167)

[a] Includes plastic with a metal plating not more than 0.005-in (0.13-mm) thick; and metal with a plastic or vinyl covering not less than 0.005-in thick.

38.3.2 A unit is to be mounted in an enclosure consisting of four vertical side walls at right angles to each other, and a horizontal top and base of 1/2-in thick plywood or soft pine with a nominal thickness of 3/4 in. The interior surfaces are to be painted flat black and the joints are to be tight or sealed. The unit is to rest on the base with the walls and top in as intimate contact with the unit as the configuration on the unit permits.

38.3.3 A unit intended for flush mounting is to be flush mounted on a vertical surface and the recessed portions are to be enclosed in accordance with 38.3.2.

38.4 Maximum overload without trip

38.4.1 A unit is to be operated under the conditions described in 38.1.1 – 38.3.3 at the maximum load it can carry without resulting in the protector required by 21.2.1 to open the circuit – ultimate trip current. During the test:

a) Transformer winding temperatures shall not exceed 140° C (284° F) for Class A insulation, or 165°C (329°F) for a Class B or F insulation, or 20°C (36°F) above the value specified in Table 38.1 for any other class of insulation.

b) The temperature of any component other than a transformer shall not exceed that specified in Table 38.1 by more than 20°C (36°F).

c) A flush-wall mounted unit shall also comply with the temperature limits specified in Table 39.1.

d) A fixed or stationary type unit shall not exceed the temperature limits specified in Table 39.1 by more than 20°C (36°F).

38.4.2 With reference to 38.4.1, readily accessible branch-circuit overcurrent-protective devices in a secondary circuit shall be shunted during the test if they would open the circuit prior to the opening of an internal protective device.

39 External Surface Temperature Limits Test

39.1 During the normal temperature test described in Section 38, Temperature Test, surface temperatures shall not exceed the applicable values specified in Table 39.1. The results of a test that is conducted at a room temperature of other than 25°C (77°F) is to be corrected to 25°C (77°F). See 38.1.8.

Table 39.1
Maximum acceptable surface temperatures

Location	Composition of surface[a]			
	Metal		Nonmetallic	
	°C	(°F)	°C	(°F)
A handle or knob and other surfaces subject to contact in operation and user maintenance	60	(140)	85	(185)
A surface subject to casual contact	70	(158)	95	(203)
Surfaces upon which a fixed or stationary unit may be mounted in service	90	(194)	90	(194)

[a] A handle, knob, or the like made of a material other than metal, that is plated or clad with metal having a thickness of 0.005 in (0.13 mm) or less is considered a nonmetallic part.

40 Dielectric Voltage-Withstand Test

40.1 A unit, at the maximum operating temperature reached in normal use, shall withstand for 1 min without breakdown the application of a 60 Hz essentially sinusoidal potential of:

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

1) Between the primary circuit and dead metal parts;

2) Between the primary and secondary circuits; and

3) Between all secondary windings, including any ferroresonant winding.

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

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

40.1.1 A dc potential of 1.414 times the rms value of the ac potential specified in 40.1 may be used instead of the ac potential.

40.2 To determine whether a unit complies with the requirements in 40.1, the unit is to be tested using a 500 VA or larger capacity transformer, the output voltage of which can be varied. The applied potential is to be increased from zero to the required test value, and is to be held at that value for 1 min. The increase in applied potential is to be at a substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

41 Induced Potential Test

41.1 If a 2-flange bobbin isolated power transformer is to be tested in accordance with (d) of the Exception to 18.2.3, the test specified in 41.2 – 41.4 shall be conducted without breakdown of insulation.

41.2 The primary winding of the 2-flange bobbin transformer is to be subjected to an alternating potential of twice the rated voltage with the ends of all other windings opened. The potential is to be applied for 7200 cycles or for 60 s. An essentially sinusoidal source is to be used, and the frequency of the source may be in the range of 120 – 1000 Hz if necessary to reduce the likelihood of saturation of the transformer core.

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

41.4 The test voltage required in 41.2 is to be initiated at one-fourth or less of the full value and brought up gradually to the full value in not more than 15 s. After being held for the time specified, the voltage is to be reduced slowly, but within 5 s, to one-fourth of the maximum value or less, and the circuit opened.

42 Testing on Transformer Insulating Materials

42.1 If required by note (c) or (g) of Table 18.1, the transformer insulating material shall be subjected to the test described in 42.2.

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

43 Strain Relief Test

43.1 The strain relief means provided on a flexible cord shall withstand for 1 min without displacement a direct pull of 35 lbs (156 N) applied to the cord, with the connections within the unit disconnected. The strain relief is not acceptable if, at the point of disconnection of the conductors, there is such movement of the cord as to indicate that stress on the connections would have resulted.

43.2 A 35-lb (16-kg) weight is to be suspended from the cord and supported by the unit so that the strain-relief means will be stressed from any angle the construction of the unit permits.

43.3 A wiring lead intended for field connection (see 12.1.2.11 and 63.4) shall withstand without damage or displacement a direct pull of:

a) 20 lbs (89 N) for 1 min applied to a lead extending from the enclosure (such as through a knockout); and

b) 10 lbs (44.5 N) for 1 min applied to a lead within a wiring compartment.

44 Overload Test

44.1 Unless known to be acceptable for the application, a switch or other device in a secondary circuit shall perform acceptably when subjected to an overload test consisting of 50 cycles of operation making and breaking 150% of the rated secondary current. There shall be no electrical or mechanical breakdown of the device, undue burning or pitting of the contacts, or opening of the fuse in the grounding connections.

44.2 In a test to determine whether a switch or other control device complies with the requirements in 44.1, the unit is to be connected to a supply circuit of rated frequency and maximum test voltage – see Table 32.1. During the test, exposed dead metal parts of the unit are to be connected to the polarity opposite to that of the switching device through a 3-A fuse. The device is to be operated for 50 cycles at a rate of not more than 10 cycles per minute, except that a faster rate may be employed with the concurrence of those concerned.

45 Overcurrent Protection Calibration Test

45.1 A fuse, or a non-adjustable manual reset circuit protective device, provided in the primary of a transformer for protection of the secondary circuit in accordance with 14.8 shall operate to open the circuit

in not more than the time indicated in Table 45.1 when the transformer is delivering the specified secondary current.

45.2 To determine if a fuse or circuit protective device complies with the requirement in 45.1, the transformer is to deliver the test current to a resistance load. During the 2-min test, the load is to be adjusted continuously to maintain the required test current. During the 60-min test, the load is to be adjusted once after 15 min of operation and the test is to be continued without further adjustment.

45.3 If the fuse or circuit protective device is used to protect more than one secondary winding or taps, each winding or partial winding is to be tested as indicated in 45.1 or 45.2 with the remaining windings delivering rated load.

Table 45.1
Maximum acceptable time to open

Rated secondary potential, V	Secondary test current, A	Maximum time for overcurrent protective device to open, min
20 or less	10	2
20 or less	6.75	60
Over 20	200/V max	2
Over 20	135/V max	60

46 Ground-Fault Circuit-Interrupter Evaluation Test For Power Units

46.1 The ground-fault circuit-interrupter protection circuit of a power unit shall remain closed with a leakage current of 4 mA and shall open with a leakage current of 6 mA when tested in accordance with 46.2.

46.2 To determine if an unit complies with 46.1, the unit is to be connected to its rated source of supply and a variable resistor is to be connected between the ungrounded pole of the line voltage branch circuit output and the output circuit grounding connection. The resistor is to be adjusted to obtain the maximum value of leakage current possible without causing the ground-fault circuit-interrupter circuit to trip, and to obtain the minimum value of leakage current required to cause the ground-fault circuit-interrupter to trip.

47 Battery Charger Overcharge Test

47.1 When connected to a supply circuit adjusted to 106% of the test voltage specified in 32.1, a battery supply of a unit is to be subjected to 7 h 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 No. 1: This requirement does not apply to a unit to be used with a battery supply that is not investigated with the unit.

Exception No. 2: This requirement does not apply to a unit provided with a regulating circuit preventing an increase in battery charging current when the ac input voltage is increased from rated value to 106% of rated value.

47.2 The most severe charging rate referred to in 48.1 is the maximum charging rate that does not cause a thermal or overcurrent protective device to open.

48 Abnormal Operation Test

48.1 General

48.1.1 A unit shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons when subjected to the tests described in 48.1.3 – 48.9.3, 48.11.1 and 49.1.1 – 49.3.1. Separate samples may be used for conducting these tests.

48.1.2 Following each test, a dielectric voltage withstand test as specified in 40.1(a) is to be conducted.

Exception: If agreeable to all involved, more than one abnormal test may be conducted on a single sample, and the dielectric voltage withstand test may be conducted after completion of all the abnormal tests.

48.1.3 The unit is to be at room temperature at the start of the output-short-circuit, switch-position, and specific-value-overload tests.

48.1.3.1 A risk of fire, electric shock, or injury to persons is considered to exist if:

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

b) The insulation breaks down when tested in accordance with 48.1.2, or

c) Live parts are made accessible (see Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 9).

48.1.3.2 During these tests the unit is to be placed on a softwood surface covered with a white tissue paper and a single layer of cheesecloth is to be draped loosely over the entire enclosure. The cheesecloth is to be untreated cotton cloth 36 in (910 mm) wide, running 14 – 15 yds/lb (28 – 30 m/kg), and having, for any square inch, a count of 32 threads in one direction and 28 in the other direction (for any square centimeter, 13 threads in one direction and 11 in the other direction).

Exception: Units not having any bottom openings need not be placed on a softwood surface covered with tissue paper.

48.1.3.3 The supply circuit is to have branch circuit overcurrent protection, the size of which equals 125% of the input current rating (20 A minimum), except where this value does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating shall be used. The test voltage is to be adjusted to the value specified in 32.1.

Exception: If a marking on the product indicates the use of branch circuit protection exceeding 125% of the input current, such protection shall be used.

48.1.3.4 The enclosure of the unit is to be connected directly to ground.

48.1.3.5 Each test is to be continued until further change as a result of the test condition is not likely. If an automatically reset protector functions during a test, the test is to be continued for 7 h. If a manual reset protector functions during a test, the test is to be continued until the protector is operated for 10 cycles using the minimum resetting time, but not at a faster rate than 10 cycles of operation per minute. The following are considered as an acceptable termination of the test:

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

b) Opening of the intended branch circuit overcurrent protection device.

c) Opening of an internal fuse.

Exception No. 1: If the manually reset protector is a circuit breaker that complies with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489, it is to be operated for 3 cycles using the minimum resetting time but 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 may be operated fewer than 10 cycles, but not less than 3 cycles.

48.1.4 The output short-circuit and specific-value-overload tests are to be conducted on the bench and under the conditions described in 38.3.2 and 38.3.3.

Exception: A unit that employs integral fuses need not be subjected to the short-circuit test under the conditions described in 38.3.2 and 38.3.3.

48.1.5 Each test is to be conducted on a separate sample unless the manufacturer requests that more than one test be conducted on the same sample.

Exception: For the overload tests, one sample may be used provided it is subjected to the tests in the following order: 200% of rated current, followed by short-circuit current.

48.1.6 A manually or automatically reset protector or other overload protective device in a unit shall open the output circuit within 2 min after initiation of the test, and within 30 s for subsequent cycles during the output-short-circuit, switch-position, and specific-value-overload tests.

Exception No. 1: The time required to open the output circuit may exceed the time specified provided the maximum temperatures attained do not exceed the limits specified in Table 39.1 for flush-wall mounted units, or 20°C (36°F) more than that specified in Table 39.1 for fixed or stationary stand-alone type units surfaces, and 20°C (36°F) more than that specified in Table 38.1 for components and materials.

Exception No. 2: The switch-position test may be waived if with the transfer switch in the battery position, the unit will not operate when connected as described for the input test – see Section 34, Power Input Test – and no risk of fire or electric shock is found to exist.

Exception No. 3: The time required to open the output circuit during the specific-value-overload test may exceed the time specified provided the unit does not emit flame or molten metal or become a risk of fire or electric shock while operating under the test condition described in 48.8.1 for 15 days.

48.2 Output short-circuit

48.2.1 The external output connections of a unit are to be short-circuited and the unit is to be connected to a source of supply adjusted to the test voltage specified in Table 32.1. The source of supply may be protected by a time-delay branch-circuit overcurrent-protective device rated not less than 20 A. During the test, the enclosure is to be connected directly to earth ground. A protective device such as an accessible fuse or circuit breaker provided as part of the unit is to remain in the circuit, and the largest fuse the fuseholder will accept is to be installed.

48.2.2 For the test described in 48.2.1, fuses or circuit breakers provided for individual low-voltage branch-circuit protection may remain in the circuit. If a fuseholder is provided, a fuse rated not less than 30 A is to be installed in the fuseholder. The short circuit may be applied across one individual low-voltage

circuit, which, for the purpose of this test, may employ output leads as described in 13.1.3 having a total length of 4 ft (1.22 m) that is, having positive and negative leads each 2 ft (610 mm) long.

48.2.3 The external output connections of an inverter are to be short-circuited and the unit is to be connected to a source of supply adjusted to the inverter rated nominal input dc voltage. The source of supply may be protected by a time-delay overcurrent-protective device rated no less than 150% of the rated inverter input current at full rated load. During the test, the enclosure is to be connected directly to earth ground. A protective device such as an accessible fuse or circuit breaker provided as part of the unit is to remain in the circuit, and the largest fuse the fuse holder will accept is to be installed. When an inverter circuit employs a microprocessor to shut down a unit due to an overload, that portion of the software shall be disabled for this test.

48.2.4 For the test described in 48.2.1 and 48.2.3, if acceptable results are based on the opening of an overcurrent-protective device, the overtemperature protective device shall be operable at the conclusion of the tests.

48.2.5 Power-inverters with three-phase AC outputs shall be subjected to three different short-circuit tests. The tests shall consist of a Line to Neutral test, a Line to Line test, and a Line to Line to Line test.

48.3 Switch position

48.3.1 A unit provided with a manual battery-to-unit transfer switch and a battery-charging circuit is to be operated as described in the input test except with the transfer switch in the battery position.

48.4 Component malfunction

48.4.1 Individual electronic components of a unit are to be, in turn, open-circuited and short-circuited.

48.4.2 The tests specified in 48.4.1 are to be conducted separately. Short circuits are to be applied between only two terminals of a multiterminal device at one time. The abnormal condition is to be introduced while the unit is operating under intended conditions. This may be accomplished by jumper leads and remote switches with consideration given to the effect these devices may have on the test.

48.5 Rectifier and capacitor short-circuit test

48.5.1 If a rectifier and an electrolytic capacitor are connected across a primary supply circuit in series with a resistance of less than 300 Ω, a risk of fire or electric shock shall not result with the capacitor or the rectifier being short-circuited.

Exception: If analysis of the test results and circuit indicates that the result obtained is the only one likely to occur, the test need be conducted only once.

48.5.2 The supply circuit of a power unit is to be protected by a branch-circuit overcurrent-protective device in accordance with 49.3.2.

48.6 Vibration test

48.6.1 After the unit is subjected to the vibration test described in 48.6.2:

a) The unit shall comply with the requirement in 48.1.1,

b) There shall be no loosening of parts, and

c) The unit shall operate normally.

48.6.2 The vibration test shall consist of vibration for 1 h at a frequency of 12.5 cycles per second with a displacement of 1/4 inch (6.4 mm) in a vertical plane. The unit is to be mounted as intended in accordance with the manufacturer's instruction manual during the test.

48.7 Surge protectors

48.7.1 A unit provided with a surge-protection device in the secondary circuit is to be subjected to the surge test described in 48.7.2.

48.7.2 A 1-μF capacitor is to be charged to 500 F. The capacitor is to be discharged directly into the secondary output network with the transformer secondary leads disconnected. The surge is to be repeated for a total of 50 times at 30 s intervals. After the surges, the unit shall operate normally at rated load. Proper polarities are to be maintained in conducting this test.

48.8 Specific value overload

48.8.1 A unit is to be operated using a load adjusted to 200% of the rated output current. The test is to be continued until the overload-protective device opens – see 48.1.6. If an automatically reset protector is provided, the test is to be continued for 15 days, or for 24 h if the protector has been evaluated for 6000 cycles at 200% of the measured current at the alternating or direct voltage value. A manually reset protector is to be operated for 50 cycles of operation, with the protective device being reset as rapidly as is possible. The protector shall be operative upon completion of the test.

48.8.2 With reference to the requirement in 48.8.1:

a) If the ultimate trip current mentioned in 38.4.2 is greater than 200% of the rated output current, the load is to be increased in increments of 100% of the rated output current.

Exception: If the next increment of rated output current is not obtainable, the maximum current value obtainable is to be used.

b) If the maximum load current obtainable is less than 200%, the maximum value obtainable is to be used.

c) If the increased load results in the opening of a fuse, the test is to be conducted with the load adjusted such that the circuit current is equal to the ampere rating of the fuse. The unit is to be operated continuously until ultimate conditions are observed.

48.9 Blanketing test

48.9.1 A unit that incorporates standoffs is to be subjected to a blanketing test. A double layer of blanket – see 48.9.3 – is to be loosely draped over the top and drawn in as close as possible against all sides of the unit. The blanket may fall or sag between any standoffs that are provided on the unit. The test is to be continued until the overload protective device opens – see 21.2.1. If an automatically reset protector is provided, the test is to be continued for 15 days. A manually reset protector is to be operated for 50 cycles of operation, with the protective device being reset as rapidly as possible. The protector shall be operative upon completion of the test.

Exception: The test may be conducted for 1 cycle if protection is provided by a fuse that is not accessible without the use of a tool.

48.9.2 Accessible secondary-circuit overcurrent-protective devices shall be shunted during the test, if they would open the circuit prior to opening of an internal protective device.

48.9.3 With reference to 48.9.1, the blanket is to be 100% unbleached plain weave napped cotton flannelette weighing 4.40 oz/yd^2 (148.4 g/m^2).

48.10 Flanged bobbin transformer abnormal test

48.10.1 A flanged bobbin transformer required to be tested as provided in (c) of the Exception to 18.2.3 – also see 18.2.4 – shall operate for 15 days with the secondary winding or windings loaded to the conditions described in (a) – (c). A risk of fire or electric shock shall not result from:

a) Short-circuiting the secondary winding;

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

c) Loading the secondary winding to the maximum normal current.

Exception: A flanged bobbin transformer used in a circuit where isolation is not required or where the secondary circuit does not extend out of the unit – see 18.1.1 – need not be subjected to this test.

48.10.2 A risk of fire as described in 48.10.1 is considered to exist if the cheesecloth or tissue paper glows or flames or the protective device, if provided, opens.

48.10.3 While still in a heated condition from the test described in 48.10.1, a transformer shall withstand the dielectric voltage withstand test described in 40.1(a)(1). The dielectric voltage withstand test potential is to be applied to the transformer approximately 1 min after completion of the test described in 48.10.1.

48.10.4 The abnormal tests may be conducted with a protective device built into the transformer or with an external protective device connected in either the primary or secondary circuit, or both. A protective device that is relied upon to open the circuit as a result of an abnormal test is to be one that has been investigated and found to be acceptable for the purpose.

48.10.5 For the purpose of these requirements, each secondary winding tap other than a center tap and each primary winding tap designed to supply power to a load are considered to be the equivalent of a secondary winding.

48.10.6 For the sequence of tests described in 48.10.1, if an abnormal operation test continues for 15 days without a winding or a protective device opening, the remaining tests need not be conducted. For example, if the test described in 48.10.1(a) continues for 15 days, the tests described in (b) and (c) need not be conducted.

48.10.7 To determine whether a transformer complies with the requirement in 48.10.1, one sample is to be subjected to each condition described in 48.10.1 (a) – (c). For a transformer that employs more than one secondary winding, each of the secondary windings is to be loaded for each condition specified in 48.10.1 with the other windings loaded to rated current. The test conditions are to be as described in 48.10.8 – 48.10.13.

48.10.8 To determine the short-circuit current value for conducting the tests described in 48.10.1(b), the transformer is to be at room temperature at the beginning of the measurement, and the short-circuit current is to be measured approximately 1 min after the voltage is applied to the primary winding. A protective device outside the transformer is to be short-circuited during the measurement of the short-circuit current. If the line fuse or transformer winding opens within 1 min after the application of the primary voltage, the short-circuit current is considered to be that value recorded just before the line fuse or winding opens. The short-circuit current of any one winding is to be measured with the other secondary windings open-circuited.

48.10.9 For the loading conditions, a variable resistor is to be connected across the secondary winding. The tests described in 48.10.1(a) – (c) are to be continued for 15 days unless a winding of the transformer or a protective device opens in a shorter time. In conducting the tests described in 48.10.1(b), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, if necessary, 1 min after voltage is applied to the primary winding.

Exception: For a switch-mode transformer, the load is to be connected to the output of the power supply connected to the transformer.

48.10.10 If short-circuiting the secondary winding causes one of the windings to open before 15 days, then the next test in the sequence described in 48.10.1(b) that continues for 15 days is to have a variable load resistor reduced to zero impedance at the end of the 15 days.

48.10.11 For a transformer that is provided with a protective device built into the transformer or that is being tested in conjunction with an external protective device, a test described in 48.10.1 (a) – (c) is to be discontinued if the protective device opens the circuit and the next test in the sequence is to be started. This procedure is to be continued until a condition specified in 48.10.1 (a) – (c) is reached that allows the circuit to hold for 15 days. The protective device mentioned above includes automatic recycling type, manual reset type, or a replaceable type.

48.10.12 If a protective device opens the circuit or a winding on any sample opens during the 15-day abnormal operation tests while the samples are unattended, the variable resistor load on the other samples is to be increased, by reducing the resistance, until the protective device opens the circuit or the winding opens, so that the samples may be subjected to the dielectric voltage withstand test described in 48.10.3 while in a heated condition. The next test in the sequence is to be in accordance with 40.1(b) and (c).

48.10.13 Samples for the 15-day abnormal operation tests described in 48.10.1 are to be prepared as follows:

a) The transformer is to be mounted either in the unit enclosure as intended or on a test bench with a double layer of cheesecloth draped over the transformer.

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

48.11 Blocked fan

48.11.1 A unit having a fan motor shall be operated for 7 h with the rotor of the fan motor stalled from rotating.

49 Evaluation of Reduced Spacings on Printed Wiring Boards

49.1 General

49.1.1 In accordance with Exception No. 4 to 29.1.1, printed wiring board traces of different potential having reduced spacings may be investigated by conducting a dielectric voltage-withstand test as described in 49.2.1 and 49.2.2 for a protected environment, see 8.1 – 8.5, or a shorted trace test as described in 49.3.1 and 49.3.2 for a unit investigated for either a protected environment or a general environment.

49.2 Dielectric voltage-withstand test

49.2.1 A printed wiring board as mentioned in 49.1.1 shall withstand for 1 min without breakdown the application of a dielectric withstand potential applied between the traces having reduced spacings in accordance with 40.1 and 40.2.

49.2.2 Power-dissipating parts, electronic devices, and capacitors connected between traces having reduced spacings are to be removed or disconnected in a manner that the spacings and insulations, rather than the component parts, are subjected to the full dielectric voltage-withstand test potential.

49.3 Shorted trace test

49.3.1 Printed wiring board traces mentioned in 49.1.1 are to be short-circuited, one location at a time, and the test is to be conducted as described in 49.2.1 and 49.2.2. As a result of this test, the overcurrent protection associated with the branch circuit to which the unit is connected shall not open, and a wire or a printed wiring board trace shall not open. If the circuit is interrupted by the opening of a component, the test is to be repeated twice using new components as necessary.

Exception: Opening of an internal overcurrent protective device is an acceptable termination of the test, and the test need not be repeated.

49.3.2 During the Shorted Trace Test the supply circuit is to have branch circuit overcurrent protection, the size of which equals 125% of the input current rating (20 A minimum), except where this value does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating shall be used.

50 Burnout Test

50.1 General

50.1.1 A unit shall not emit flame or molten metal or become a risk of fire or electric shock while operating as in the temperature test except under the conditions described in 50.2.1. With reference to 50.3.1, the burnout test of the transformer shall be followed by a dielectric voltage-withstand test, as required by 40.1(a). During each test all dead metal parts of the enclosure of the unit are to be connected directly to ground, and:

a) The unit is to rest on a soft-pine surface covered with white tissue paper; and

b) A double layer of cheesecloth is to be draped over the unit.

Exception: A nonmetallic enclosure with exposed dead metal parts that are not likely to become energized need not be grounded.

50.2 Relay and solenoid burnout

50.2.1 An electromagnetic relay or solenoid constructed as described in 7.19 is to be tested by blocking the armature or the plunger in the de-energized position. The unit is then to be connected to its rated source of supply and operated until burnout of the coil occurs or temperatures become constant. During the test, the unit enclosure is to be connected directly to ground.

50.3 Transformer burnout

50.3.1 A resistive load that will cause the input to draw three times the current obtained during normal operation – see 34.1 – is to be connected directly to the transformer secondary winding with the unit

connected to 100% of the maximum test voltage specified in Table 32.1. For a transformer having a center-tapped secondary, a single load shall be connected across the secondary winding that results in the greatest potential. During this test all dead metal parts of the enclosure of the unit are to be connected directly to ground, the unit is to rest on a soft-pine surface covered with white tissue paper, and a double layer of cheesecloth is to be draped over the unit. The transformer is to be operated continuously:

a) Until ultimate conditions are observed;

b) For 7 h if cycling of an automatically reset protector occurs; or

c) For 50 cycles of resetting a manually reset protector.

Exception: A nonmetallic enclosure with exposed dead metal parts that are not likely to become energized need not be grounded.

50.3.2 A ferroresonant transformer is to be tested as described in 50.3.1, except that a resistive load that will draw the maximum power input – see Section 34, Power Input Test – is to be connected directly to the transformer secondary winding, with the converter or inverter connected to 106% of the maximum test voltage specified in Table 32.1.

50.3.2.1 A switch mode transformer is to be tested as described in 50.3.1 except the output of the transformer is to be connected to a resistive load that will draw maximum current without causing shutdown due to operation of circuitry or overcurrent protective devices provided as part of the product. This condition is to be held to the position immediately before foldback.

50.3.3 For the test required by 50.3.1, primary overcurrent protective devices, and secondary manually or automatically reset protectors integral with the transformer and connected in the secondary winding, are to remain in the circuit.

50.3.4 An open switch or other open contact device used within an enclosure that has openings in the bottom shall operate for 50 cycles with the secondary output short-circuited or carrying an equivalent current. There shall be no emission of flame or molten metal.

51 Gasket Tests

51.1 The requirements in this section apply to a gasket that is required for protection against dust and other contaminants entering an enclosure described in Section 8, Enclosures Used for Protected Environments.

51.2 Neoprene or rubber compounds and solid polyvinyl-chloride material, except foamed materials, shall have physical properties as indicated in Table 51.1 before and after the conditioning indicated in Table 51.2.

Table 51.1
Physical properties for gaskets

Physical property[a]	Neoprene or rubber compound		Polyvinyl-chloride materials	
	Before conditioning	After conditioning	Before conditioning	After conditioning
Tensile set – maximum set when 1 in (25.4 mm) gauge marks are stretched to 2-1/2 in (63.5 mm), held for 2 min and measured 2 min after release	1/4 in (6.4 mm)	–	Not specified	Not specified
Elongation – minimum increase in distance between 1 in gauge marks at break	250% [3-1/2 in (88.9 mm)]	65% of original	250% [3-1/2 in (88.9 mm)]	75% of original
Tensile strength – minimum force at breaking point	850 psi (5.86 MPa)	75% of original	1200 psi (8.27 MPa)	90% of original

[a] To be determined using the test methods and apparatus described in the Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension, ASTM D412, except the method for tensile set is to be as specified in this table.

51.3 Foamed neoprene or rubber compounds shall not harden or otherwise deteriorate to a degree that affects their sealing properties after conditioning as specified in Table 51.2.

Table 51.2
Gasket conditioning

Maximum gasket temperature[a]		Conditioning	
°C	(°F)	Rubber or neoprene	Thermoplastic
60	(140)	Air oven aging for 70 h at 100 ±2°C (212 ±3.6°F)	Air oven aging for 168 h at 87 ±2°C (189 ±3.6°F)
75	(167)	Air oven aging for 168 h at 100 ±2°C (212 ±3.6°F)	Air oven aging for 240 h at 100 ±2°C (212 ±3.6°F)
80	(176)	Air oven aging for 168 h at 113 ±2°C (235 ±3.6°F)	
90	(194)	Air oven aging for 240 h at 121 ±2°C (250 ±3.6°F)	Air oven aging for 168 h at 121 ±2°C (250 ±3.6°F) or 1440 hours at 97 ±2°C (207 ±3.6°F)
105	(221)	Air oven aging for 168 h at 136 ±2°C (277 ±3.6°F)	

[a] Measured during the normal temperature test.

51.4 A thermoplastic gasket shall not deform or melt, or otherwise deteriorate to a degree that will affect its sealing properties after the conditioning indicated in Table 51.2.

51.5 Gaskets of materials other than those specified in 51.2 – 51.4 shall be non-absorptive and shall provide equivalent resistance to property changes.

52 Atomized Water Test

52.1 The enclosure specified in Section 8, Enclosures Used for Protected Environment, is to be subjected to a spray of atomized water by using a nozzle that produces a round pattern 3 – 4 inches (75 – 100 mm) in diameter, measured 12 in (305 mm) from the nozzle. The pressure is to be 30 psi (207 kPa). The water is to be supplied by a suction feed with a siphon height of 4 – 8 in (100 – 250 mm). No less than 5 fluid ounces per linear foot (495 cc/m) of test length is to be applied at a rate of 3 gallons (11.4 L) per hour. The nozzle is to be held 12 – 15 in (305 – 380 mm) from the enclosure, and the spray of water is to be directed at all areas of potential dust entry, such as seams, joints, bushings, connectors, and the like. A conduit may be installed to equalize the internal and external pressures, but it is not to serve as a drain. No sealing compound is to be used.

52.2 For this test, covers, except covers that are part of the protected environment enclosure, are to be removed.

52.3 At the conclusion of the procedure specified in 52.1, the product is to be subjected to the dielectric voltage withstand test specified in 40.1(a), and, if cord connected, to the Leakage Current Test in Section 33.

53 Label Adhesion Test

53.1 Unless known to be acceptable for the application, a pressure-sensitive label that is required to be permanent shall be tested as described in 53.2.

53.2 After being subjected to the conditions described in 53.3 – 53.6 a pressure-sensitive label or a label secured by cement or adhesive is considered to be of a permanent nature if immediately following removal from each test medium, and after being exposed for 24 h to room temperature following removal from each medium each sample demonstrates good adhesion and the edges are not curled, and:

a) The label resists defacement or removal as demonstrated by scraping across the test panel with a flat metal blade 1/32-in (0.8-mm) thick, held at right angles to the test panel.

b) The printing is legible and is not defaced by rubbing with thumb or finger pressure.

53.3 OVEN-AGING TEST – Three samples of the label, applied to test surfaces as in the intended application, are to be placed for 240 h in an oven maintained at the temperature specified in Table 53.1.

Table 53.1
Temperatures, oven-aging

Maximum temperature during normal temperature test of surface to which applied		Oven temperature	
°C	(°F)	°C	(°F)
60	(140 or less)	87	(189)
80	(176 or less)	105	(221)
100	(212 or less)	121	(250)
125	(257 or less)	150	(302)
150	(302 or less)	180	(356)
Over 150	(Over 302)	a	

[a] A label that is applied to a surface attaining a temperature greater than 150°C (302°F), during the normal temperature test, is to be oven-aged at a temperature representative of the temperatures attained by the appliance during normal and abnormal operation.

53.4 IMMERSION TEST – Three samples of the label, applied to test surfaces as in the intended application, are to be placed for 24 h in a controlled atmosphere maintained at a temperature of 23 ±2°C (73 ±4°F) at a relative humidity of 50 ±5%. The samples are then to be immersed in water for 48 h at a temperature of 21 ±2°C (70 ±4°F).

53.5 STANDARD ATMOSPHERE TEST – Three samples of the label, applied to test surfaces as in the intended application, are to be placed for 72 h in a controlled atmosphere maintained at a temperature of 23 ±2°C (73 ±4°F) at a relative humidity of 50 ±5%.

53.6 UNUSUAL CONDITION EXPOSURE TEST – If the labels are exposed to unusual conditions in service, such as oil, grease, cleaning solutions, or the like, three samples of the label applied to test

surfaces as in the intended application are to be placed for 24 h in a controlled atmosphere maintained at a temperature of 23 ±2° C (73 ±4° F) at a relative humidity of 50 ±5%. The samples are then to be immersed for 48 h in a solution representative of service use maintained at the temperature the solution would attain in service, but in no case less than 23 ±2°C.

MANUFACTURING AND PRODUCTION TESTS

54 Dielectric Voltage-Withstand Test

54.1 Each unit shall withstand without electrical breakdown, as a routine production-line test, the application of a potential at a frequency within the range of 40 – 70 Hz, between the primary wiring, including connected components, and accessible dead metal parts that are likely to become energized, and between primary wiring and accessible low-voltage (42.4 Vpeak or less) metal parts, including terminals.

54.2 The production-line test shall be in accordance with either condition A or condition B of Table 54.1.

54.2.1 A dc potential of 1.414 times the rms value of the ac potential specified in Table 54.1 may be used instead of the ac potential.

Table 54.1
Production-line test conditions

Unit rating, Vac	Condition A		Condition B	
	Potential, V	Time, s	Potential, V	Time, s
Less than 100	1000	60	1200	1
100 – 130	1250	60	1500	1
131 – 250	1500	60	1800	1
251 – 350	2200	60	2700	1

54.3 The unit may be in a heated or unheated condition for the test.

54.4 The test shall be conducted when the unit is complete – fully assembled. It is not intended that the appliance be unwired, modified, or disassembled for the test.

Exception No. 1: Parts such as snap covers or friction-fit knobs that would interfere with performance of the test need not be in place.

Exception No. 2: The test may be performed before final assembly if the test represents that for the completed unit.

54.5 If a unit employs a solid-state component that is not relied upon to reduce a risk of electric shock and that can be damaged by the dielectric potential, the test may be conducted before the component is electrically connected provided that a random sampling of each day's production is tested at the potential specified in Table 54.1. The circuitry may be rearranged for the purpose of the test to minimize the likelihood of solid-state-component damage while retaining representative dielectric stress of the circuit.

54.6 The test equipment shall include a transformer having an essentially sinusoidal adequate output, a means of indicating the test potential, an audible or visual indicator of electrical breakdown, and either a manually reset device to restore the equipment after electrical breakdown or an automatic reject feature of any unacceptable unit.

54.7 If the output of the test equipment transformer is less than 500 VA, the equipment shall include a voltmeter in the output circuit to directly indicate the test potential.

54.8 If the output of the test equipment transformer is 500 VA or larger, the test potential may be indicated:

a) By an acceptable voltmeter in the primary circuit or in a tertiary-winding circuit,

b) By a selector switch marked to indicate the test potential, or

c) In the case of equipment having a single test-potential output, by a marking in a readily visible location to indicate the test potential.

When marking is used without an indicating voltmeter, the equipment shall include a positive means, such as an indicator lamp, to indicate that the manually reset switch has been reset following a dielectric breakdown.

54.9 Test equipment, other than that described in 54.6 – 54.8 may be used if found acceptable to accomplish the intended factory control.

54.10 During the test, the primary switch is to be in the on position, both sides of the primary circuit of the unit are to be connected together and to one terminal of the test equipment, and the second test-equipment terminal is to be connected to the accessible dead metal.

Exception No. 1: A unit resistive, high-impedance winding, or the like having circuitry not subject to excessive secondary-voltage build-up in case of electrical breakdown during the test may be tested with a single-pole primary switch, if used, in the off position, or with only one side of the primary circuit connected to the test equipment when the primary switch is in the on position, or when a primary switch is not used.

Exception No. 2: The primary switch is not required to be in the on position if the testing means applies full test potential between primary wiring and dead metal parts with the switch not in the on position.

55 Grounding Continuity Test

55.1 Each unit that has a power-supply cord having a grounding conductor shall be tested, as a routine production-line test, to determine that electrical continuity exists between the grounding blade of the attachment plug and accessible dead metal parts of the unit that are likely to become energized.

55.2 Only a single test need be conducted if the accessible metal selected is conductively connected by design to all other accessible metal.

55.3 Any acceptable indicating device – an ohmmeter, a battery-and-buzzer combination, or the like – may be used to determine whether an appliance complies with the grounding continuity requirement in 55.1.

RATING

56 General

56.1 The input of a unit shall be rated in amperes or watts and volts, and in frequency expressed in one of the following terms: hertz, Hz, cycles-per-second, cps, cycles/second, or c/s.

56.2 With reference to 56.1, for a unit having a single voltage rating, such as 115 V, rather than being rated for a range of voltages, such as 110 – 115 V, maximum rated voltage is considered to be 120 V. For a

unit nominally rated 230 V, maximum rated voltage is considered to be 240 V. If the rating is given in terms of a range of voltages, maximum rated voltage is considered to be 120 V or 240 V, minimum.

56.3 The output circuit of a unit shall be rated in amperes and volts.

56.4 If a unit includes an attachment-plug receptacle intended as a general use outlet, the added load that the receptacle may impose on the unit and its supply connections shall be included in the electrical rating of the unit.

MARKINGS

57 Details

57.1 Unless otherwise stated, all markings are required to be permanent, that is, either by being molded, die-stamped, paint-stenciled; stamped or etched metal that is permanently secured; or indelibly stamped on a pressure-sensitive label secured by adhesive that, upon investigation is found to comply with the applicable requirements for indoor use labels in the Standard for Marking and Labeling Systems, UL 969.

57.2 A marking as required by 57.1 need not be located on the outside of an enclosure, provided it is readily visible by opening a door or removing a cover after installation. A marking that is not visible unless a cover is removed is acceptable only if the field wiring will not be disturbed by removing the cover and if the marking is visible at the time it is needed.

57.3 A required marking on a flush-mounted panel shall be visible with the panel mounted on the enclosed base, except that required wiring and installation instructions may be visible upon removal of the panel from the enclosure base.

58 Content

58.1 A unit shall be marked with:

a) The manufacturer's name, trade name, or trademark – hereinafter referred to as the manufacturer's name;

b) A distinctive catalog number or the equivalent;

c) The input voltage, frequency, and amperes or watts;

d) The words "Provided with integral protection against overloads;"

e) The output voltage and current in amperes; and

f) The date or other dating period of manufacture not exceeding any three consecutive months.

Exception No. 1: The manufacturer's identification may be in a traceable code if the unit is identified by a brand or trademark owned by a private labeler.

Exception No. 2: The date of manufacture may be abbreviated; or may be in a nationally accepted conventional code, or in a code affirmed by the manufacturer if the code:

a) Does not repeat in less than 20 years; and

b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.

58.2 Polarity identification shall be provided for output connections. The polarity is to be identified by:

a) The words "battery positive," "converter positive," and "negative;"

b) The words "battery" and "converter" followed by the signs "+" for positive and "− " for negative;

c) Color coding of red for battery positive, black for battery negative, blue for converter positive, and white for negative; or

d) The abbreviations "Pos" and "Neg" with the symbols "+" and "−."

58.3 With reference to the requirements in 58.2, the words "battery," "converter," "positive," and "negative" may be abbreviated "Batt.," "Conv.," "Pos." and "Neg.," respectively.

58.4 A unit shall be marked to indicate the branch-circuit protection provided for each secondary-circuit-output connection – terminals, pigtail leads, plug and receptacle combinations, and the like.

58.5 If a manufacturer produces or assembles a unit at more than one factory, each unit shall have a permanent, distinctive marking – which may be in code – by which it may be identified as the product of a particular factory.

58.6 If a unit incorporates an automatic means to change from direct-current unit power to direct-current battery power, the automatic function shall be described in the manufacturer's instructions.

58.7 If a transfer switch is provided to change from direct-current unit power to direct-current battery power, the switch position shall be permanently marked as specified in paragraph 58.2.

58.8 A transfer switch or relay provided with a terminal or lead for a battery connection shall be marked to indicate the current and voltage rating and the maximum size conductor that can be connected.

58.9 A unit employing devices such as switches, relays, or the like, that tend to produce arcs or sparks shall be marked, "WARNING – This unit employs components that tend to produce arcs or sparks – To prevent fire or explosion, do not install in compartments containing batteries or flammable materials."

58.10 A cautionary warning, or danger marking shall be permanent and shall be located on a part that requires a tool for removal.

58.11 A cautionary marking to instruct the operator shall be visible and legible to the operator during normal operation of the unit.

58.12 A cautionary marking shall be prefixed by the word "CAUTION," "WARNING," or "DANGER" in letters not less than 1/8-in (3.2-mm) high. The remaining letters shall not be less than 1/16-in (1.6-mm) high.

58.13 Each interchangeable fuse shall be marked to indicate the ampere and voltage rating and type of the fuse to be used for replacement. The marking shall be located so that it is apparent as to which fuse the marking applies.

58.14 In addition to the marking required in 58.13, a marking shall be provided adjacent to the fuseholder or fuseholders and shall consist of the word "CAUTION" and the following or the equivalent: "For continued protection against risk of fire, or electric shock replace only with same type and ratings of fuse".

58.15 The current rating of a manually reset protector used for branch-circuit protection shall be permanently and legibly marked either on or adjacent to the protector.

58.16 A unit shall be marked "CAUTION – To prevent fire, do not cover or obstruct ventilation openings. Do not mount in zero-clearance compartment. Overheating may result." An equivalent wording may be used for the statements following the word "CAUTION."

58.17 A unit incorporating an integral battery charger shall be clearly and permanently marked to specify the rating of the battery charger and whether this rating is part of the total output rating.

58.18 A unit shall be marked to indicate the manufacturer and catalog or model designation of a matching attachment plug or receptacle provided for the low-voltage output connection.

58.19 Unless a receptacle provided for the low-voltage output connection and its attachment plug have been tested for current interruption, a unit shall be permanently marked "For disconnect use only – not for current interruption," or with equivalent wording.

58.20 The position of an operating handle or knob shall be permanently marked, if necessary, as a guide for intended operation.

58.21 A unit provided with a marking in lieu of integral ground-fault circuit-interrupter protection shall be marked:

a) With the word "WARNING" and the following or the equivalent: "Risk of electric shock. Use only (manufacturer's name), type (catalog number) ground-fault circuit-interrupter [receptacle (s) or circuit breaker(s)]. Other types may fail to operate properly when connected to this unit"; or

b) With the word "WARNING" and the following or the equivalent: "Risk of electric shock. Use only the ground-fault circuit-interrupter [receptacle (s) or circuit breaker (s)] specified in the installation and operating instructions manual supplied with this unit. Other types may fail to operate properly when connected to this unit."

58.22 Ungrounded dead-metal parts specified in 9.3.3 shall be plainly marked with the word "WARNING" and the following or the equivalent: "Risk of Electric Shock," (identify part or parts not earth grounded) "are not bonded to ground, test before touching." The marking shall be provided on or adjacent to the ungrounded dead-metal parts, and shall be visible so that each part or group of parts is positively identified.

58.23 A unit in compliance with the requirements for a Class CTL panelboard in the Standard for Panelboards, UL 67, shall be marked "Distribution Panelboard" or the equivalent.

58.24 A unit with two or more branch circuit outputs that do not comply with either Part II of this standard or the applicable requirements for a Class CTL panelboard in the Standard for Panelboards, UL 67, shall be marked with the word "WARNING" and the following or equivalent: "Unit requires use of a Distribution Panelboard for proper connection."

58.25 A fixed power inverter/converter that exceeds the temperature limits specified in Table 38.1 – see footnote (j) of Table 38.1 – shall be legibly marked where readily visible after installation with the work "CAUTION" and the following or equivalent "Hot Surfaces – To Prevent Burns – Do Not Touch."

58.26 For a product with a charging function intended for charging lithium batteries where the product and the storage battery combination is not identified, the product shall be marked with the following or equivalent statement: “CAUTION – To Reduce the Risk of Fire, Use only battery packs that include the battery management system and all necessary protection for the battery pack integral to the pack.”

INSTRUCTIONS

59 Instruction Manual

59.1 The installation and operating instructions manual for a unit provided with a marking in lieu of integral ground-fault circuit-interrupter protection shall indicate that ground-fault circuit-interrupters shall be installed in the recreational vehicle wiring system to protect all branch circuits. In addition, if a marking as specified in (b) of the Exception to 24.1 is used, the installation and operation instructions manual shall also specify the manufacturer and catalog number for each acceptable ground-fault circuit-interrupter protective device.

59.2 A stationary or fixed power inverter/converter that exceeds the temperature limits specified in Table 38.1 – see footnote (j) of Table 38.1 – shall be provided with instructions specifying that: "The power unit is to be installed so that it is not likely to be contacted by people" or equivalent wording.

59.3 The operating instructions for a unit intended to be connected to the cigarette lighter or power outlet rated greater than 100 VA input shall include the following or equivalent wording. The blanks shall be completed with the appropriate current and voltage ratings based on the adapter input ratings. "CAUTION – Risk of Fire. Do not replace any vehicle fuse with a rating higher than recommended by the vehicle manufacturer. This product is rated to draw ___ amperes from a ___ V vehicle outlet. Ensure that the electrical system in your vehicle can supply this product without causing the vehicle fusing to open. This can be determined by making sure the fuse in the vehicle which protects the outlet is rated higher than ___ amperes. Information on the vehicle fuse ratings are typically found in the vehicle operator's manual. If a vehicle fuse opens repeatedly, do not keep on replacing it. The cause of the overload must be found. On no account should fuses be patched up with tin foil or wire as this may cause serious damage elsewhere in the electrical circuit or cause fire."

59.4 If required by Exception No. 1 or Exception No. 3 to 21.2.3, the instruction manual shall include a statement indicating that branch rated overcurrent protection for the ac output circuit is to be provided at the time of installation.

59.5 For converter/inverters that are intended to charge lithium based batteries, the instruction manual shall state the following or the equivalent: "The converter/inverter is intended to recharge batteries. The battery that is connected to this product is only suitable if it complies with the given battery standard for that battery type and is provided with a battery management system that will monitor and control the electrical and thermal health of the battery during charging. When installing this converter/inverter, the battery is to be verified as in compliance with the applicable battery standard."

PART II – POWER-CONVERTER SYSTEMS

60 General

60.1 The requirements in Sections 61 – 68 supplement and, in some cases, modify the general requirements in Sections 3 – 58.

CONSTRUCTION

61 Frame and Enclosure

61.1 An overall enclosure shall employ materials throughout that are acceptable for the purpose and shall be so constructed as to have the strength and rigidity necessary to resist the ordinary abuses to which it may be subjected, including the tests specified in this standard so that:

a) It will retain its shape;

b) Doors will close tightly; and

c) Covers, fronts, and the like will fit properly.

61.2 The enclosure shall not have an open hole or slot for the movement of an operating handle.

61.3 The portion of an enclosure housing the line-voltage circuit breaker shall completely enclose all live parts and wiring and shall comply with the requirements in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50, except for modifications and additional requirements as specified in this standard.

61.4 With reference to 61.3, a barrier shall be provided to separate a circuit-breaker compartment and field-wiring compartment from a ventilated portion of the enclosure. See 61.6.

61.5 Mating parts of an enclosure of a power converter system that incorporate a two-piece enclosure, such as a flush wall-mounted converter system, shall be polarized if the enclosure is intended to be mounted in only one way.

61.6 A but joint may be employed at a metal barrier used to separate the unit compartment from the field-wiring compartment or circuit-breaker compartment provided that:

a) Ventilating openings are located at least 1 in (25.4 mm) away from the joint; and

b) The barrier is located not more than 1/32 in (0.8 mm) from walls and covers.

61.7 A component housing line-voltage circuit breakers shall be sufficiently deep to allow a door or cover to be closed with the handle of a circuit in any operating position.

61.8 The thickness of sheet-metal enclosures for compartments other than line-voltage circuit-breaker and field-wiring connection compartments shall comply with the requirements in 7.3.

61.9 A door may employ a captive fastener that is designed to be closed by hand in lieu of a latch. Such fasteners shall be located or used in multiple so as to hold the cover closed over its entire length.

62 Power-Supply Assembly

62.1 A power-converter system shall be constructed and arranged to permit connection of the power-supply assembly for the required current rating. If two or more 15-A or 20-A circuits are provided, the main power-supply assembly shall be rated 30 A.

62.2 A power-converter system shall be provided with:

a) Complete detailed installation instructions for the power-supply assembly, and

b) The power-supply assembly strain-relief means either in position or loose in the wiring compartment.

62.3 A connector base motor-attachment plug intended for connection to a cord set may be provided for connection to the source of supply.

62.4 With reference to the requirement in 62.1, the power-supply assembly current rating shall be in accordance with Table 62.1.

Table 62.1
Minimum current rating of power-supply assembly

Number of line-voltage branch circuits	Current rating of branch circuit breakers, A	Minimum current rating of power-supply assembly, A
1	15[a]	15
1	20[a]	20
2	One 15 and one 20 or two 20	30
3	One 15 and two 20	30

[a] Ground-fault circuit-interrupter protection is required. See 64.2.

62.5 The power-supply cord shall comply with the requirements applicable to power-supply cords for recreational vehicles.

63 Supply and Output Connections

63.1 A supply- and remote-circuit wiring compartment shall be provided with pressure wire connectors, wire-binding screws, or pigtail leads for the input supply and remote circuits. A grounding bus shall be provided for the connection of each grounding conductor. Field-wiring leads shall not be used for grounding.

63.2 Supply and remote circuits shall be identified by color coding or marking.

63.3 A pigtail lead employed for a remote line-voltage circuit shall be provided with a wire connector, on the end of the lead and taped, or the lead may be cut, folded over and taped. See 63.4.

63.4 A pigtail lead intended for field connection shall be provided with strain relief complying with 43.3 so that stress on the lead will not be transmitted to terminals, splices, or interior wiring.

63.5 A compartment for supply connections shall be provided with acceptable connection means so that the grounded circuit conductor will be insulated from the equipment-grounding conductors and from equipment enclosures and other grounded parts.

63.6 A power-converter system shall incorporate a solderless pressure terminal connector acceptable for a No. 8 bare copper grounding conductor for bonding the system to the frame of a recreational vehicle.

63.7 A wiring terminal shall secure the maximum and minimum number of conductors of a size having an ampacity adequate for the application.

63.8 A wiring terminal shall be located so that it will be accessible for examination, and connections may be tightened or branch-circuit wires removed without loosening any screws that secure bus bars, switches, circuit breakers, fuseholders, or the like.

63.9 When installed as intended, an equipment-grounding terminal or terminal assembly shall provide a reliable bond to the frame or enclosure. The resistance of the connection between any installed equipment-grounding conductor and the frame or enclosure shall not exceed 0.005 Ω.

63.10 To determine whether a bonding connection complies with the requirement in 63.9, a current of 30 A is to be passed through the connection. The resulting drop in voltage is to be measured between a point on the conductor 1/16 in (1.6 mm) from the connection and a similar point on the frame or enclosure not less than 1/16 in from the bonding connection.

63.11 Except as indicated in 68.7 the equipment-grounding terminal or assembly shall be green or the head of the terminal screw shall be green and it shall not be likely to be removed during the normal servicing of the unit.

64 Overcurrent Protection

64.1 A power-converter system shall be provided with overcurrent protection as specified in Table 62.1. The circuit breakers shall be rated 125 V minimum. See 7.8 and 7.9.

64.2 With reference to 64.1, a power-converter system incorporating only one 15- or 20-A line voltage branch circuit shall employ ground-fault circuit-interrupter protection in accordance with the requirements for a Class A device contained in the Standard for Ground-Fault Circuit Interrupters, UL 943, which will serve to interrupt the supply circuit in the event of a ground fault, with or without any combination of the following fault conditions present in the supply circuit:

a) The ungrounded and grounded supply conductors transposed.

b) An open grounded circuit conductor.

64.3 With reference to 64.1, each circuit breaker shall be acceptable for branch-circuit protection and shall incorporate a manual off position properly identified. The circuit breaker shall be connected to open all ungrounded conductors of the circuit. A multiple-pole circuit breaker shall be of the common-trip type.

Exception: A combination of single-pole circuit breakers and handle ties that complies with the applicable requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489, may be used as the protection for each ungrounded conductor supplying line-to-line connected loads of a power-converter system rated for connection to one of the following circuits of a grounded system:

a) Single-phase circuit, or

b) 3-wire direct-current circuit.

64.4 There shall be no overcurrent-protective device in the permanently grounded wire of any circuit unless opening of the overcurrent-protective device simultaneously opens all the conductors of that circuit.

64.5 An accessible means shall be provided so that each branch circuit can be independently de-energized.

64.6 The input current rating of a power-converter system shall not exceed 50% of that of the branch circuit to which it will be connected.

65 Transfer Switch/Mechanisms

65.1 A transfer switch/mechanism provided to transfer from unit to line power shall disconnect both the grounded and ungrounded circuit conductors.

65.2 With reference to the requirement in 65.1 the rating of a transfer switch/mechanism and associated wiring shall be acceptable for the higher of the unit or line-supply ratings. See 68.6.

66 Spacings

66.1 An uninsulated live part shall be spaced at least 1 in (25.4 mm) from a door.

66.2 Spacings at line-voltage field-wiring terminals shall not be less than the values specified in Table 66.1.

Table 66.1
Minimum acceptable spacings

Potential involved	Minimum spacings between uninsulated live parts of opposite polarity, in (mm)				Minimum spacing through air or over surface between uninsulated live parts and grounded dead metal	
	Through air		Over surface			
V	in	(mm)	in	(mm)	in	(mm)
0 – 150	1/2	(12.7)	3/4	(19.1)	1/2	(12.7)
NOTE – Applies to the sum of the spacings involved where an isolated dead part is interposed. See 66.3.						

66.3 If an isolated dead metal part is interposed between or is in close proximity:

a) To live parts of opposite polarity;

b) To a live part and an exposed dead metal part; or

c) To a live part and a dead metal part that may be grounded,

the spacing may be not less than 3/64 in (1.2 mm) between the isolated dead metal part and any one of the other parts previously mentioned, provided the total spacing between the isolated dead metal part and the two other parts is not less than the value specified in Table 66.1.

PERFORMANCE

67 Temperature Test

67.1 The temperature test shall be conducted as indicated in Section 38, Temperature Test, except as indicated in 67.2 and 67.3.

67.2 Direct-current secondary-output circuits are to be loaded as specified in Section 34, Power Input Test. Line-voltage alternating-current remote circuits including internal loads are to be loaded to 80% of the circuit-breaker rating. Additional line-voltage circuits are to be resistance-loaded to an input current of 80% of the total input rating of the power-converter system.

67.3 The temperature rise on a bus, a connecting bar, and a factory-wired circuit-breaker terminal shall not exceed 65°C (117°F). The temperature of associated wiring – for example, supply assembly, remote circuit wiring, and the like – shall not exceed the rated temperature limit. All other temperature rises shall comply with the maximum acceptable temperature rises specified in Table 38.1.

MARKINGS

68 Details

68.1 A power-converter system shall be marked with the manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified, a distinctive catalog number or the equivalent, and the voltage rating and total current rating.

68.2 A power-converter system shall be marked to specify the rating of the factory-wired equipment provided on each individual line-voltage branch circuit – for example, a convenience receptacle mounted on the enclosure of a power-converter system, and the like.

68.3 With reference to the requirement in 68.2, if pressure terminals are provided for additional remote circuits, a power-converter system shall be marked, adjacent to the pressure terminals: "For connection of remote circuits," or the equivalent.

68.4 A power-converter system shall be marked "Suitable for direct connection to ____ ampere, 125 volt recreational vehicle power-supply assembly."

68.5 If a transfer mechanism is employed to switch from generator to line-power, a power-converter system shall be marked to specify the action required to switch the power unless the system is automatic.

68.6 If a combination line-generator system is provided, marking adjacent to the means for connection shall specify the maximum generator rating. See 65.2.

68.7 The color identification required by 63.11 need not be provided if the equipment-grounding terminal or assembly is identified by the marking "Equipment-Grounding Terminal" or a suitable abbreviation adjacent to the terminal on a wiring diagram.

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SUPPLEMENT SA – MARINE POWER CONVERTERS/INVERTERS AND POWER CONVERTER/ INVERTER SYSTEMS

INTRODUCTION

SA1 Scope

SA1.1 These requirements cover marine power units intended for permanent installation aboard vessels as covered by the Fire Protection Standard for Pleasure and Commercial Motor Craft, NFPA 302, the applicable publications of the American Boat and Yacht Council Inc., and Electrical Engineering Regulations Subchapter J (46 CFR, Parts 110-113) of the United States Coast Guard (USCG).

SA1.2 These requirements cover marine units which may also employ semiautomatic and fully automatic circuits for charging batteries.

SA1.3 Charging circuits in which the charging output current is manually controlled, requiring constant attention, shall not be employed.

SA1.4 These requirements supplement the applicable requirements in Sections 1 – 58, inclusive (Part I).

SA2 Glossary

SA2.1 FULLY AUTOMATIC BATTERY CHARGING CIRCUIT – A battery charging circuit in which the output current is proportional to the state of battery charge and system load with automatic compensation for input voltage variations.

SA2.2 IGNITION-PROTECTED DEVICE OR COMPONENT – A device or component that will not ignite a mixture of propane and air surrounding it under normal operating conditions. An ignition-protected device may not be explosion proof, as the term is applied to commercial vessels. An ignition-protected device may have exposed input and output wiring, as specified in the Fire Protection Standard for Pleasure and Commercial Motor Craft, NFPA 302, the applicable American Boat and Yacht Council Standards, and the USCG Regulations for uninspected vessels.

SA2.3 SEMIAUTOMATIC BATTERY CHARGING CIRCUIT – A charging circuit in which the output current is proportional to the state of battery charge and system load with the input voltage manually adjusted.

CONSTRUCTION

SA3 General

SA3.1 A marine unit shall employ mounting means such that it will be held securely in position when subjected to vibration, shock, pitching, yawing and rolling.

SA3.2 The battery charging circuit of a marine unit shall be provided with an ammeter or other similar means for indicating the output current. A battery charger incorporating means of manual input voltage adjustment shall also employ an input voltmeter. Voltage and current indicators employed that are other than an ammeter or a voltmeter shall not increase the risk of fire, electric shock, or injury to persons.

SA3.3 With reference to SA3.2, a meter may be located in an area remote from the marine unit provided:

a) The meter shunt is located within the marine unit enclosure.

b) Overcurrent protection for external meter leads is provided within the marine unit enclosure.

SA4 Frame and Enclosure

SA4.1 General

SA4.1.1 A marine unit intended to be mounted on a bulkhead or other vertical surface shall be provided with mounting holes of the same nominal size as the mounting screws.

SA4.1.2 Keyhole slots shall not be used for mounting a marine unit.

Exception: Keyhole slots for mounting may be provided if there are at least two round holes sized to accommodate permanent mounting screws or the keyhole slots are arranged so that complete removal of at least two mounting screws is needed in order to remove the unit.

SA4.1.3 The enclosure of a marine unit intended to be installed in an open cockpit or on a weatherdeck shall comply with the requirements in Sections SA4, General, Section SA5, Protection Against Corrosion, Section SA16, Leakage Current, Insulation Resistance, and Dielectric Voltage Withstand (Repeated) and Section SA17, Salt Spray Corrosion Test.

SA4.2 Enclosures for open cockpit or weatherdeck mounting

SA4.2.1 The enclosure of a marine unit for open cockpit or weatherdeck mounting shall be constructed so as to exclude a beating rain.

SA4.2.2 The requirements in SA4.2.3 – SA4.2.6 apply to marine units that are intended for permanent open cockpit or weatherdeck mounting installation.

SA4.2.3 When subjected to the rain test described in Section SA17, Salt-Spray Corrosion Test, an enclosure shall prevent rain from entering the enclosure.

SA4.2.4 A gasket employed in a marine unit for open cockpit or weatherdeck mounting shall be tested as specified in Section SA25, Accelerated Aging of Gaskets, Sealing Compounds and Adhesives.

SA4.2.5 A marine unit for open cockpit or weatherdeck mounting shall be provided with external means for mounting.

Exception: An enclosure may be provided with internal means for mounting if the mounting means is designed so as to prevent water from entering the enclosure.

SA4.2.6 All openings for conduit other than in the bottom shall be threaded.

SA5 Protection Against Corrosion

SA5.1 Iron and steel parts shall be protected against corrosion by enameling, painting, galvanizing, plating, or an equivalent means.

Exception No. 1: Bearings, laminations, other parts of iron or steel such as washers and screws need not comply with this requirement.

Exception No. 2: A part the corrosion of which would not result in a risk of fire, electric shock or injury to persons need not comply with this requirement.

SA5.2 The interior of a metal compartment housing a lead-acid battery shall be protected by two coats of acid-resistant paint, two coats of enamel individually baked on, or the equivalent.

SA5.3 An enclosure of sheet-steel intended for outdoor use shall be protected against corrosion by one of the following coatings: