UL 458

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

Underwriters Laboratories Inc. (UL)
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UL Standard for Safety
for
Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts, UL 458

Fourth Edition, Dated December 14, 1993

Revisions: This Standard contains revisions through and including September 11, 1998.

A change is indicated by a note following the affected item. The note is preceded and followed by an asterisk.

The revisions dated September 11, 1998 include a reprinted title page (page 1) for this Standard.

The revisions dated September 11, 1998 were issued to make editorial corrections.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

The master for this Standard at UL's Northbrook Office is the official document insofar as it relates to a UL service and the compliance of a product with respect to the requirements for that product and service, or if there are questions regarding the accuracy of this Standard.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing, Recognition, and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

This Standard consists of pages dated as shown in the following checklist:

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2	September 11, 1998
3	July 8, 1996
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1

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 14, 1993

Approval as an American National Standard (ANSI) covers the numbere d paragraphs on pages dated December 14, 199 3, January 27, 1995, and September 11, 1998. Th ese pages should not be discarded when revised or additional pages are issued if it is desired to retain the ANSI approved text.

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Approved as ANSI/UL 458-1985, December 13, 1985
Approved as ANSI/UL 458-1991, March 22, 1991
Approved as ANSI/UL 458-1996, March 8, 1996

Revisions of this standard will be made by issuing revised or additional page s bearing their date of issue. A UL Standar d is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction differing from those detailed in the requirements of this Standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

1.1 These requirements cover fixed and stationary power converters and power-converter systems having a rated nominal input of 120, 120/240, or 240 volts, alternating current and a nominal output of 24 volts or less, 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.

1.1 effective April 13, 1993

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 volts ac 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.

1.2 effective April 13, 1993

1.3 These requirements also cover converters/inverters that are additionally intended to charge batteries.

1.3 effective April 13, 1993

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

1.5 Power-inverters covered by Part I of this standard are intended for connection to a 12- or 24- volt dc battery supply.

1.5 effective April 13, 1993

1.6 Power-converter systems covered by Part II of this standard are intended for direct connection to a power-supply assembly and incorporate means for the connection of a maximum of three line-voltage branch circuits only.

1.7 Power-inverter systems covered by Part II of this standard are intended for direct connection to a power-supply assembly and incorporate means for the connection of a maximum of three line-voltage branch circuits only; not including the main disconnect.

1.7 effective April 13, 1993

1.8 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.

1.8 effective April 13, 1993

1.9 A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this standard, and that involves a risk of fire, electric shock, or injury to persons shall be evaluated using the appropriate additional component and end-product requirements to determine that the level of safety as originally anticipated by the intent of this standard is maintained. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard shall not be judged to comply with this standard. Where appropriate, revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

1.9 revised September 11, 1998

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.

2.2 effective April 13, 1993

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.

2.3 effective April 13, 1993

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.

2.4 effective April 13, 1993

2.5 CLASS 2 TRANSFORMER – A step-down, isolation type transformer having a secondary voltage of not more than 30 volts rms (42.4 peak) under any condition of loading including open circuit and complying with the applicable requirements in the Standard for Class 2 and Class 3 Transformers, UL 1585.

2.5 effective April 13, 1993

2.6 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.

2.6 effective April 13, 1993

2.7 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.

2.7 effective April 13, 1993

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

2.8 effective April 13, 1993

2.9 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.

2.9 effective April 13, 1993

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

2.10 effective April 13, 1993

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

2.11 effective April 13, 1993

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

2.12 effective April 13, 1993

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

2.13 effective April 13, 1993

2.14 LOW-VOLTAGE, LIMITED ENERGY CIRCUIT – A circuit involving an alternating voltage of not more than 30 volts rms (42.4 volts peak) or a direct voltage of not more than 60 volts 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.

2.14 effective April 13, 1993

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

2.15 effective April 13, 1993

2.16 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.

2.16 effective April 13, 1993

2.17 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.

2.17 effective April 13, 1993

2.18 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.

2.18 effective April 13, 1993

2.19 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.

2.19 effective April 13, 1993

2.20 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.

2.20 effective April 13, 1993

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

2.21 effective April 13, 1993

2.22 PROTECTED ENVIRONMENT ENCLOSURE – A part or total enclosure of an appliance that is constructed as defined in Section 7, Enclosures Used for Protected Environments, so as to maintain a protected environment.

2.22 effective April 13, 1993

2.23 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 volts or more and either an available continuous power level of 240 volt-amperes or more, or a reactive energy level of 20 joules or more. For example, a tool, or other metal short circuiting a component may cause a burn or a fire if enough energy is available at the component to vaporize, melt, or more than warm the metal.

2.23 effective April 13, 1993

2.24 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 volts peak ac or 60 volts dc, and the continuous current flow through a 1500 ohm resistor connected across the potential exceeds 5 milliamperes.

2.24 effective April 13, 1993

2.25 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 6, Frame and Enclosure.

2.25 effective April 13, 1993

2.26 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.

2.26 effective April 13, 1993

2.27 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.

2.27 effective April 13, 1993

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

2.28 effective April 13, 1993

2.29 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.

2.29 effective April 13, 1993

2.30 STAND ALON E UNITS – Units that are intended to be permanently mounted in place but not recessed in the wall.

2.30 effective April 13, 1993

2.31 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.

2.31 effective April 13, 1993

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

2.32 effective April 13, 1993

2.33 TOOL – A sc rewdriver, coin, key, or any other object that may be used to operate a screw latch, or simila r fastening means.

2.33 effective April 13, 1993

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

2.34 effective April 13, 1993

2.35 USER SERV ICING – Any form of servicing that can be performed by personnel other than those who ar e trained to maintain the unit. Some examples of user servicing are:

a) The installation of accessories by me ans 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.

2.35 effective April 13, 1993

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this s tandard shall comply with the requirements for that component.

3.1 effective December 14, 1993

3.2 A component need not comply with a specific requirement that:

a) Involves a feature or characteristic not needed 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 comp onent shall be used in accordance with its recognized rating established for the intended conditions for use.

3.3 effective December 14, 1993

3.4 Specific components are recognized as being 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 for which they have been recognized.

3.4 effective December 14, 1993

4 General

4.1 Units of Measurement

4.1.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

4.2 Undated References

4.2.1 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

5 General

5.1 A converter or inverter shall employ materials that are acceptable for the intended use.

5.1 effective April 13, 1993

6 Frame and Enclosure

6.1 A converter or inverter 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.

6.1 effective April 13, 1993

6.2 A converter or inverter 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.

6.2 effective April 13, 1993

6.3 A cast- or sheet-metal section of the enclosure shall have a thickness not less than that specified in Table 6.1.

Table 6.1
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,	
	Inch	(mm)	Inch	(mm)	Inch	(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)

6.4 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 6.6 need not comply with this requirement.

6.4 effective April 13, 1993

6.5 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.

6.6 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 inch^2 (387.1 mm^2) or less. Nonmetallic parts protruding through a hole having an area larger than 0.6 inch^2 shall be made of materials that comply with the requirement in 6.4.

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

6.6 revised September 11, 1998

6.7 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.

6.7 effective April 13, 1993

6.8 Overtemperature and overcurrent protection shall be located within the converter or inverter enclosure. See 20.2.1 – 20.2.3.

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.

6.8 effective April 13, 1993

6.9 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.

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

6.10 effective April 13, 1993

6.11 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.

6.12 Material supporting terminals or used as internal electrical insulation of an electrical instrument shall comply with the requirements in Section 16, 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.

6.13 Supporting feet of a converter or inverter 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.

6.13 effective April 13, 1993

6.14 A compartment or part of an enclosure that will contain splices made in the field shall not be provided with ventilating openings.

6.15 The enclosure of a converter or inverter 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 converter or inverter is supported. See Section 49, Burnout Test.

6.15 effective April 13, 1993

6.16 If a screen is needed in the bottom of an enclosure to comply with the requirements in 6.18 and 6.19, it shall be 14 mesh steel with a minimum wire diameter of 0.018 inch (0.46 mm) and shall be mechanically secured in position.

6.17 For a converter or inverter having holes in the bottom of the enclosure, the requirements in 6.15 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.

6.17 effective April 13, 1993

Table 6.2
Knockout or hole sizes and dimensions of bushings

Trade size of conduit	Knockout or hole diameter		Bushing dimensions			
			Overall diameter		Height	
Inches	Inches	mm	Inches	mm	Inches	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

Table 6.2 effective April 13, 1993

6.18 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 49.1.1 and 49.2.1.

6.19 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 49.3.4.

7 Enclosures Used For Protected Environments

7.1 A protected environment enclosure provided for compliance with 28.1.1 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 51.

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

7.1 effective April 13, 1993

7.2 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.

7.2 effective April 13, 1993

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

7.3 effective April 13, 1993

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

7.4 effective April 13, 1993

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

7.5 effective April 13, 1993

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

8.1 General

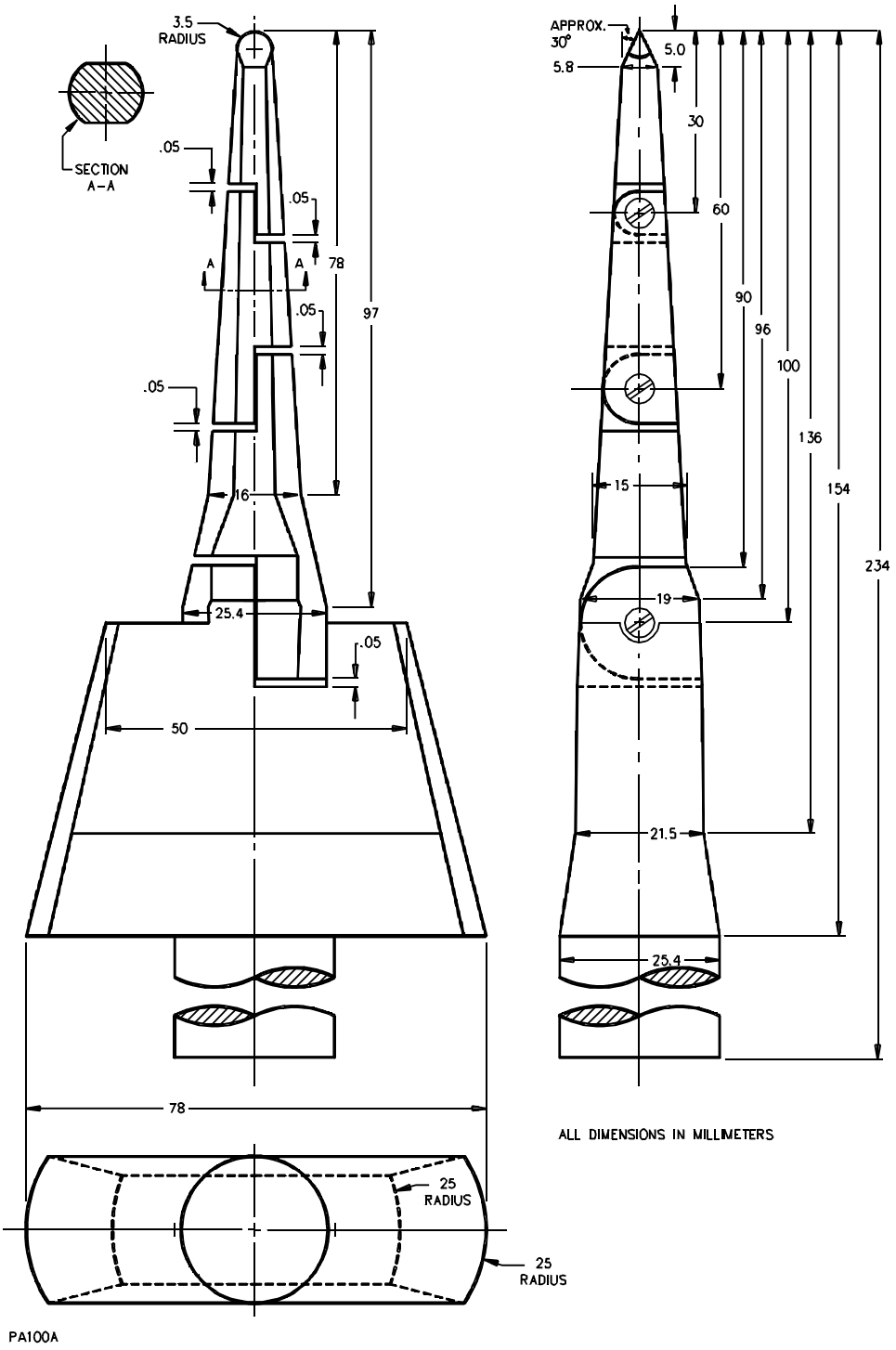
8.1.1 An uninsulated live part, film-coated wire, or moving part, that could result in a risk of electric shock or injury to persons shall be located or enclosed so that unintentional contact is precluded.

8.1.1 effective April 13, 1993

8.1.2 An opening in the enclosure of a converter or inverter that will not permit entrance of a 3/4 inch (19.1 mm) diameter rod is acceptable if a probe as illustrated in Figure 8.1 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.

8.1.2 effective April 13, 1993

Figure 8.1
Accessibility probe



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

Exception: Perforated sheet metal not less than 0.020 inch (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.

8.1.3 effective April 13, 1993

8.1.4 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.

8.1.4 effective April 13, 1993

8.2 User servicing

8.2.1 Live parts, film-coated wire, and moving parts shall be arranged and covers located so as to reduce th e 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 converter or inverter.

8.2.1 effective April 13, 1993

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

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

b) Recessed at least 1/8 inch (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 8.2.1, 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.

8.2.2 effective April 13, 1993

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

8.2.4 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.

8.3 Serviceman servicing

8.3.1 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.

8.3.2 The electrical components mentioned in 8.3.1 include a fuse and an adjustable control.

8.3.3 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 57.22.

8.3.3 effective April 13, 1993

9 Assembly

9.1 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 28, Spacings.

9.2 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.

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

9.4 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.

10 Protection Against Corrosion

10.1 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.

11 Supply Connections

11.1 Permanently-connected converters or inverters

11.1.1 General

11.1.1.1 A converter or inverter 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 converter or inverter.

11.1.1.1 effective April 13, 1993

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

11.1.1.3 A knockout shall be surrounded by a flat surface adequate for seating of a conduit bushing or locknut of the appropriate size.

11.1.1.4 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 converter or inverter is installed as intended.

11.1.1.4 effective April 13, 1993

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

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

11.1.1.6 effective April 13, 1993

11.1.1.7 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 11.1.1.4.

11.1.1.8 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.

11.1.1.9 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.

11.1.1.9 effective April 13, 1993

11.1.2 Wiring terminals and leads

11.1.2.1 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 converter or inverter is installed.

11.1.2.1 effective April 13, 1993

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

11.1.2.2 effective April 13, 1993

11.1.2.3 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 No. 10 AWG or smaller conductor if upturned lugs or the equivalent are provided to hold the wire in position.

11.1.2.4 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.

11.1.2.5 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 No. 14 AWG conductor.

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

11.1.2.6 A wire-binding screw shall thread into metal.

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

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

11.1.2.8 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.

11.1.2.9 Upturned lugs, a cupped washer, or the equivalent shall be capable of retaining a conductor of the size specified in 11.1.2.2 under the head of the screw or washer.

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

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

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

11.1.2.12 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.

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

11.1.2.14 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.

11.1.2.15 With reference to the requirements in 11.1.2.14, 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.

11.1.2.16 With reference to 11.1.2.15, guards provided along the sides of terminals and extending not less than 1/4 inch (6.4 mm) beyond the terminals before wiring, with a corresponding guard between double-pole switching mechanisms, are acceptable.

11.1.2.17 To determine whether a construction other than that described in 11.1.2.16 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 inches (152 mm) inside the box from its point of entrance into the box.

11.2 Cord connection

11.2.1 General

11.2.1.1 Other than a flush-wall mounted converter or a converter or inverter for which specific installation instructions are required, a converter or inverter 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, SE OO, SO, ST, STO, SJ, SJE, SJEOO, SJO, SJT, SJTO, SP-3, or SPT-3 flexible cord with a grounding conductor.

11.2.1.1 revised July 8, 1996

11.2.1.2 The current and voltage ratings of a flexible supply cord and attachment plug for a converter or inverter shall not be less than the input rating of the converter or inverter. The loads drawn by a single or duplex receptacle shall be included in determining the input rating as described in 55.4.

11.2.1.2 effective April 13, 1993

11.2.1.3 The length of supply cord external to the converter or inverter shall not be more than 3 feet (914 mm) measured from the face of the attachment plug to the point of entry.

11.2.1.3 effective April 13, 1993

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

11.2.1.4 effective April 13, 1993

11.2.1.5 The ampacity of the attachment plug shall not be less than 125 percent of the marked input rating of the converter or inverter.

11.2.1.5 effective April 13, 1993

11.2.1.6 A cord-connected converter 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.

11.2.2 Strain relief

11.2.2.1 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 42.1.

11.2.2.2 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.

11.2.2.2 revised July 8, 1996

11.2.2.3 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.

11.2.2.4 Means shall be provided to prevent the flexible cord from being pushed into the converter or inverter 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.

11.2.2.4 effective April 13, 1993

11.3 Bushings

11.3.1 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.

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

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

11.3.4 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 inch (1.6 mm) thick where the cord passes through the enclosure.

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

12 Low-Voltage Output Connections and Wiring

12.1 General

12.1.1 A converter shall have one of the following provisions for output connections:

a) A wiring compartment and terminals complying with the requirements in 12.1.2 – 12.1.5,

b) A receptacle or attachment plug complying with the requirements in 12.1.6 – 12.1.12,

c) Unenclosed individual leads complying with the requirements in 12.1.13 – 12.1.15.

12.1.2 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.

12.1.3 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.

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

12.1.5 A field-wiring terminal assembly provided as part of a transfer switch or relay shall comply with the requirements in 11.1.2.1 – 11.1.2.10, and shall be of such size as to accommodate a load based on 1.25 times the output current rating of the converter. A lead provided for this purpose shall be capable of carrying the same current without exceeding its temperature rating.

12.1.6 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.

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

12.1.8 An attachment plug or a receptacle other than as mentioned in 12.1.9 shall be secured to the enclosure or to another rigid part of the converter.

12.1.9 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 converter 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 feet (914 mm). The cord shall comply with the requirements for strain-relief specified in Section 42, Strain Relief Test.

12.1.10 An attachment-plug receptacle shall have recessed contacts.

12.1.11 If a matching attachment plug or receptacle is used on a converter, the converter shall be marked in accordance with 57.19.

12.1.12 Unless a receptacle and its attachment plug have been investigated for current interruption, the converter shall be marked in accordance with 57.20.

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

12.1.14 Unenclosed individual leads intended for connection external to the converter shall comply with the requirements in Section 42, Strain Relief Test.

12.1.15 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.

12.1.16 Each secondary-output branch circuit shall be marked in accordance with 57.5 to indicate the corresponding branch-circuit protection provided for each secondary-output connection.

12.2 Cigar lighter inputs

12.2.1 An inverter intended to be connected to the cigar lighter outlet of a vehicle, while delivering its normal output load, shall not exceed 8 amperes at the cigar lighter outlet.

12.2.1 effective April 13, 1993

13 Secondary Circuits

Section 13 effective April 13, 1993

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

13.2 All secondary circuits other than as specified in 13.3 – 13.11, are to be investigated as primary circuits. In addition, all safety circuits shall be investigated using the requirements for primary circuits.

13.3 Except as noted in 28.1.13, 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.

13.4 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.

13.5 Except as noted in 28.1.13 and 28.1.14, a circuit that does not extend out of the converter or inverter need not be investigated if the open-circuit potential or no-load output of the supply is:

a) Not more than 42.4 volts peak ac or 60 volts dc; and

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

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

2) 150/V max amperes for 30-60 volts dc,

when measured in accordance with 36.1 and 36.2.

13.6 The power supply of a circuit as mentioned in 13.5 that is not limited to available energy in accordance with 13.5(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 13.9 – need not be investigated if the current is limited in accordance with 13.7, 13.8 or 13.9.

13.7 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 13.6 shall be rated or set at not more than the values specified in Table 13.1.

13.8 A fuse or circuit protective device may be connected in the primary of the transformer to limit the current in accordance with 13.6 provided that the protection is equivalent to that specified in 13.7 as determined by the Overcurrent Protection Calibration Test, Section 44.

Table 13.1
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 31.1.

13.9 One or more resistors or a regulating network used to limit the current in accordance with 13.6 shall be such that the current under any condition of loading including short circuit does not exceed 8 amperes measured at 1 minute of operation.

13.10 If a regulating network is used to limit the voltage or current in accordance with 13.5 – 13.9, 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.

13.11 In a circuit of the type described in 13.6, 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.

14 Live Parts

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

14.2 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 volts rms (42.4 volts peak) or less; but unplated iron or steel is not acceptable. Stainless steel and other corrosion-resistant alloys may be used for current-carrying parts.

14.3 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.

14.4 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.

15 Internal Wiring

15.1 General

15.1.1 The internal wiring of a converter or inverter 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.

15.1.1 effective April 13, 1993

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

15.1.3 Unless a converter or inverter 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.

15.1.3 effective April 13, 1993

15.1.4 The length of the power-supply cord inside a converter or inverter shall not be more than the need for the electrical connections.

15.1.4 effective April 13, 1993

15.1.5 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 15.1.2;

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 15.1.2 is reliably secured on each individual conductor.

15.2 Tubing

15.2.1 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.

15.2.2 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 15.2.3, the wall thickness shall comply with the requirements for the tubing as a component.

15.2.3 Polyvinyl chloride tubing shall not be less than 0.017 inch (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-inch-thick polyvinyl chloride tubing.

15.3 Protection of wiring

15.3.1 Internal wiring shall be protected if, when judged in accordance with 8.1.2, 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.

15.3.2 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.

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

15.3.3 effective April 13, 1993

15.3.4 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.

15.3.5 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 inch (4.8 mm) into a wireway.

15.4 Electrical connections

15.4.1 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.

15.4.2 With reference to 15.4.1, 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.

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

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

15.4.5 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.

15.4.6 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.

15.4.7 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.

15.5 Separation of circuits

15.5.1 Unless provided with insulation acceptable for the highest of the circuit voltages, factory-installed insulated conductors of different circuits within a converter or inverter 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.

15.5.1 effective April 13, 1993

15.5.2 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.

15.5.3 Field-installed conductors of a circuit shall be segregated (see 15.5.4) or separated by barriers (see 15.6.1 – 15.6.4) 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.

15.5.4 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 inch (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 inches (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.

15.6 Barriers

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

15.6.2 A barrier of metal shall be at least as thick as specified in 6.3. A barrier of insulating material shall not be less than 0.028 inch (0.71 mm) thick and shall be supported so that it cannot be readily deformed to defeat its purpose.

15.6.3 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 inch (1.6 mm) from the enclosure walls and interior mechanisms, component-mounting panels, and other parts that serve to provide segregated compartments.

15.6.4 With reference to 15.6.3, 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.

16 Insulating Materials

16.1 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.

16.2 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.

17 Transformers

Section 17 effective April 13, 1993

17.1 General

17.1.1 A transformer used to supply a Class 2 circuit, that extends from the converter or inverter 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 17.1.2 – 17.2.3 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.

17.1.2 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.

17.1.3 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 Cutoffs for Use in Electrical Appliances and Components, UL 1020.

17.2 Coil insulation

17.2.1 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 17.1.

17.2.2 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 8, shall comply with Note a or c of Table 17.1.

17.2.3 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 17.1.

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 17.1,

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 47.10.1 – 47.11.1.

d) The transformer complies with the induced potential tests specified in 40.1 – 40.4.

17.2.4 With reference to (c) of the Exception to 17.2.3, 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 2.14 or a limited energy circuit in accordance with 2.12.

Table 17.1
Transformer insulation

	Insulation required	Type of insulation
1.	Insulation between the primary wires of opposite polarity and between secondary wires of opposite polarity having a potential greater than 30 volts rms (42.4 volts peak)	a, b, c or d
2.	Insulation between the primary and any secondary winding	a, b, c or d
3.	Insulation between any winding or lead connections and dead-metal parts	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 converter or inverter, 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 inch (0.71 mm); polyethylene terephthalate film, not less than 0.007 inch (0.178 mm) thick; or aramid paper, not less than 0.0085 inch (0.203 mm) thick.

[b] A thermoplastic or thermostat coil form not less than 0.028 inch thick.

[c] A material having a thickness less than 0.028 inch may be used provided that it is equivalent to Note a or b and the material has a minimum dielectric breakdown strength of 5000 volts for the thickness used when tested as specified in Testing on Transformer Insulating Materials, Section 41.

[d] Spacings specified in Table 17.2 may be used in place of the specified insulation.

Exception: Spacings in Table 28.2, 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 inch (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 inch 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 volts for the thickness used for Note e and 5000 volts for the thickness used for Note f when tested as specified in Testing on Transformer Insulating Materials, Section 41.

[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 17.2 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 39.1 and 39.2. 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 40.1 – 40.4.

Table 17.2
Spacings within a transformer

Potential involved, volts	Minimum spacing through air and over surface, inch (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 Resistors

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

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

19 Switches and Controllers

19.1 A switch or other control device shall have current and voltage ratings not less than those of the circuit that it controls when the converter or inverter is operated as intended.

19.1 effective April 13, 1993

19.2 A primary-circuit switch that controls an inductive load having a power factor less than 75 percent, such as a transformer or some ballasts, and 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.

19.3 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 amperes or more may be used to control a 15-watt or smaller lamp.

20 Overload-Protective Devices

20.1 General

20.1.1 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 converter is installed in accordance with manufacturer's installation instructions.

20.1.2 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.

20.2 Overcurrent-overtemperature protection

20.2.1 Integral overtemperature or overcurrent protection for all secondary circuits shall be provided. See 6.6 – 6.7.

20.2.2 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.

20.2.3 If secondary output load branch circuit protection is provided, the overcurrent-protective devices shall be fuses or manually reset circuit breakers. See 6.8 – 6.9.

20.2.4 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 converter or inverter 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.

20.2.4 revised September 11, 1998

21 Fuses and Fuseholders

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

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

21.2 effective April 13, 1993

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

21.3 effective April 13, 1993

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

21.4 effective April 13, 1993

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

21.5 effective April 13, 1993

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

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

22 Receptacles

22.1 A 15- or 20-ampere 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 converter or inverter.

22.1 effective April 13, 1993

23 Inverter Output Circuits

23.1 Inverter equipment having output circuits for supplying 120 volts, 60 hertz, 2-wire with ground or 120/240 volts, 60 hertz, 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: Inverter equipment 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 equipment is marked in accordance with 57.22, and

b) The installation and operating instructions manual for the inverter comply with 58.1.

Exception No. 2: A portable inverter:

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

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

need not be provided with integral ground-fault circuit-interrupter protection.

23.1 revised January 27, 1995

24 Lampholders

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

24.1 effective April 13, 1993

24.2 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.

25 Capacitors

25.1 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.

25.2 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 inch (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 converter having an enclosure that complies with the requirements in 6.1 – 6.4.

26 Transient Voltage Surge Suppressors

26.1 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 Transient Voltage Surge Suppressors, UL 1449.

26.1 effective April 13, 1993

27 Printed Wiring

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

No Text on This Page

27.2 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 converter or inverter.

27.2 effective April 13, 1993

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

28 Spacings

28.1 General

28.1.1 General environment spacings shall be as specified in Table 28.1. Protected environment spacings – see 7.1 – 7.5 – shall be as specified in Table 28.2. For the purpose of this requirement, a general environment is considered to be an environment other than a protected environment.

Exception No. 1: Converters or inverters 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 Tables 28.1 and 28.2. See 28.1.2 and 28.1.3.

Exception No. 2: Spacings may be as provided in 28.2.1 if liners and barriers are used.

Exception No. 3: Spacings may be as provided in 28.1.2, 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 28.1.2.

Exception No. 4: On printed wiring boards having a flammability classification of 94V-0 and constructed from a base material having a minimum Comparative Tracking Index (CTI) rating of 100 and 175 volts 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 48, or an analysis of the circuit indicates that no more than 12.5 milliamperes 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 inch. If these foils are in circuit described in 13.3 – 13.9, no spacing is specified.

Exception No. 6: The spacing requirements in Tables 28.1 and 28.2 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 Tables 28.1 and 28.2. 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.

28.1.1 effective April 13, 1993

28.1.2 With reference to Exception No. 1 to 28.1.1 and with reference to 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 converters or inverters in which the transient voltages are known and are controlled by a transient suppressive device and to converters or inverters that withstand 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.

28.1.2 effective April 13, 1993

28.1.3 A converter or inverter shall be considered overvoltage category II and/or overvoltage category I as defined in UL 840.

28.1.3 effective April 13, 1993

28.1.4 In order to apply Clearance B (controlled overvoltage) clearances as defined in UL 840, controlled overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product.

28.1.4 effective April 13, 1993

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

28.1.5 effective April 13, 1993

28.1.6 With reference to Exception No. 1 to 28.1.1 and the pollution degree levels described in UL 840, pollution degree 2 is considered applicable to converters or inverters employing protected environment enclosure as described in Section 7, Enclosures Used for Protected Environments. Pollution degree 3 is considered applicable to converters or inverters intended for use in a general environment.

28.1.6 effective April 13, 1993

Table 28.1
Spacings for converters or inverters intended for use in a general environment

Involved in V RMS (peak)	Minimum spacings, inch (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 28.1.1.

[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 inch (6.4 mm).

Table 28.1 revised September 11, 1998

Table 28.2
Spacings for converters or inverters intended for use within a protected environment

Involved in V RMS (Peak)	Minimum spacings, inch (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 28.1.1.

[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 ground dead-metal part shall not be less than 1/4 inch (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 inch (0.58 mm) plus 0.0002 inch (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 inch (1.2 mm) is acceptable.

Table 28.2 effective April 13, 1993

28.1.7 With reference to Exception No. 2 to 28.1.1 concerning conformal coatings, minimum spacings of 1/32 inch (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.

28.1.7 effective April 13, 1993

28.1.8 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 Tables 28.2 and 28.3 do not necessarily apply to the inherent spacings of a component of a converter, 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 Tables 28.2 and 28.3.

Exception No. 2: As provided in 28.2.1.

28.1.8 effective April 13, 1993

Table 28.3
Minimum acceptable spacings between an uninsulated live part and a metal enclosure or other accessible dead metalpart, including a fitting for conduit or armored cable

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

28.1.9 With reference to 28.1.8, a properly applied lock washer is considered an acceptable method of rigidly securing a part.

28.1.9 effective April 13, 1993

28.1.10 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.

28.1.10 effective April 13, 1993

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

28.1.11 effective April 13, 1993

28.1.12 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.

28.1.12 effective April 13, 1993

28.1.13 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 2.14. Spacings are determined by the applicable dielectric voltage withstand test specified in Section 39, Dielectric Voltage-Withstand Test.

28.1.13 revised September 11, 1998

28.1.14 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 2.12. Spacings in circuits that exceed 30 volts (42.4 peak) are to be investigated by the applicable dielectric voltage-withstand test specified in Section 39, 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.

28.1.14 revised September 11, 1998

28.1.15 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.

28.1.16 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 39.1.

28.2 Insulation barriers

28.2.1 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 28.1.1 shall not be less than 0.028 inch (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 inch (0.33 mm) thick may be used in conjunction with an air spacing of not less than 50 percent 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 volts rms or less.

Exception No. 2: Mica not less than 0.006 inch (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 28.2.1 may be used if, upon investigation, it is found to be acceptable for the particular application.

28.2.1 effective April 13, 1993

28.2.2 A wrap of thermoplastic tape, complying with the requirements in the Standard for 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 inch (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 inch (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 37.

d) The tape is not subject to compression.

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

28.2.2 effective April 13, 1993

29 Grounding

29.1 A converter or inverter shall have a terminal or lead for connecting the metal enclosure and enclosure parts to ground.

Exception: A portable inverter:

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

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

need not be provided with a terminal or lead.

29.1 revised January 27, 1995

29.2 With reference to 29.1, in a converter or inverter 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 converter, 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.

29.2 effective April 13, 1993

29.3 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.

29.4 A wire-binding screw for the connection of a field-installed equipment grounding conductor shall have a green colored head that is hexagonal, slotted, or both. 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 converter or inverter.

29.4 effective April 13, 1993

29.5 The grounding connection shall be located so that it is unlikely to be removed during normal servicing of the converter or inverter.

29.5 effective April 13, 1993

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

29.7 A wiring terminal for connection of an equipment-grounding conductor shall comply with the requirements in 11.1.2.3 – 11.1.2.9.

29.8 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.

29.9 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.

29.10 A terminal shall be provi ded on the outside of a converter or inverter solely for connection of the enclosure to the chassis of a land vehicle. The terminal shall be of a size th at will secure a No. 8 AWG copper bonding conductor, and shall be marked in accordance with Section 56, Details (plainly identified b y being marked "Chassis Bonding Lug", or with the IEC Publication 417, Symbol 5019.) See Figure 29.1.

Exception: This requirement does not apply to marine crafts.

29.10 effective January 27, 1995

Figure 29.1
IEC Publication 417, Symbol 5019

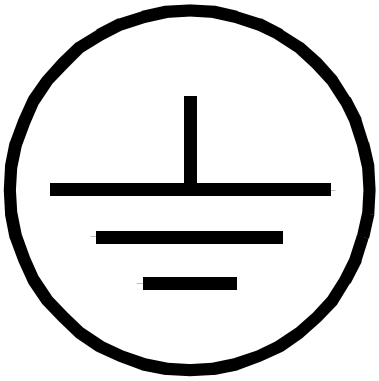


Figure 29.1 effective April 13, 1993

29.11 The terminal menti oned in 29.10 shall not be secured to a part of the enclosure that is readily movable, such as a cover, hood, and the like.

30 Bonding of Internal Parts

30.1 General

30.1.1 An exposed d ead 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 adequately grounded or bonded interposing metal barrier or part in such a manner that the interposed part will be the first to be subjected to an electrical fault.

30.1.2 An uninsulated metal part, such as a ba ffle, 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.

30.1.3 With reference to 30.1.2, internal parts that are painted or otherw ise coated prior to assembly shall be secured in position by a fastening means that will reliably penetrate the surface coating.

30.1.3.1 The grounding connection and the output neu tral of an inverter that is intended to be connected to the cigar lighter outlet of a vehicle shall be bonded to the inverter frame or enclosure. See 12.2.1.

30.1.3.1 added January 27, 1995

30.1.4 Uninsula ted live parts and wiring shall be separated from a moving or movable part, such as a relay o r contactor magnet and armature, by clamping, positioning, or an equivalent means that will maintain permanen t separation.

30.1.5 A metal part, such as an adhesive-attached metal m arking plate, a screw, a handle, or the like, that is located on the outside of an en closure or cabinet, need not be bonded if it is isolated from electrical components and wiring by a ground ed metal part so that it is not likely to become energized, or separated from wiring and spaced fro m 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.

No Text on This Page

30.2 Bonding conductor

30.2.1 Bonding shall be accomplished by metal-to-metal contact between parts or by a separate bonding conductor as specified in 30.2.2 – 30.2.4.

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

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

30.2.4 A separate bonding conductor shall not be smaller than the conductors supplying a converter.

30.2.5 A separate bonding con ductor for an inverter shall have an ampacity rating equal to the total inverter output.

30.2.5 effective April 13, 1993

PERFORMANCE

31 General

31.1 A representative sample of a converter or inverter shall be subjected to the tests described in Sections 32 – 52. Unless otherwise specified, all tests are to be conducted at not less than the rated voltage of the converter or the highest of a rated voltage range, and an ambient temperature of 25 °C at rated frequency. See Table 31.1.

31.1 effective April 13, 1993

Table 31.1
Values of test voltages

Rated voltage	Test voltage
110 – 115	120
Between 116 – 219	Rated voltage
220 – 230	240

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

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

32 Leakage Current Test

32.1 The leakage current of a cord-connecte d converter or inverter rated for a nominal 120-volt supply, when tested in accordance with 32.2 – 32.6 shall not be more than 0.75 milliampere.

32.1 effective April 13, 1993

32.2 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 8.1.2. 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 volts rms (42.4 volts peak). 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.

32.3 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 centimeters in contact with the surface. If the surface is less than 10 by 20 centimeters, 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 converter.

32.4 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 ohms resistive shunted by a capacitance of 0.15 microfarad.

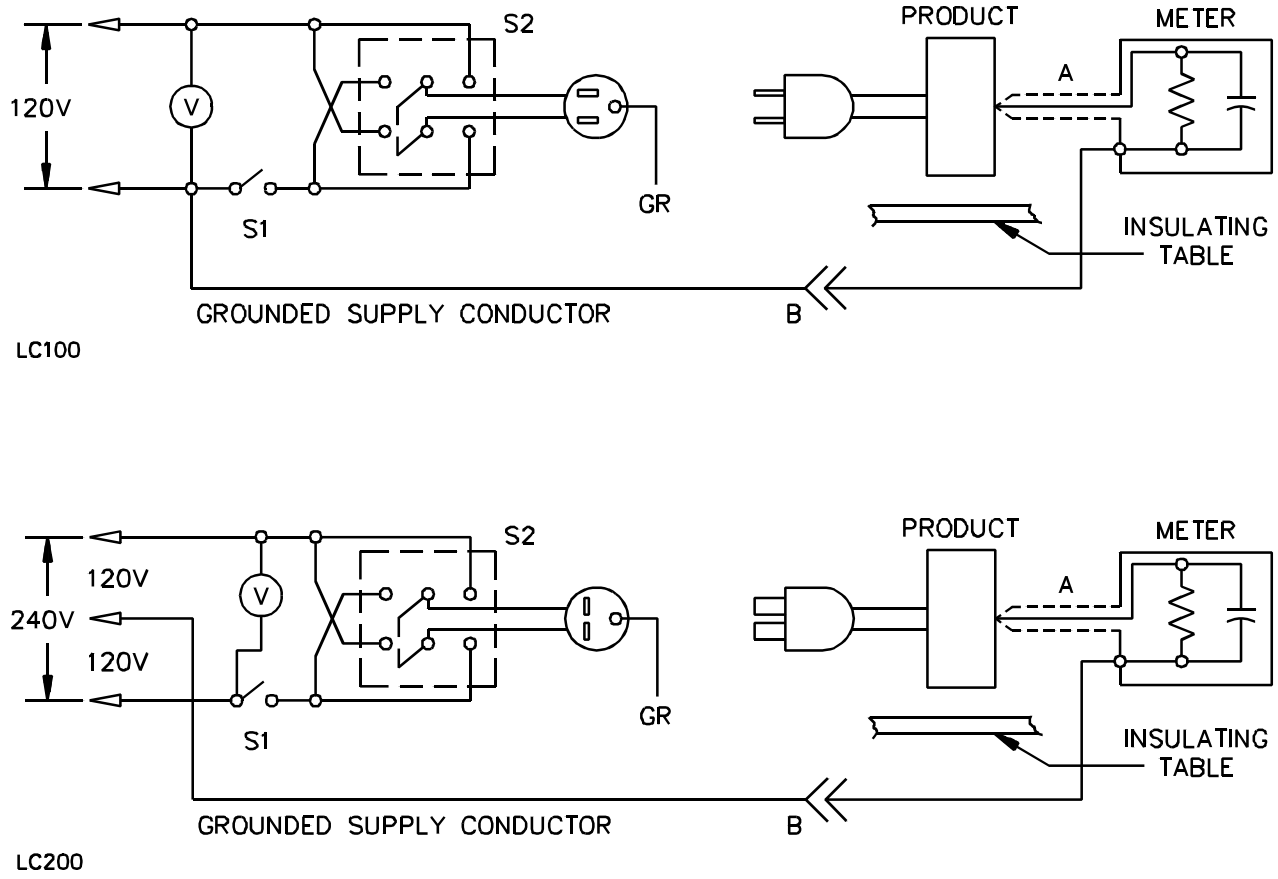
b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

c) Over a frequency range of 0 – 100 kilohertz, 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-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 0.75 milliampere, the measurement is to have an error of not more than 5 percent at 60 hertz.

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

32.4 effective April 13, 1993

Figure 32.1
Leakage-current measurement circuit



32.5 A sample of the converter or inverter 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 volts. The test sequence, with reference to the measuring circuit, Figure 32.1, is as follows:

a) With switch S1 open, the converter or inverter 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 converter or inverter switching devices in all their normal operating positions.

b) Switch S1 is then to be closed energizing the converter or inverter, and within a period of 5 seconds the leakage current is to be measured using both positions of switch S2 and with the converter or inverter 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 converter or inverter as in the normal temperature test.

32.5 effective April 13, 1993

32.6 Normally, the complete leakage current test program as described in 32.5 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.

33 Power Input Test

Section 33 effective April 13, 1993

33.1 The input current to a converter or inverter shall be measured with the converter or inverter operating while connected to the maximum normal load, see 33.2 – 33.4. The current input shall not be more than 110 percent of the rated value.

33.1 revised January 27, 1995

33.2 Maximum normal load for a converter or inverter that does not incorporate an integral battery charger circuit is to be a resistive load adjusted to obtain rated output.

33.3 For a converter or inverter 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 microfarad capacitor in parallel with a resistor; and

b) Equally dividing – see 37.1.3 – among the secondary output-branch circuits a resistive load equal to the difference between the total secondary-output-current rating of the converter or inverter, and the output-current rating of the battery-charging circuit.

33.4 The maximum normal load for a converter or inverter 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-microfarad capacitor in parallel with a resistor adjusted to draw rated output current.

34 Output Voltage Measurement Test

34.1 The output voltage of a secondary circuit connected to a resistive load shall be within the value specified in Table 34.1.

Table 34.1
Output voltage of secondary circuits

Converter output rating, volts	Minimum voltage at full rated output load, volts	Maximum voltage at 5 percent of rated output load, volts
12	10.5	15.5
24	21.0	31.0

35 Capacitor Voltage Measurement Test

35.1 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.

36 Output Voltage and Current Test

Section 36 effective April 13, 1993

36.1 With respect to 13.5, 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.

36.2 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-minute period to maintain maximum load current.

37 Temperature Test

37.1 Normal

37.1.1 When tested on an open bench as described in 37.1.2 – 37.1.11, with the output load adjusted to deliver the maximum normal-load current, see 33.2 – 33.4, a converter or inverter shall not attain a temperature at any point high enough to constitute a risk of fire, adversely affect any material employed in the converter, or exceed the temperature limits specified in Table 37.1. See also 37.1.8.

37.1.1 effective April 13, 1993

Table 37.1
Maximum acceptable temperatures

	Material and component parts	Degrees C	Degrees F
1.	Any point on or within a terminal box or compartment of a converter in which field-installed conductors are to be connected including such conductors themselves	60	140
2.	Field wiring terminals	75	167
3.	Varnished cloth insulation	85	185
4.	Fiber employed as electrical insulation	90	194
5.	Wood and other combustible material	90	194
6.	Phenolic composition employed as electrical insulation or as a part the deterioration of which would result in a risk	150[a]	302[a]
7.	Rubber- or thermoplastic-insulated wire and cord	60[a,b]	140[a,b]
8.	Capacitor		
	Electrolytic	65	149
	Other types	90[c]	194[c]
9.	Sealing compound	d	d
10.	Class 105 insulation systems on coil windings of a relay, solenoid, and the like		
	Thermocouple method	90[e]	194[e]
	Resistance method	110	230
11.	Class 130 (B) insulation systems on coil windings of a relay, solenoid and the like		
	Thermocouple method	110[e]	230[e]
	Resistance method	120	248
12.	Class 105 (A) transformer insulation system on coil windings of a transformer		
	Thermocouple method	90	194
	Resistance method	95	203
13.	Class 130 (B) transformer insulation system on coil windings of a transformer		
	Thermocouple method	110	230
	Resistance method	120	248
14.	Selenium rectifiers	75[f]	167[f,g]
15.	Silicon rectifiers	100[g]	212[g]
16.	Solid contact, bus and connecting bar	90[h]	194[h]
17.	Class 155 (F) insulation systems on coil windings of a transformer		
	Thermocouple method	135	275
	Resistance method	145	293
18.	Class 180 (H) insulation systems on coil windings of a transformer		
	Thermocouple method	150	302
	Resistance method	160	320
19.	Class 200(N) insulation systems on coil windings of a transformer		
	Thermocouple method	165	330
	Resistance method	175	347

(Continued)

Table 37.1 (Cont'd)

Material and component parts	Degrees C	Degrees F
20. Class 220 (R) insulation systems on coil windings of a transformer		
Thermocouple method	180	356
Resistance method	190	374
21. Class 105 (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
22. Class 130 (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

[a] The temperature limitati ons 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.

[b] A short length of rubber- or thermoplastic-insulated flexible cord inside a converter 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 eac h individual conductor.

[c] A capacitor that operates at a temperature rise of more than 90 °C (140 °F) may be judged on the basis of its marked temperature limit. In any case, the measured temperature shall not exceed the temperature rating of the capacitor.

[d] Unless a thermosetting compound, the maximum sealing compound temperature, is 15 °C (27 °F) less than the softening point of th e compound as determined in accordance with the Test for Softening Point by the Ball- and Ring-Apparatus, ASTM E28-1992.

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

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

[g] The limitation does not apply to a material th at has been investigated and found acceptable for a higher temperature limit. A component that operates at a temperature exceeding 100 °C is to be judged on the basis of the manufacturer's rating.

[h] Contacts of silver or a silver alloy in components that function in a high ambient are acceptable, without any additional tests if they do not attain a temperature higher than 100 °C (212 °F) when the device is tested at the ambient temperature in question. If the contacts attain a temperature higher than 100 °C but no higher than 150 °C, they shall perform acceptably when subjected to the overload and endurance tests conducted at the high ambient temperature in question.

Table 37.1 revised January 27, 1995

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

37.1.3 With reference to 37.1.1, the load shall be subdivided between the output circuits so that at least one circuit of each rating is loaded to 80 percent of its rating and the remainder of the load is distributed equally among the other circuits.

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

37.1.4 effective April 13, 1993

37.1.5 Unless investigated and found acceptable – see 6.13 – 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 converter supported by the metal insert. At the request of the manufacturer, the test may be conducted without any means of support.

37.1.6 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 inch (0.8 mm) thick.

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

37.1.7 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:

$$Tc = \frac{R}{r}(k + t1) - k$$

in which:

Tc is the temperature of the winding at the end of the test in EC;

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 EC; 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.

37.1.7 effective April 13, 1993

37.1.8 All temperature values in Table 37.1 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 37.2.

37.1.8 effective April 13, 1993

Table 37.2
Temperature measurement correction

Ambient temperature rating of converter or inverter	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
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 39.1.

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 39.1. If the test ambient temperature is other than the rated ambient, correction is to be made as described in item B of note a.

Table 37.2 effective April 13, 1993

37.1.9 Thermocouples are to consist of wires not larger than No. 24 AWG and not smaller than No. 30 AWG. When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of No. 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 for special thermocouples as listed in the table of limits of error of thermocouples in Temperature Measurement Thermocouples, ANSI MC96.1-1982.

37.1.10 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.

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

37.2 Maximum output without fan operation

37.2.1 A converter or inverter 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 37.1.1 – 37.1.11 except that the load is to be reduced to the maximum load it can carry without resulting in operation of the cooling fan. The converter shall comply with the temperature limits specified in Tables 37.1 and 37.2.

37.2.1 effective April 13, 1993

37.3 Zero clearance

37.3.1 A converter or inverter mounted in a wooden enclosure as described in 37.3.2 and 37.3.3 shall comply with the requirements in 37.1.1 – 37.2.1. In addition, the surface temperatures on parts exposed to contact on a converter or inverter for flush-wall installation shall not exceed those specified in Table 37.3.

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

Exception No. 2: A temperature rise may be 20EC (36EF) greater than that specified in Table 37.1.

37.3.1 revised January 27, 1995

Table 37.3
Maximum acceptable temperature limits

		Degrees	
		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 inch (0.13 mm) thick; and metal with a plastic or vinyl covering not less than 0.005 inch thick.

37.3.2 A converter or inverter 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-inch-thick plywood or soft pine with a nominal thickness of 3/4 inch. The interior surfaces are to be painted flat black and the joints are to be tight or sealed. The converter or inverter is to rest on the base with the walls and top in as intimate contact with the converter or inverter as the configuration on the converter or inverter permits.

37.3.2 effective April 13 1993

37.3.3 A converter or inverter intended for flush mounting is to be flush mounted on a vertical surface and the recessed portions are to be enclosed in accordance with 37.3.2.

37.3.3 effective April 13, 1993

37.4 Maximum overload without trip

37.4.1 A converter or inverter is to be operated under the conditions described in 37.1.1 – 37.3.3 at the maximum load it can carry without resulting in the protector required by 20.2.1 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 above the value specified in Table 37.1 for any other class of insulation.

b) The temperature of any component other than a transformer shall not exceed that specified in Table 37.1 by more than 20 °C (36 °F).

c) A flush-wall mounted converter or inverter shall also comply with the temperature limits specified in Table 38.1.

d) A fixed or stationary type unit shall not exceed the temperature limits specified in Table 38.1 by more than 20 °C.

37.4.1 effective April 13, 1993

37.4.2 With reference to 37.4.1, 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.

38 External Surface Temperature Limits Test

38.1 During the normal temperature test described in Section 37, Temperature Test, surface temperatures shall not exceed the applicable values specified in Table 38.1. 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 37.1.8.

38.1 effective April 13, 1993

Table 38.1
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 converter 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 inch (0.13 mm) or less is considered a nonmetallic part.

Table 38.1 effective April 13, 1993

39 Dielectric Voltage-Withstand Test

39.1 A converter or inverter, at the maximum operating temperature reached in normal use, shall withstand for 1 minute without breakdown the application of a 60-hertz 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 volts or less and dead metal parts; 1000 volts plus twice the maximum rated secondary circuit voltage between a secondary circuit, including any ferroresonant winding, operating at more than 50 volts and dead metal parts.

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

39.1 effective April 13, 1993

39.1.1 A dc potential of 1.414 times the rms value of the ac potential specified in 39.1 may be used instead of the ac potential.

39.1.1 added January 27, 1995

39.2 To determine whether a converter complies with the requirements in 39.1, the converter is to be tested using a 500 volt-ampere 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 minute. 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.

40 Induced Potential Test

Section 40 effective April 13, 1993

40.1 If a 2-flange bobbin isolated power transformer is to be tested in accordance with (d) of the Exception to 17.2.3, the test specified in 40.2 – 40.4 shall be conducted without breakdown of insulation.

40.2 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 seconds. 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.

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

40.4 The test voltage required in 40.2 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 seconds. After being held for the time specified, the voltage is to be reduced slowly, but within 5 seconds, to one-fourth of the maximum value or less, and the circuit opened.

41 Testing on Transformer Insulating Materials

Section 41 effective April 13, 1993

41.1 If required by note c or g of Table 17.1, the transformer insulating material shall be subjected to the test described in 41.2.

41.2 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 inch (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 second. The result is acceptable if there is no dielectric breakdown.

42 Strain Relief Test

Section 42 effective April 13, 1993

42.1 The strain relief means provided on a flexible cord shall withstand for 1 minute without displacement a direct pull of 35 pounds (156 N) applied to the cord, with the connections within the converter or inverter 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.

42.2 A 35-pound (16-kilogram) weight is to be suspended from the cord and supported by the converter or inverter so that the strain-relief means will be stressed from any angle the construction of the converter or inverter permits.

43 Overload Test

43.1 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 percent 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.

43.2 In a test to determine whether a switch or other control device complies with the requirements in 43.1, the converter or inverter is to be connected to a supply circuit of rated frequency and maximum test voltage – see Table 31.1. During the test, exposed dead metal parts of the converter or inverter are to be connected to the polarity opposite to that of the switching device through a 3-ampere 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.

43.2 effective April 13, 1993

44 Overcurrent Protection Calibration Test

Section 44 effective April 13, 1993

44.1 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 13.8 shall operate to open the circuit in not more than the time indicated in Table 44.1 when the transformer is delivering the specified secondary current.

44.2 To determine if a fuse or circuit protective device complies with the requirement in 44.1, the transformer is to deliver the test current to a resistance load. During the 2-minute test, the load is to be adjusted continuously to maintain the required test current. During the 60-minute test, the load is to be adjusted once after 15 minutes of operation and the test is to be continued without further adjustment.

44.3 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 44.1 or 44.2 with the remaining windings delivering rated load.

Table 44.1
Maximum acceptable time to open

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

45 Ground-Fault Circuit-Interrupter Evaluation Test For Power Inverters

Section 45 effective April 13, 1993

45.1 The ground-fault circuit-interrupter protection circuit of a power inverter 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 45.2.

45.2 To determine if an inverter complies with 45.1, the inverter 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.

46 Battery Charger Operation Test

Section 46 effective April 13, 1993

46.1 During charging, a converter or inverter shall:

a) Achieve the electrolyte specific gravity of the test battery at full charge capacity;

b) Minimize gas formation or evaporation of the electrolyte; and

c) Not cause the temperature of the electrolyte to exceed 49 °C (120 °F), when tested as specified in 46.2.

One hour after de-energizing the converter or inverter, the specific gravity of the electrolyte shall be at full charge capacity.

46.2 The converter or inverter is to be connected to a 70 ampere-hour battery discharged in accordance with 46.3, and operated as intended until the battery is fully charged and then de-energized.

46.3 Prior to the test in 46.2, the battery is to be discharged to 1.75 volts per cell at a rate not exceeding the discharge rate assigned by the battery manufacturer, but in any case, the rate of discharge is not to exceed one-sixth of the ampere-hour capacity of the battery.

47 Abnormal Operation Test

47.1 General

47.1.1 A converter or inverter 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 47.1.3 – 47.9.3, 47.11.1 and 48.1.1 – 48.3.1. Separate samples may be used for conducting these tests.

47.1.1 effective April 13, 1993

47.1.2 Following each test, a dielectric voltage withstand test as specified in 39.1(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.

47.1.2 effective April 13, 1993

47.1.3 The converter or inverter is to be at room temperature at the start of the output-short-circuit, switch-position, and specific-value-overload tests.

47.1.3 effective April 13, 1993

47.1.3.1 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 enc losure of the converter or inverter as evidenced by ignition, glowing, or charring of the cheesecloth or tissue paper,

b) The insulation breaks down when tested in accordance with 47.1.2, or

c) Live parts are made accessible (see Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 5).

47.1.3.1 added January 27, 1995

47.1.3.2 During these tests the converter or inverter is to be placed on a softw ood surface covered with a white tissue paper and a si ngle layer of cheesecloth is to be draped loosely over the entire enclosure. The cheesecloth is to be untreated cotton cloth 36 inches (910 mm) wide, running 14 – 15 yar ds per pound (28 – 30 m/kg), and having, for any square inch, a count of 32 threads in one direction and 28 in the other dire ction (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.

47.1.3.2 added January 27, 1995

47.1.3.3 The s upply circuit is to have branch circuit overcurrent protection, the size of which equals 125 percent of the input current rating (20-ampere mi nimum), 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 31.1.

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

47.1.3.3 added January 27, 1995

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

47.1.3.4 added January 27, 1995

47.1.3.5 Each test is to be continued until further change as a result of the test condition is not likely. If a n automatically reset protector functions during a test, the test is to be continued for 7 hours. If a manual rese t protector functions during a test, the test is to be continued until the protector is operated for 10 cycles using th e minimum resetting time, but not at a faster rate than 1 0 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 capac itors, 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.

47.1.3.5 revised September 11, 1998

47.1.4 The output short-circuit and specific-value-overload tests are to be conducted on the bench and under the conditions described in 37.3.2 and 37.3.3.

Exception: A converter or inverter that employs integral fuses need not be subjected to the short-circuit test under the conditions described in 37.3.2 and 37.3.3.

47.1.4 effective April 13, 1993

47.1.5 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 percent of rated current, followed by short-circuit current.

47.1.6 A manually or automatically reset protector or other overload protective device in a converter or inverter shall open the output circuit within 2 minutes after initiation of the test, and within 30 seconds 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 38.1 for flush-wall mounted units, or 20EC (36EF) more than that specified in Table 38.1 for fixed or stationary stand-alone type units surfaces, and 20EC (36EF) more than that specified in Table 37.1 for components and materials.

Exception No. 2: The switch-position test may be waived if with the transfer switch in the battery position, the converter or inverter will not operate when connected as described for the input test – see Section 33, 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 converter or inverter does not emit flame or molten metal or become a risk of fire or electric shock while operating under the test condition described in 47.8.1 for 15 days.

47.1.6 revised January 27, 1995

47.2 Output short-circuit

47.2.1 The external output connections of a converter or inverter are to be short-circuited and the converter or inverter is to be connected to a source of supply adjusted to the test voltage specified in Table 31.1. The source of supply may be protected by a time-delay branch-circuit overcurrent-protective device rated not less than 20 amperes. 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 converter or inverter is to remain in the circuit, and the largest fuse the fuseholder will accept is to be installed.

47.2.1 revised January 27, 1995

47.2.2 For the test described in 47.2.1, 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 amperes 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 12.1.3 having a total length of 4 feet (1.22 m) that is, having positive and negative leads each 2 feet (610 mm) long.

47.2.3 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.

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47.3 Switch position

47.3.1 A converter or inverter provided with a manual battery-to-converter transfer switch and a battery-chargin g circuit is to be operated as described in the input test except with the transfer switch in the battery position.

47.3.1 effective April 13, 1993

47.4 Component malfunction

47.4.1 Individual electronic components of a converter or inverter are to be, in turn, open-circuited and short-circuited.

47.4.1 revised January 27, 1995

47.4.2 The tests specified in 47.4.1 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 equipment is operating under intended conditions. This may be accomplished by jumper leads and remote switches wit h consideration given to the effect these devices may have on the test.

47.4.2 effective April 13, 1993

47.5 Rectifier and capacitor short-circuit test

47.5.1 If a rectifier and an electrolytic capacitor are connected across a primary supply circuit in series with a resistance of less than 300 ohms, a risk of fire or electric shoc k 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.

47.5.1 effective April 13, 1993

47.5.2 The supply circuit of a power converter is to be protected by a branch-circuit overcurrent-protective device in accordance with 48.3.2.

47.5.2 effective April 13, 1993

47.6 Vibration test

47.6.1 After the converter or inverter is subjected to the vibration test described in 47.6.2:

a) The converter or inverter shall comply with the requirement in 47.1.1,

b) There shall be no loosening of parts, and

c) The converter or inverter shall operate normally.

47.6.1 effective April 13, 1993

47.6.2 The vibration test shall consist of vibration for 1 hour at a frequency of 12.5 cycles per second with a displacement of 1/4 inc h (6.4 mm) in a vertical plane. The converter or inverter is to be mounted as intended during the test.

47.6.2 effective April 13, 1993

47.7 Surge protectors

47.7.1 A converter or inverter provided with a surge-protection device in the secondary circuit is to be subjected to the surge test described in 47.7.2.

47.7.1 effective April 13, 1993

47.7.2 A 1-microfarad capacitor is to be charged to 500 volts. 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 second intervals. After the surges, the converter or inverter shall operate normally at rated load. Proper polarities are to be maintained in conducting this test.

47.7.2 effective April 13, 1993

47.8 Specific value overload

47.8.1 A converter or inverter is to be operated using a load adjusted to 200 percent of the rated output current. The test is to be continued until the overload-protective device opens – see 47.1.6. If an automatically reset protector is provided, the test is to be continued for 15 days, or for 24 hours if the protector has been evaluated for 6000 cycles at 200 percent 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.

47.8.1 effective April 13, 1993

47.8.2 With reference to the requirement in 47.8.1:

a) If the ultimate trip current mentioned in 37.4.2 is greater than 200 percent of the rated output current, the load is to be increased in increments of 100 percent 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 percent, 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.

47.8.2 effective April 13, 1993

47.9 Blanketing test

47.9.1 A converter or inverter that incorporates standoffs is to be subjected to a blanketing test. A double layer of blanket – see 47.9.3 – is to be loosely draped over the top and drawn in as close as possible against all sides of the converter or inverter. The blanket may fall or sag between any standoffs that are provided on the converter or inverter. The test is to be continued until the overload protective device opens – see 20.2.1. 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.

47.9.1 effective April 13, 1993

47.9.2 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.

47.9.3 With reference to 47.9.1, the blanket is to be 100 percent unbleached plain weave napped cotton flannelette weighing 4.40 ounces per square yard (148.4 grams per square meter).

47.10 Flanged bobbin transformer abnormal test

47.10.1 A flanged bobbin transformer required to be tested as provided in (c) of the Exception to 17.2.3 – also see 17.2.4 – 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 converter or inverter – see 17.1.1 – need not be subjected to this test.

47.10.1 effective April 13, 1993

47.10.2 A risk of fire as described in 47.10.1 is considered to exist if the cheesecloth or tissue paper glows or flames or the protective device, if provided, opens.

47.10.2 effective April 13, 1993

47.10.3 While still in a heated condition from the test described in 47.10.1, a transformer shall withstand the dielectric voltage withstand test described in 39.1(a)(1). The dielectric voltage withstand test potential is to be applied to the transformer approximately 1 minute after completion of the test described in 47.10.1.

47.10.3 effective April 13, 1993

47.10.4 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.

47.10.4 effective April 13, 1993

47.10.5 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.

47.10.5 effective April 13, 1993

47.10.6 For the sequence of tests described in 47.10.1, 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 47.10.1(a) continues for 15 days, the tests described in (b) and (c) need not be conducted.

47.10.6 effective April 13, 1993

47.10.7 To determine whether a transformer complies with the requirement in 47.10.1, one sample is to be subjected to each condition described in 47.10.1(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 47.10.1 with the other windings loaded to rated current. The test conditions are to be as described in 47.10.8 – 47.10.13.

47.10.7 effective April 13, 1993

47.10.8 To determine the short-circuit current value for conducting the tests described in 47.10.1(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 minute 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.

47.10.8 effective April 13, 1993

47.10.9 For the loading conditions, a variable resistor is to be connected across the secondary winding. The tests described in 47.10.1(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 47.10.1(b), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, if necessary, 1 minute 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.

47.10.9 effective April 13, 1993

47.10.10 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 47.10.1(b) that continues for 15 days is to have a variable load resistor reduced to zero impedance at the end of the 15 days.

47.10.10 effective April 13, 1993

47.10.11 For a transforme r 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 47.10.1 (a) – (c) is to be discontinued if th e protective device opens the circuit and the next test in the sequence is to be started. This procedure is to b e continued until a condition specified in 47.10.1 (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.

47.10.11 effective April 13, 1993

47.10.12 If a protective device opens the circuit or a winding on any sample opens during the 15-day abnorma l operation tests while the samples are un attended, the variable resistor load on the other samples is to be increased, by reducing the resistance, until the protective device opens the circui t or the winding opens, so that the samples may be subjecte d to the dielectric voltage withstand test described in 47.10.3 while in a heated condition. The next test in the sequence is to be in accordance with 39.1 (b) and (c).

47.10.12 effective April 13, 1993

47.10.13 Samples for the 15-day abnormal operation tests described in 47.10.1 are to be prepared as follows:

a) The transformer is to be mounted either in the converter or inverter 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.

47.10.13 effective April 13, 1993

47.11 Blocked fan

47.11.1 A converter or inverter having a fan motor shall be operated for 7 hours with the rotor of the fan motor stalled from rotating.

47.11.1 effective April 13, 1993

48 Evaluation of Reduced Spacings on Printed Wiring Boards

Section 48 effective April 13, 1993

48.1 General

48.1.1 In accordance with Exception No. 4 to 28.1.1, printe d wiring board traces of different potential having reduced spacings may be investigated by c onducting a dielectric voltage-withstand test as described in 48.2.1 and 48.2.2 for a protected environment, see 7.1 – 7.5, or a shorted trace test as described in 48.3.1 and 48.3.2 for a converter or inverter investigated for either a protected environment or a general environment.

48.2 Dielectric voltage-withstand test

48.2.1 A printed wiring board as me ntioned in 48.1.1 shall withstand for 1 minute without breakdown the application of a dielectric withstand potential applied between the traces having reduced spacings in accordance with 39.1 and 39.2.

48.2.2 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.

48.3 Shorted trace test

48.3.1 Printed wiring board traces mentioned in 48.1.1 are to be short-circuited, one location at a time, and the test is to be conducted as described in 48.2.1 and 48.2.2. As a result of this test, the overcurrent protection associated with the branch circuit to which the converter or inverter 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.

48.3.2 During the Shorted Trace Test the supply circuit is to have branch circuit overcurrent protection, the size of which equals 125 percent of the input current rating (20 amperes 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.

49 Burnout Test

49.1 General

49.1.1 A converter or inverter 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 49.2.1. With reference to 49.3.1, the burnout test of the transformer shall be followed by a dielectric voltage-withstand test, as required by 39.1(a). During each test all dead metal parts of the enclosure of the converter or inverter are to be connected directly to ground, and:

a) The converter or inverter 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 converter or inverter.

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

49.1.1 effective April 13, 1993

49.2 Relay and solenoid burnout

49.2.1 An electromagnetic relay or solenoid constructed as described in 6.19 is to be tested by blocking the armature or the plunger in the de-energized position. The converter or inverter 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 converter or inverter enclosure is to be connected directly to ground.

49.2.1 effective April 13, 1993

49.3 Transformer burnout

49.3.1 A resistive load that will cause the input to draw three times the current obtained during normal operation – see 33.1 – is to be connected directly to the transformer secondary winding with the converter or inverter connected to 100 percent of the maximum test voltage specified in Table 31.1. The transformer is to be operated continuously:

a) Until ultimate conditions are observed;

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

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

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 converter or inverter are to be connected directly to ground, the converter or inverter 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 converter or inverter.

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

49.3.1 revised January 27, 1995

49.3.2 A ferroresonant transformer is to be tested as described in 49.3.1, except that a resistive load that will draw the maximum power input – see Section 33, Power Input Test – is to be connected directly to the transformer secondary winding, with the converter or inverter connected to 106 percent of the maximum test voltage specified in Table 31.1.

49.3.2 effective April 13, 1993

49.3.2.1 A switch mode transformer is to be tested as described in 49.3.1 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.

49.3.2.1 added January 27, 1995

49.3.3 For the test required by 49.3.1, 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.

49.3.4 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.

50 Gasket Tests

Section 50 effective April 13, 1993

50.1 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 7, Enclosures Used for Protected Environments.

50.2 Neoprene or rubber compounds and solid polyvinyl-chloride material, except foamed materials, shall have physical properties as indicated in Table 50.1 before and after the conditioning indicated in Table 50.2.

50.3 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 50.2.

50.4 A thermoplastic gas ket shall not deform or melt, or otherwise deteriorate to a degree that will affect its sealing properties after the conditioning indicated in Table 50.2.

50.5 Gaskets of materials other than those specified in 50.2 – 50.4 shall be non-absorptive and shall provid e equivalent resistance to property changes.

Table 50.1
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 inch (25.4 mm) gauge marks are stretched to 2- 1/2 inches (63.5 mm), held for 2 minutes and measured 2 minutes after release	1/4 inch (6.4 mm)	–	Not specified	Not specified
Elongation – minimum increase in distance between 1 inch gauge marks at break	250 percent [3-1/2 inches (88.9 mm)]	65 percent of original	250 percent [3-1/2 inches (88.9 mm)]	75 percent of original
Tensile strength – minimum force at breaking point	850 psi (5.86 MPa)	75 percent of original	1200 psi (8.27 MPa)	90 percent of original

[a] To be determined using the test methods and apparatus de scribed in Standard Test Methods for Rubber Properties in Tension, ASTM D412-80, except the method for tensile set is to be as specified in this table.

Table 50.2
Gasket conditioning

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

[a] Measured during the normal temperature test.

Table 50.2 revised July 8, 1996

51 Atomized Water Test

Section 51 effective April 13, 1993

51.1 The enclosure specified in Section 7, 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 inches (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 inches (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 inches (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.

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

51.3 At the conclusion of the procedure specified in 51.1, the product is to be subjected to the dielectric voltage withstand test specified in 39.1(a), and, if cord connected, to the Leakage Current Test in Section 32.

52 Label Adhesion Test

52.1 Unless known to be acceptable for the application, a pressure-sensitive label that is required to be permanent shall be tested as described in 52.2.

52.2 After being subjected to the conditions described in 52.3 – 52.6 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 hours 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 inch (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.

52.3 OVEN-AGING TEST – Three samples of the label, applied to test surfaces as in the intended application, are to be placed for 240 hours in an oven maintained at the temperature specified in Table 52.1.

Table 52.1
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.

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

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

52.6 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 hours in a controlled atmosphere maintained at a temperature of 23 ±2 °C (73 ±4 °F) at a relative humidity of 50 ±5 percent. The samples are then to be immersed for 48 hours 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

53 Dielectric Voltage-Withstand Test

53.1 Each converter 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 hertz, 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 volts peak or less) metal parts, including terminals.

53.2 The production-line test shall be in accordance with either condition A or condition B of Table 53.1.

53.2.1 A dc potential of 1.414 times the rms value of the ac potential specified in Table 53.1 may be used instead of the ac potential.

53.2.1 added January 27, 1995

Table 53.1
Production-line test conditions

Converter rating	Condition A		Condition B	
	Potential, volts	Time, seconds	Potential, volts	Time, seconds
230 volts or less	1000	60	1200	1

53.3 The converter may be in a heated or unheated condition for the test.

53.4 The test shall be conducted when the converter 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 appliance.

53.5 If a converter 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 53.1. 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.

53.6 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.

53.7 If the output of the test equipment transformer is less than 500 volt-amperes, the equipment shall include a voltmeter in the output circuit to directly indicate the test potential.

53.8 If the output of the test equipment transformer is 500 volt-amperes 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.

53.9 Test equipment, other than that described in 53.6 – 53.8 may be used if found acceptable to accomplish the intended factory control.

53.10 During the test, the primary switch is to be in the on position, both sides of the primary circuit of the converter 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 converter 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.

54 Grounding Continuity Test

54.1 Each converter 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 appliance that are likely to become energized.

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

54.3 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 54.1.

RATING

55 General

55.1 The input of a converter 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.

55.2 With reference to 55.1, for an appliance having a single voltage rating, such as 115 volts, rather than being rated for a range of voltages, such as 110 – 115 volts, maximum rated voltage is considered to be 120 volts. For a converter nominally rated 230 volts, maximum rated voltage is considered to be 240 volts. If the rating is given in terms of a range of voltages, maximum rated voltage is considered to be 120 volts or 240 volts, minimum.

55.3 The output circuit of a converter shall be rated in amperes and volts.

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

MARKING

56 Details

56.1 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.

56.1 effective April 13, 1993

56.2 A marking as required by 56.1 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.

56.3 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.

57 Content

57.1 A converter or inverter 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 converter or inverter 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.

57.1 effective April 13, 1993

57.2 If a manufacturer produces or assembles a converter or inverter at more than one factory, each converter or inverter shall have a distinctive marking, that may be in a traceable code, by which it may be identified as being the product of a particular factory.

57.2 effective April 13, 1993

57.3 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; or

c) Color coding of red for battery positive, blue for converter positive, and white for negative.

57.4 With reference to the requirements in 57.3, the words "battery," "converter," "positive," and "negative" may be abbreviated "Batt.," "Conv.," "Pos." and "Neg.," respectively.

57.5 A converter 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.

57.6 If a manufacturer produces or assembles a converter 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.

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

57.8 If a transfer switch is provided to change from direct-current converter power to direct-current battery power, the switch position shall be permanently marked as specified in paragraph 57.3.

57.9 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.

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

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

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

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

57.14 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.

57.14 effective April 13, 1993

57.15 In addition to the marking required in 57.14, 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".

57.15 effective April 13, 1993

57.16 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.

57.17 A converter 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."

57.18 A converter 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.

57.19 A converter 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.

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

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

57.22 Inverter equipment 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 inverter equipment"; 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 inverter. Other types may fail to operate properly when connected to this inverter equipment."

57.22 effective April 13, 1993

57.23 Ungrounded dead-metal parts specified in 8.3.3 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.

57.23 effective April 13, 1993

58 Instruction Manual

58.1 The installation and operating instructions manual for inverter equipment 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 23.1 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.

58.1 effective April 13, 1993

PART II POWER-CONVERTER SYSTEMS

59 General

59.1 The requirements in Sections 60 – 67 supplement and, in some cases, modify the general requirements in Sections 3 – 57.

CONSTRUCTION

60 Frame and Enclosure

60.1 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.

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

60.3 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, UL 50, except for modifications and additional requirements as specified in this standard.

60.4 With reference to 60.3, a barrier shall be provided to separate a circuit-breaker compartment from a field-wiring compartment, and to separate a circuit-breaker compartment and field-wiring compartment from a ventilated portion of the enclosure. See 60.6.

60.5 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.

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

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

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

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

60.8 The thickness of sheet-metal enclosures for compartments other than line-vol tage circuit-breaker and field-wiring connection compartments shall comply with the requirements in 6.3.

60.9 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.

61 Power-Supply Assembly

61.1 A power-converter system shall be constructed and arranged to permit connection of the power-suppl y assembly for the required current rating. If two or more 15-ampere or 20-ampere circuits are provided, the mai n power-supply assembly shall be rated 30 amperes.

61.1 revised July 8, 1996

61.2 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.

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

61.4 With reference to the requirement in 61.1, the power-suppl y assembly current rating shall be in accordance with Table 61.1.

Table 61.1
Minimum current rating of power-supply assembly

Number of line-voltage branch circuits	**Current rating of branch circuit breakers, amperes**	Minimum current rating of power-supply assembly, amperes
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 63.2.

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

62 Supply and Output Connections

62.1 A supply- and remote-circuit wir ing 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.

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

62.3 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.

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

62.5 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.

62.6 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.

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

62.8 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.

62.9 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 ohm.

62.10 To determine whether a bonding connection complies with the requirement in 62.9, a current of 30 amperes is to be passed through the connection. The resulting drop in voltage is to be measured between a point on the conductor 1/16 inch (1.6 mm) from the connection and a similar point on the frame or enclosure not less than 1/16 inch from the bonding connection.

62.11 Except as indicated in 67.7 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 converter.

63 Overcurrent Protection

63.1 A power-converter system shall be provided with overcurrent protection as specified in Table 61.1. The circuit breakers shall be rated 125 volts minimum. See 6.6 – 6.9.

63.2 With reference to 63.1, a power- converter system incorporating only one 15- or 20-ampere 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.

63.3 **Deleted July 8, 1996**

63.4 With reference to 63.1 and 63.3, each circuit breaker shall be acceptable for branch-circuit protection and shall incorporate a manual of f 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,

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.

63.4 revised September 11, 1998

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

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

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

64 Transfer Switches

64.1 A transfer switch or relay provided to change from inverter to line power shall disconnect both the grounded and ungrounded circuit conductors.

64.1 revised January 27, 1995

64.2 With reference to the requirement in 64.1 the rating of a transfer mechanism and associated wiring shall b e acceptable for the higher of the inverter or line-supply ratings. See 67.6.

64.2 revised January 27, 1995

65 Spacings

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

65.2 Spacings at line-voltage field-wiring terminals shall not be less than the values specified in Table 65.1.

Table 65.1
Minimum acceptable spacings

Potential involved, volts	Minimum spacings between uninsulated live parts of opposite polarity, inch (mm)				Minimum spacing through air or over surface between uninsulated live parts and grounded dead metal	
	Through air		Over surface		inch	(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 65.3.						

65.3 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 inch (1.2 mm) between the isolated dead metal part and any one of the other parts previously mentioned, provi ded the total spacing between the isolated dead metal part and the two other parts is not less than the value specified in Table 65.1.

PERFORMANCE

66 Temperature Test

66.1 The temperature test shall be conducted as indicated in Section 37, Temperature Test, except as indicated in 66.2 and 66.3.

66.2 Direct-current secondary-output circuits are to be loaded as specified in Section 33, Power Input Test. Line-voltage alternating-current remote circuits including internal l oads are to be loaded to 80 percent of the circuit-breaker rating. Additional line-voltage circuits are to be resistance-loaded to an input current of 80 percent of the total input rating of the power-converter system.

66.3 The temperature ris e 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 maximu m acceptable temperature rises specified in Table 37.1.

MARKING

67 Details

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

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

67.3 With reference to the requirement in 67.2, if pressure terminals are provided for additional remote circuits, a power-converter system shal l be marked, adjacent to the pressure terminals: "For connection of remote circuits," or the equivalent.

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

67.5 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.

67.6 If a combination line-genera tor system is provided, marking adjacent to the means for connection shall specify the maximum generator rating. See 64.2.

67.7 The color identification required by 62.11 need not be prov ided 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

Section SA1 effective April 13, 1993

SA1.1 These requirements cover marine power converters or inverters intended for permanent installation aboard vessels as covered by the Standard for Motor Craft (Pleasure and Commercial), NFPA 302-1972, 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 converters/inverters 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 – 57, inclusive (Part I).

SA2 Glossary

Section SA2 effective April 13, 1993

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 Standard for Motor Craft (Pleasure and Commercial), NFPA 302-1972, 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

Section SA3 effective April 13, 1993

SA3.1 A marine converter or inverter 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 converter 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 converter provided:

a) The meter shunt is located within the marine converter enclosure.

b) Overcurrent protection for external meter leads is provided within the marine converter or inverter enclosure.

SA4 Frame and Enclosure

Section SA4 effective April 13, 1993

SA4.1 General

SA4.1.1 A marine converter or inverter 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 converter or inverter.

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.

SA4.1.2 revised January 27, 1995

SA4.1.3 The enclosure of a marine converter or inverter 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 SA14, Leakage Current, Insulation Resistance, and Dielectric Voltage Withstand (Repeated) and Section SA15, Salt Spray Corrosion Test.

SA4.2 Enclosures for open cockpit or weatherdeck mounting

SA4.2.1 The enclosure of a marine converter or inverter 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 converters or inverters that are intended for permanent open cockpit or weatherdeck mounting installation.

SA4.2.3 When subjected to the rain test described in Section SA15, Salt-Spray Corrosion Test, an enclosure shall prevent rain from entering the enclosure.

SA4.2.4 A gasket employed in a marine converter or inverter for open cockpit or weatherdeck mounting shall be tested as specified in Section SA23, Accelerated Aging of Gaskets, Sealing Compounds and Adhesives.

SA4.2.5 A marine converter or inverter 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

Section SA5 effective April 13, 1993

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:

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G90 in the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M-94, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM designation. The weight of the zinc coating may be determined by any acceptable method; however, in case of question, the weight of the coating shall be established in accordance with the Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M-93.

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00061 inch (0.0155 mm) on each surface with a minimum thickness of 0.00054 inch (0.0137 mm). The thickness of coating shall be established by the metallic-coating-thickness test as described in Metallic Coating Thickness, Section SA22. An annealed coating shall comply with SA5.4 and SA5.5.

c) A zinc coating conforming with (1) or (2) below and with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint applied after forming on each surface. The acceptability of the paint may be determined by consideration of its composition or by corrosion tests if these are considered necessary.

1) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M-94, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM designation. The weight of zinc coating may be determined by any acceptable method; however, in case of question the weight of coating shall be established in accordance with the Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M-93. An A60 alloyed coating shall comply with SA5.4.

2) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00041 inch (0.0104 mm) on each surface with a minimum thickness of 0.00034 inch (0.0086 mm). The thickness of the coating shall be established in accordance with the metallic-coating-thickness test described in Section SA22. An annealed coating shall comply with SA5.4.

d) A cadmium coating not less than 0.0010 inch (0.025 mm) thick on both surfaces. The thickness of coating shall be established in accordance with the Metallic-Coating-Thickness, Section SA22.

e) A cadmium coating not less than 0.00075 inch (0.0191 mm) thick on both surfaces with one coat of outdoor paint on both surfaces; or not less than 0.00051 inch (0.0130 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established in accordance with the metallic-coating-thickness test described in Section SA22 and the paint shall be as specified in (c).

f) Other finishes, including paints, metallic finishes, or combinations of the two may be accepted when comparative tests with galvanized sheet steel-without annealing, wiping, or other surface treatment - conforming with (a) indicate they provide equivalent protection. Among the factors that are taken into consideration when judging the acceptability of such coating, systems are exposed to salt spray, moist carbon dioxide-sulphur dioxide-air mixtures, moist hydrogen sulphide-air mixtures, ultraviolet light, and water.

SA5.3 revised July 8, 1996

SA5.4 An annealed coating on sheet steel that is bent or similarly formed, or extruded or rolled at the edge of holes after annealing shall be additionally painted in the affected area if the process damages the zinc coating.

SA5.5 If flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 power magnification, the zinc coating is considered to be damaged. Simple sheared or cut edges and punched holes are not required to be additionally protected, but extruded and rolled edges at holes are to comply with the requirements in SA5.4.

SA5.6 The acceptability of outdoor paint may be determined by consideration of its composition or, if necessary, by tests.

SA6 Supply Connections

Section SA6 effective April 13, 1993

SA6.1 A cord-connected marine converter or inverter shall be provided with Type S, SE, SEOO, SO, SJ, SJE, SJEOO, SJO, STO, ST, SJT, or SJTO cord.

SA6.1 revised July 8, 1996

SA6.2 A marine converter or inverter employing demountable brackets shall be provided with a power supply cord having a grounding conductor and an attachment plug.

SA7 Internal Wiring

Section SA7 effective April 13, 1993

SA7.1 Internal wiring shall have stranded conductors and be acceptable for use on marine crafts.

SA7.2 A permanent marine converter or inverter shall have a terminal or lead for connecting the metal enclosure and enclosure parts to ground.

SA8 Battery Connections

Section SA8 effective April 13, 1993

SA8.1 Connections between the battery charging circuit of a marine conver ter or inverter and a battery shall be made by means of terminals or an equivalent permanent connection or by use of plug connectors as described in SA8.2. Clips shall not be used for battery connections.

SA8.2 Marine converters or inverters provided with demountable brackets for servicing shall employ plug connections for secondary output load circuits and the battery charging circuit.

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SA9 Ignition Protection

Section SA9 effective April 13, 1993

SA9.1 A marine converter or inverter intended for installation in an area in which ignition-protected equipment is required shall be:

a) Subjected to the ignition-protection test in Section SA21,

b) Subjected to the normal temperature test in Section 37 while mounted in a 50 °C ambient chamber, and

c) marked in accordance with SA25.6.

SA9.1 revised January 27, 1995

SA9.2 With reference to SA9.1, a marine converter or inverter intended for use in an area in which ignition-protected equipment is not required shall be marked in accordance with SA25.5.

SA10 Receptacles

Section SA10 effective April 13, 1993

SA10.1 An attachment plug receptacle shall not be employed in a marine converter or inverter intended for use in an area in which ignition-protected equipment is required.

SA11 Arcing Parts

Section SA11 effective April 13, 1993

SA11.1 A component that can produce an arc, such as a snap switch or a relay, shall not be employed in a marine converter intended for use in an area in which ignition-protected equipment is required, and shall be marked in accordance with SA25.5.

Exception: A component that complies with the ignition protection test in Section SA21 need not comply with this requirement.

SA12 Electrical Components

Section SA12 effective April 13, 1993

SA12.1 A component such as a resistor, a transformer, a solid-state device, and the like, that exceeds 150 °C (302 °F) during normal operation of the marine converter or inverter, shall comply with the requirements for ignition-protection test in Section SA21.

PERFORMANCE

SA13 General

Section SA13 effective April 13, 1993

SA13.1 A representative sample of a marine converter or inverter shall be subjected to the output-voltage-control, vibration, shock, and ignition-protection tests described in Sections SA14 – SA21.

Exception: Marine converters or inverters marked in accordance with SA25.7 are not subjected to the tests described in Sections SA14 and SA15.

SA13A Water Spray Test

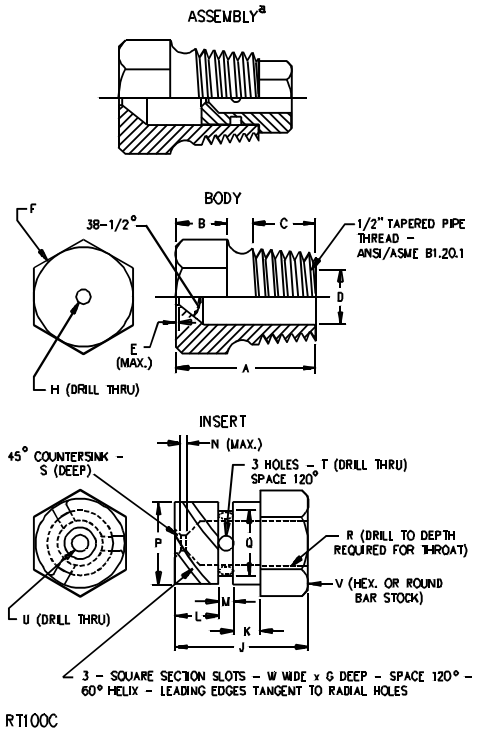
SA13A.1 After being subjected to the water spray test as described in SA13A.2 – SA13A.4, a marine converter or inverter intended for open cockpit or weather deck mounting shall have no water within its enclosure at a level higher than the lowest live part.

SA13A.1 added January 27, 1995

SA13A.2 The water spray test apparatus is to consist of three spray heads co nstructed in accordance with the details shown in Figure SA13A.1 and mounted in a water-supply pipe rack as sh own in Figure SA13A.2. The water pressure is to be maintained at 5 lb per square inch (34 Kpa) at each spray he ad. The distance between the center nozzle and the converter or inverter is to be a pproximately 5 feet (1.5 m). The marine converter or inverter is to be brought into the focal area of the three spray heads in such a position and under such conditions as are most likely to result in entrance of water into the marine converter or inverter, except that consideration is to be given to the normal mounting position. If the marine converter or inverter employs a fan or other moving part, the operation of which is likely to facilitate the entrance of water, it is to be energized and operated as intended.

SA14.2 revised and relocated as SA13A.2 January 27, 1995

Figure SA13A.1
Water spray head



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

[a] Nylon Rain-Test Spray Heads are available from Underwriters Laboratories Inc.

[b] ANSI B94.11M Drill size.

[c] Optional – To serve as wrench grip.

Figure SA14.1 revised and relocated as Figure SA13A.1 January 27, 1995

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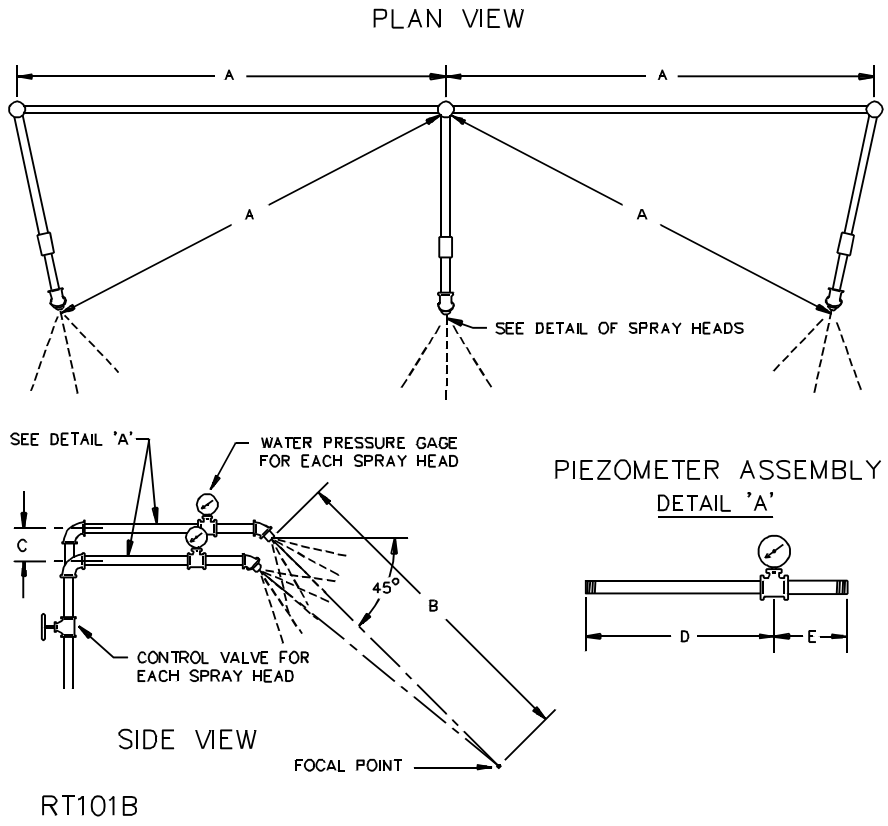
Figure SA13A.2
Water spray head piping



Item	inch	mm
A	28	710
B	55	1400
C	2-1/4	55
D	9	230
E	3	75

Figure SA14.2 revised and relocated as Figure SA13A.2 January 27, 1995

SA13A.3 The water to be used for t he test is to have its resistivity adjusted, before the test is started, to 3500 ohm-centimeters ±5 percent when measured at 25 °C (77 °F). At the conclusion of the test, the resistivity of the water is not to be less than 3200 ohm-centimeters or more than 3800 ohm-centimeters at 25 °C (77 °F).

SA14.3 revised and relocated as SA13A.3 January 27, 1995

SA13A.4 The water spray is to be applied to the converter or inverter for 4 hours.

SA13A.4 added January 27, 1995

SA13B Drip Test

SA13B.1 After being subjected to the drip test as described in SA13B.2, a marine converter or inverter not intended for open cockpit or weatherdeck mounting shall have no water within its enclosure at a level higher than the lowest live part.

SA13B.1 added January 27, 1995

SA13B.2 The converter or inverter is to be mounted in accordance with its installation instructions beneath a drip pan that produces both splashing and dripping. The pan is to extend beyond all exposed sides of the converter or inverter. The bottom of the pan is to be equipped with uniformly distributed spouts; one spout for each 20 square inches (129 cm^2) of pan area. Each spout is to drip water out a rate of at least 20 drops per minute. The converter or inverter is to be subjected to continuously dripping water for 30 minutes while orientated from 0 – 15 degrees from the vertical.

SA13B.2 added January 27, 1995

SA14 Leakage Current, Insulation Resistance, and Dielectric Voltage-Withstand (Repeated)

SA14.1 After being subjected to the Water Spray Test, Section SA13A, or the Drip Test, Section SA13B, a marine converter or inverter shall:

a) For a cord-connected marine converter or inverter rated for a nominal 120 volts supply, comply with the requirement in 32.1 of Part 1 in a repeated leakage-current test, except that the test is to be discontinued when the leakage current stabilizes.

b) For a marine converter or inverter other than as mentioned in (a), have an insulation resistance of not less than 50,000 ohms.

c) After the test required by (a) or (b), comply with the requirements in Dielectric Voltage-Withstand Test, Section 39 of Part I in a repeated dielectric voltage-withstand test.

SA14.1 revised January 27, 1995

SA14.2 *Revised and relocated as SA13A.2 January 27, 1995*

SA14.3 *Revised and relocated as SA13A.3 January 27, 1995*

Figure Figure SA14.1
Rain test spray head

Figure SA14.1 revised and relocated as Figure SA13A.1 January 27, 1995

Figure SA14.2
Rain-test spray head piping

Figure SA14.2 revised and relocated as Figure SA13A.2 January 27, 1995

SA15 Salt Spray Corrosion Test

Section SA15 effective April 13, 1993

SA15.1 A marine converter or inverter intended for open cockpit or weatherdeck mounting shall be tested as described in SA15.2 – SA15.4. Following the test, SA14.1(b) and (c) shall be repeated.

SA15.2 The sample is to be supported vertically and exposed to salt spray (fog) as specified by the test method for Salt Spray (Fog) Testing, ASTM B117-1973. The apparatus used for salt spray exposure is to consist of a fog chamber, 48 by 30 by 36 inches (1.2 by 0.8 by 0.9 m) inside dimensions, having a salt solution reservoir, a supply of conditioned compressed air, a dispersing tower for producing a salt fog, sample supports, provision for heating the chamber, and necessary means of control. The dispersion tower is to be located in the center of the chamber and is to be supplied with salt solution and with warmed, humidified air at a pressure of 17 to 19 psig (117 to 131 kPa), so as to disperse the salt solution in the form of a fine mist or fog throughout the interior of the chamber. The temperature within the chamber is to be maintained at 33.5 – 36 °C. Condensate accumulation on the cover of the chamber is not to be permitted to drop on the samples, and drops of the solution which fall from the samples are not to be recirculated, but are to be removed through a drain located in the floor of the chamber.

SA15.3 The salt solution is to consist of 5 percent by weight of common salt (sodium chloride) and distilled water. The pH value of this solution as collected after spraying in the test apparatus is to be between 6.5 and 7.2, and the specific gravity between 1.026 and 1.040 at 35 °C.

SA15.4 The duration of the test shall be 200 hours.

SA15.4 revised January 27, 1995

SA16 Output Voltage Control

Section SA16 effective April 13, 1993

SA16.1 While connected to a source of supply of 107 volts (rms), the battery charging circuit of a marine converter/inverter is to be operated continuously for at least 24 hours at 25 °C (77°F) using a battery discharged as specified in SA18.1 as the load. The charging circuit shall:

a) Return 2.1 – 2.35 volts per battery cell and the electrolyte temperature shall not exceed 120 °F (49°C), and

b) Maintain a voltage of 2.15 – 2.35 volts per cell in the fully charged battery under no-load conditions.

A battery is considered to be charged if it retains its full specific gravity as specified in Table SA17.1 for 1 hour after being disconnected from the charging circuit.

SA16.2 The test mentioned in SA16.1 is then to be repeated, with the input voltage adjusted to 127 volts (rms). A marine converter/inverter which incorporates a semiautomatic battery charging circuit is to be manually adjusted for this test.

SA16.3 With reference to SA16.1, the battery used for the test is to have an ampere-hour capacity of at least six times the rated output of the battery charging circuit or 60 ampere-hours, whichever is greater. If the ampere-hour rating obtained is not a standard ampere-hour rating, the next higher rating shall be used.

SA17 Electrolyte Conditioning

Section SA17 effective April 13, 1993

SA17.1 The battery is to be charged at room temperature at a rate that will not damage the battery plates – not more than 20 amperes for a 200 ampere-hour battery – until the full-charge specific gravity is attained as measured by a temperature-correction hydrometer. The battery is considered to be charged if it retains its full-charge specific gravity as specified in Table SA17.1 for 1 hour after being disconnected from the charging circuit.

Table SA17.1
Specific gravity

Battery type	Specific gravity range
Lead-acid (floating)	1.210 – 1.220
Lead-acid (automotive)	1.265 – 1.285
Other than lead-acid	Full-charge condition as specified by the battery manufacturer

SA18 Battery Discharge

Section SA18 effective April 13, 1993

SA18.1 Following the electrolyte conditioning, the battery is to be connected to a load and then discharged to 1.75 volts per cell, with 8 – 24 hours, at a rate not exceeding the discharge rate assigned by the battery manufacturer, and not exceeding one-sixth of the ampere-hour capacity of the battery. The discharge ampere-hours shall be at least 100 percent of the ampere-hour rating of the battery.

SA19 Vibration

Section SA19 effective April 13, 1993

SA19.1 A marine converter or inverter shall withstand the vibration specified in Table SA19.1 for 12 hours when tested as described in SA19.2 and SA19.3 without structural damage to the mounting means or the enclosure that might result in:

a) An increase in the risk of fire, electric shock, or injury to persons;

b) A reduction of spacings to a value less than the minimum specified in Spacings, Section 28; or

c) Exposure of a live part.

The intended operation of the marine converter or inverter shall not be impaired.

Exception: The test need not be conducted for a marine converter or inverter that is marked for use on a vessel more than 65 feet (19.8 m) long and marked in accordance with SA25.7.

Table SA19.1
Vibration test requirements

Location	Duration	Peak-to-peak amplitude, inch	Frequency
Ignition-protected marine converter	12 hours – 4 each in planes x, y and z	0.020 ±0.001	10 – 60 Hz
Marine converter installed above cockpit deck – not ignition protected	12 hours – 4 each in planes x, y and z	0.015 ±0.001	10 – 60 Hz

SA19.2 The marine converter or inverter is to be mounted as intended on a rigid test fixture that is secured to the vibration table. The marine converter or inverter is to be wired so as to permit the device to be monitored in accordance with SA19.4 during the last hour of vibration in each plane and after the complete vibration test.

SA19.3 The marine converter or inverter is to be subjected to a variable frequency test in each of three rectilinear axes, horizontal, lateral, and vertical, for 4 hours in each plane – total of 12 hours – at a peak-to-peak amplitude as indicated in Table SA19.1. The vibration frequency is to be automatically cycled at a constant rate from 10 Hz to 60 Hz to 10 Hz every 4 minutes.

SA19.4 To determine whether a marine converter or inverter operates as intended, the converter or inverter is to be connected to a supply adjusted to rated voltage, and the output circuits shall be connected as indicated below.

a) The battery charging circuit is to be connected to a fully charged battery. A variable resistive load adjusted to draw the maximum rated output of the battery charger is to be connected in parallel with the battery. With the variable resistive load both connected and disconnected, the output voltage of the charging circuit shall be maintained at 2.15 – 2.35 volts per cell.

b) Simultaneously, the secondary output load circuits of a converter are to be connected to variable resistive load(s) adjusted to draw the maximum rated output current.

c) Separately, the output load circuits of an inverter are to be connected to variable resistive load(s) adjusted to draw the maximum rated output current.

Exception No. 1: Marine type which are designed for "Float" type battery connection and operation are to be connected as described in (a) only.

Exception No. 2: Marine converter or inverters that are not intended to be used for battery charging shall be connected as indicated in (b) only.

SA20 Shock

Section SA20 effective April 13, 1993

SA20.1 A marine converter or inverter th at has been subjected to the vibration test in Section SA19, Vibration, shall withstand 5000 impacts of 10 g peak with a duration of 20 – 25 milliseconds – measured at the zero reference line of the half-sine wave shock pulse – without structural damage to the mounting means or the enclosure that might result in:

a) An increase in the risk of fire, electric shock, or injury to persons;

b) A reduction of spacings to a value less than the minimum specified in Spacings, Section 28; or

c) Exposure of a live part.

The intended operation of the marine converter or inverter shall not be impaired and the converter or inverter shall comply with the requirements in SA19.4 upon completion of the test.

Exception: A marine converter or inverter that is marked for use on a vessel more than 65 feet (19.8 m) long in accordance with SA25.7.

SA20.2 The marine converter or inverter is to be mounted as intended on a rigid test fixture secured to the shock table. The converter or inverter need not be operable during the test.

SA21 Ignition Protection

Section SA21 effective April 13, 1993

SA21.1 A marine converter or inverter intended for use in an area in which ignition-protected equipment is required shall operate in an explosive mixture of propane and air as described in (a) – (e) without igniting the mixture. Each potential ignition source, including individual components such as a switch or a relay that is considered to be a potential source o f ignition, is to be operated 50 times. Either the device contacts or a spark plug shall be provided to produce a positive arc for ignition of the gas mixture in the enclosure under test.

a) The propane and air mixture is to be drawn into a component containing a source of ignition by copper tubing connected to a vacuum pump outside the chamber. Cop per tubing having an inside diameter of 0.061 ±0.0071 inch (1.55 ±0.18 mm) and a length of at least 6 inches (152 mm) is to be used as a flame arrester and to reduce the ef fect of an increase in volume of the enclosure of the device under test. All joints are to be gas tight and are to withstand 50 internal explosions.

b) If a component does not have gaps or seams to permit gas to enter it when a vacuum is applied, a separate copper tube havi ng an inside diameter of 0.061 ±0.007 inch and a length of 6 inches is to be fitted to the enclosure and the free end is to be open to the explosion chamber.

c) Means are to be provided to indica te positively that an explosion has occurred within the enclosure when the spark plug is fired or the ignition source is activated. This may be by sound, monitoring the pressure in the gas pick-up tube, or pressure changes in the explosion chamber.

d) A mixture of propane and air held as close to the maximum explosive proportions as possible is to be fed into the explosion chamber at a rate of approximately 1 cubic foot per minute (0.0005 m^3/s). During the 50 test explosions, the mixture is to be varied between 4.25 and 5.25 percent propane by volume with at least one-half of the explosions conducted at the mixture that gives the maximum explosive pressure.

e) Prior to each test explosion, the vacuum pump is to be operated long enough to completely purge the enclosure of burned gas and to draw in the mixture from the explosion chamber.

SA21.2 A marine converter or inverter having resistors or other parts that attain external temperatures exceeding 150°C (302°F) is to be operated in an explosive atmosphere under the input and output conditions that produce the maximum temperature as follows:

a) The complete marine converter or inverter may be subjected to the test or individual components may be tested under simulated load conditions.

b) A component is to be installed in the explosion chamber, energized to produce the maximum temperature encountered in service, and held at that input for 1/2 hour with the propane and air mixture in the chamber held between 4.25 and 5.25 percent propane by volume.

SA22 Metallic Coating Thickness

Section SA22 effective April 13, 1993

SA22.1 The method of determining the thickness of a zinc or cadmium coating by the metallic-coating-thickness test is described in SA22.2 – SA22.7. The aforementioned applies only if the required thickness is specified.

SA22.2 The solution used for the test is to be made from distilled water and is to contain 200 grams per liter of reagent grade chromic acid (CrO_3) and 50 grams per liter of reagent grade concentrated sulfuric acid (H_2SO_4). The latter is equivalent to 27 milliliters per liter of reagent grade concentrated sulfuric acid, specific gravity 1.84, containing 96 percent of H_2SO_4.

SA22.3 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube having an inside bore of 0.025 inch (0.64 mm) and a length of 5.5 inches (140 mm). The lower end of the capillary tube is to be tapered to form a tip, the drops from which are about 0.05 ml each. To preserve an effectively constant level, a small glass tube is to be inserted in the top of the funnel through a rubber stopper and its position is to be adjusted to that when the stopcock is open, the rate of dropping is 100 ±5 drops per minute. If desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

SA22.4 The sample and the test solution are to be kept in the test room long enough to acquire the temperature of the room, which is to be noted and recorded. The test is to be conducted at a room temperature of 70 – 90 °F (21 – 32°C).

SA22.5 Each sample is to be thoroughly cleaned before testing. All grease, lacquer, paint, and other nonmetallic coatings are to be removed completely by means of solvents. Samples are then to be thoroughly rinsed in water and dried with clean cheesecloth. Care should be exercised to avoid contact of the cleaned surface with the hands of any foreign material.

SA22.6 The sample to be tested is to be supported 0.7 – 1 inch (17.9 – 25.4 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested is to be inclined about 45 ° from the horizontal.

SA22.7 The stopcock is to be opened and the time in seconds until the dropping solution dissolves the protective metal coating, exposing the base metal is to be measured with a stopwatch. The end point is the first appearance of the base metal recognizable by a change in color at that point.

SA22.8 Each sample of a test lot is to be subjected to the test at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface and at an equal number of points on the outside surface, at places where the metal coating may be expected to be the thinnest. On enclosures made from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.

SA22.9 To calculate the thickness of the coating being tested, select from Table SA22.1 the thickness factor appropriate for the temperature at which the test was conducted and multiply by the time in seconds required to expose base metal as described in SA22.7.

Table SA22.1
Coating thickness factors

Temperature		Thickness factors, 0.00001 inch (0.0003 mm) per second	
°F	°C	Cadmium platings	Zinc platings
70	(21.1)	1.331	0.980
71	(21.7)	1.340	0.990
72	(22.2)	1.352	1.000
73	(22.8)	1.362	1.010
74	(23.3)	1.372	1.015
75	(23.9)	1.383	1.025
76	(24.4)	1.395	1.033
77	(25.0)	1.405	1.042
78	(25.6)	1.416	1.050
79	(26.1)	1.427	1.060
80	(26.7)	1.438	1.070
81	(27.2)	1.450	1.080
82	(27.8)	1.460	1.085
83	(28.3)	1.470	1.095
84	(28.9)	1.480	1.100
85	(29.4)	1.490	1.110
86	(30.0)	1.501	1.120
87	(30.6)	1.513	1.130
88	(31.1)	1.524	1.141
89	(31.7)	1.534	1.150
90	(32.2)	1.546	1.160

SA23 Accelerated Aging of Gaskets, Sealing Compounds and Adhesives

Section SA23 effective April 13, 1993

SA23.1 SA23.1 and SA23.2 apply to gaskets and sealing compounds employed in marine converters or inverters to make an enclosure acceptable for open cockpit or weatherdeck mounting. SA23.7 applies to an adhesive used to secure a gasket.

SA23.2 Neoprene and rubber gasket materials shall have physical properties as specified in Table SA23.1 before and after accelerated aging under the conditions specified in Table SA23.2.

Exception: Foamed materials as described in SA23.3 need not comply with this requirement.

Table SA23.1
Physical properties for gaskets

	Neoprene or rubber compound		Polyvinyl chloride material	
	Before conditioning	After conditioning	Before conditioning	After conditioning
Recovery – Maximum set when 1 inch (25.4 mm) gauge marks are stretched to 2-1/2 inches (63.5 mm), held for 2 minutes and measured 2 minutes after release	1/4 inch (6.4 mm)	–	Not specified	
Elongation – Minimum increase in distance between 1 inch (25.4 mm) gauge marks at break	250 percent [1 to 3-1/2 inches (25.4 – 88.9 mm)]	65 percent of original	250 percent [1 to 3-1/2 inches (25.4 – 88.9 mm)]	75 percent of original
Tensile strength – Minimum force at breaking point	850 psi (5860 kPa)	75 percent of original	1200 psi (8273 kPa)	90 percent of original

Table SA23.2
Accelerated aging conditions

Measured temperature rise			
°C	°F	Material	Conditioning
35	63	Rubber or neoprene	Air oven aging for 70 hours at 100 ±2 °C (212 ±3.6 °F)
35	63	Thermoplastic	Air oven aging for 168 hours of 87 ±2 °C (189 ±3.6 °F)
50	90	Rubber or neoprene	Air oven aging for 168 hours at 100 ±2 °C (212 ±3.6 °F)
50	90	Thermoplastic	Air oven aging for 240 hours at 100 ±2 °C (212 ±3.6 °F)
55	99	Rubber, neoprene or thermoplastic	Air oven aging for 168 hours at 113 ±2 °C (235 ±3.6 °F)
65	117	Rubber or neoprene	Air oven aging for 240 hours at 121 ±2 °C (250 ±3.6 °F)
65	117	Thermoplastic	Air oven aging for 168 hours at 121 ±2 °C (250 ±3.6 °F) or 1440 hours at 97 ±2 °C (207 ±3.6 °F)
80	144	Rubber, neoprene or thermoplastic	Air oven aging for 168 hours at 136 ±2 °C (277 ±3.6 °F)

Table SA23.2 revised July 8, 1996

SA23.3 Foamed neoprene and foamed rubber gasket materials shall be subjected to accelerated aging under the conditions specified in Table SA23.2. The material shall not harden or otherwise deteriorate to a degree that will affect its sealing properties.

SA23.4 Thermoplastic gasket materials shall be subjected to accelerated aging under the conditions specified in Table SA23.2. A thermoplastic material shall not deform or melt, or otherwise deteriorate to a degree that will affect its sealing properties. A solid polyvinyl-chloride material shall have physical properties as specified in Table SA23.1 before and after the accelerated aging.

SA23.5 Tensile strength and elongation are to be determined using the test methods and apparatus described in Tension Testing of Vulcanized Fiber, ASTM D412-1968.

SA23.6 A sealing compound shall be applied to the surface it is intended to seal. For a temperature rise not exceeding 35°C (63°F), a representative sample of the surface with the sealing compound applied shall be conditioned for seven days in an air oven at 87.0 ±1.0 °C (189.0 ±1.8 °F). The sealing compound shall not melt, become brittle or otherwise deteriorate to a degree that will affect its sealing properties as determined by comparing the aged sample to the unaged sample.

SA23.7 For a gasket secured by an adhesive and exposed to a temperature rise not exceeding 35 °C (63°F), a sample of the gasket secured to the mounting surface by the adhesive shall be exposed for 72 hours to each of the following conditions:

a) A temperature of 100.0 ±1.0 °C (212.0 ±1.8 °F),

b) Immersion in distilled water at a temperature of 23.0 ±1.0 °C (73.0 ±1.8 °F), and

c) A temperature of minus 10.0 ±1.0 °C (14.0 ±1.8 °F).

The force required to peel the gasket from its mounting surface after exposure shall not be less than 50 percent of the value determined using the unconditioned sample, but not less than 2 pounds per inch (0.04 kilograms per millimeter) of gasket width.

SA23.8 The temperature rises specified in this section correspond to the maximum temperature rise measured on the gasket during the temperature test. A material other than those mentioned in this section shall be nonabsorptive and it, and all materials having a higher temperature rise, shall provide equivalent resistance to aging and temperatures.

SA24 Label Adhesion

Section SA24 effective April 13, 1993

SA24.1 In addition to the requirements covered in 52.1 – 52.6 of Part I, labels provided in a marine converter or inverter intended for open cockpit or weatherdeck mounting shall be investigated in accordance with SA24.2.

SA24.2 OPEN COCKPIT AND WEATHERDECK EXPOSURE – Three test panels, see 52.2, are to be exposed to ultraviolet rays and water spray for 720 hours. The test cycle is to consist of exposure to ultraviolet rays for 102 minutes followed by exposure to ultraviolet rays and a fine spray of water for 18 minutes using Type D apparatus, as described in Practice for Operating Light- and Water-Exposure Apparatus (Carbon Arc Type) for Exposure of Nonmetallic Materials, ASTM G23-1969.

MARKING

SA25 Details

Section SA25 effective April 13, 1993

SA25.1 A marine converter or inverter which employs a battery charging circuit shall be marked to indicate that it is intended for continuous duty.

SA25.2 A marine converter which does not incorporate a battery charging circuit shall be marked "This converter is not intended for charging batteries" or the equivalent.

SA25.3 A marine converter or inverter which employs a battery chargin g circuit shall be marked, where readily visible to the user when charging batteries, to spe cify the type of batteries to be charged, the number of cells in the battery, and the ampere-hour or equivalent rating of the battery.

Exception: The ampere-hour rating need not be marked if the battery charging circuit is current-limited.

SA25.4 A marine converter or inverter which incorporates a semiautomatic battery charging circuit shall be marked with the word "CA UTION" and the following or the equivalent: "To reduce the risk of fire or explosion of the battery as a result of overcharging, compensate input voltage. See instructions."

SA25.5 A marine converter or inverter that was not subjected to the ignition-protection tests described i n Section SA21 sh all be marked with the word "DANGER" and the following or the equivalent: "To reduce the risk of explosion - Do not install in machinery space or area in which ignition-protected equipment is required."

SA25.6 A marine converter or inverter that complies with the requirements for ignition protection in Section SA21 shall be marked with the words "Ignition Protected."

SA25.7 A marine converter or inverter not intended for use on a weatherdeck shall be marked with the wor d "CAUTION" and the following or the equivalent: "To reduce the risk of electric shock - Do not expose to rain o r spray."

INSTRUCTIONS

SA26 Instruction Manual

Section SA26 effective April 13, 1993

SA26.1 A marine converter or inverter shall be provided with explicit important safety, installation, operation an d maintenan ce instructions for the user; and, if applicable, with assembly instructions. The instructions shall b e consistent with the requirements mentioned in SA1.1.

SA26.2 The important safety instructions and instructions for user asse mbly, installation, operating and maintenance, shall be in the same manual. The important safety instructions shall appea r before the instructions for user assembly, installation, operation and maintenance.

SA26.3 In an instruction manua l intended for use with more than one model or type of marine converter or inverter, the instructions applicable to each model or type shall be explicitly identified.

Exception: Instructions that are exactly the same for more than one model or type of marine converter or inverter, and that could not result in confusion or misunderstanding due to different location of controls, operating modes, and the like need not comply with this requirement.

SA26.4 Instructions shall be legible, and shall contrast with the background.

SA26.5 The headings for the user assembly , installation, operation, maintenance, and important safety instructions, and the opening statements of the instructions specified in SA27.4 – "IMPORTANT SAFETY INSTRUCTIONS" and "SAVE THESE INSTRUCTIONS" – shall be entirely in upper case letters not less than 3/16 inch (4.8 mm) high or emphasized to distinguish them from the rest of the text. Upper case letters in the instructions shall not be less than 5/64 inch (2.0 mm) high, and lower case letters shall not be less than 1/16 inch (1.6 mm) high.

SA26.6 There shall be no substitute for the word "CAUTION," "WARNING" or "DANGER" in the text of the instructions.

SA26.7 The text of the instructions required by SA27.4 and SA27.5 shall be verbatim, or in equally definitive terminology.

Exception: If a specific conflict in the application to a marine converter or inverter exists, or if the wording would not be applicable, variations from the specified wording may be used.

SA26.8 An illustration may be used with a required instruction to clarify the intent, but shall not replace the instruction.

SA27 Important Safety Instructions

Section SA28 effective April 13, 1993

SA27.1 Important safety instructions shall warn the user of reasonably foreseeable risks of fire, electric shock, or injury to persons; and shall state the precautions that should be taken to reduce such risks.

SA27.2 The important safety instructions shall include the appropriate items in SA27.4 and SA27.5 followed by the applicable instructions in Sections SA28 – SA30.

SA27.3 The items in the list in SA27.4 shall be numbered, and other instructions deemed necessary by the manufacturer to reduce the risk of fire, electric shock, or injury to persons may be included.

SA27.4 The important safety instructions shall include those items in the following list that are applicable to the particular marine converter. The statement "IMPORTANT SAFETY INSTRUCTIONS," and the statement "SAVE THESE INSTRUCTIONS" shall precede the list. The word "CAUTION," "WARNING" or "DANGER" shall be entirely in upper case letters.

a) ALL MARINE CONVERTERS – The following items shall be included for all types of marine converters, unless otherwise noted:

IMPORTANT SAFETY INSTRUCTIONS

1) SAVE THESE INSTRUCTIONS – This manual contains important safety and operating instructions for marine converter Models _____.

Exception: If the instructions are exactly the same for all models, specific model numbers need not be specified.

2) CAUTION – To reduce risk of injury, charge only _____ type rechargeable batteries. Other types of batteries may burst causing personal injury and damage.

Exception: Marine converters without battery charging feature need not comply with this requirement.

3) Do not expose charger to rain or snow.

Exception: Marine converter or inverters investigated for open cockpit or weatherdeck mounting need not comply with this requirement.

4) Use of an attachment not recommended or sold by the ma rine converter manufacturer may result in a risk of fire, electric shock, or injury to persons.

5) Do not disas semble marine converter or inverter; take it to a qualified serviceman when service or repair is required. Incorrect reassembly may result in a risk of electric shock or fire.

6) To reduce risk of electric shock, unplug marine conver ter or inverter from outlet before attempting any maintenance or cleaning. Turning off controls will not reduce this risk.

b) MARINE POWE R CONVERTERS WITH BATTERY CHARGING FEATURE – All of the following items shall be included for a marine converter or inverter having a battery charging feature.

1) WARNING – RISK OF EXPLOSIVE GASES.

i) WORKING IN VICINITY OF A LEAD-ACID BATTERY IS DANGEROUS. BATTERIES GENERATE EXPLOSIVE GASES DURING NORMAL BATTERY OPERAT ION. FOR THIS REASO N, IT IS OF UTMOST IMPORTANCE THAT EACH TIME BEFORE SERVICIN G EQUIPM ENT IN THE VICINITY OF THE BATTERY, YOU READ THIS MANUAL AN D FOLLOW THE INSTRUCTIONS EXACTLY.

ii) To reduce risk of battery explosion, follow these instructions and those published b y battery manufacturer and manufacturer of any equipment you intend to use in vicinity o f battery. Review cautionary marking on these products and on engine.

2) PERSONAL PRECAUTIONS

i) Someone should be within range of y our voice or close enough to come to your aid when you work near a lead-acid battery.

ii) Have plenty of fresh water and soap nearby in case battery acid contacts skin, clothing, or eyes.

iii) Wear complete eye protection and clothing protection. Avoid touching eyes whil e working near battery.

iv) If battery acid contacts skin or clothing, wash immediately with soap and water. If acid enters eye, immediately flood eye with running cold water for at least 10 minutes and ge t medical attention immediately.

v) NEVER smoke or allow a spark or flame in vicinity of battery or engine.

vi) Be extra cautious to reduce risk of dropping a metal tool onto battery. It might spark or short-circuit battery or other electrical part that may cause explosion.

vii) Remove personal metal items such as rings, bracelets, necklaces, and watches when working with a lead-acid battery. A lead-acid battery can produce a short-circuit current high enough to weld a ring or the like to metal, causing a severe burn.

viii) NEVER charge a frozen battery.

ix) If necessary to remove battery from vessel, always remove grounded terminal fro m battery first. Make sure all accessories in the vessels are off, so as not to cause an arc.

x) Be sure area around battery is well ventilated.

xi) Clean battery terminals. Be careful to keep corrosion from coming in contact with eyes.

xii) Study all battery manufactu rer's specific precautions such as removing or not removing cell caps while charging and recommended rates of charge.

xiii) Add distilled water in each cell until battery acid reaches level specified by batter y manufacturer. This helps purge excessive gas from cells. Do not overfill. For a batter y without cell caps, carefully follow manufacturer's recharging instructions.

3) MARINE CONVERTER OR INVERTER LOCATION

i) Locate marine converter or inverter away from battery in a separate, well ventilate d compartment.

ii) Never place marine converter or inverter directly above battery; gases from battery will corrode and damage marine converter.

iii) Never allo w battery acid to drip on marine converter or inverter when reading gravity or filling battery.

iv) Do not operate marine converter or inverter in a closed-in area or restrict ventilation in any way.

4) DC CONNECTION PRECAUTIONS

i) Connect and disconnect DC output connections only after setting any marine converter or inverter switches to off po sition and removing AC cord from electric outlet or opening AC disconnect.

5) EXTERNAL CONNECTIONS TO CHARGER SHALL COMPLY WITH THE UNITED STATE S COAST GUARD ELECTRICAL REGULATIONS (33CFR183, SUB PART I).

SA27.5 The instructions for a marine converter or inverter shall include (a) – (d) as applicable to the particular converter.

a) For all grounded cord-connected marine converters or inverters:

GROUNDING AND AC POWER CORD CONNECTION INSTRUCTIONS – Converters/inverters should be grounded to reduce risk of electric shock. Converter/inverter is equipped with an electric cord having an equipment-grounding conductor and a grounding plug. The plug must be plugged into an outlet that is properly installed and grounded in accordance with all local codes and ordinances.

DANGER – Never alter AC cord or plug provided – if it will not fit outlet, have proper outlet installed by a qualified electrician. Improper connection can result in a risk of an electric shock.

b) For a grounded, cord-connected marine converter, with an input rating less than 15 amperes and intended for use on a nominal 120 volt circuit:

This marine converter/inverter is for use on a nominal 120 volt circuit, and has a grounding plug that looks like the plug illustrated in sketch A in Figure SA27.1. A temporary adapter, which looks like the adapter illustrated in sketches B and C, may be used to connect this plug to a two-pole receptacle as shown in sketch B if a properly grounded outlet is not available. The temporary adapter should be used only until a properly grounded outlet can be installed by a qualified electrician.

DANGER – Before using adapter as illustrated, be certain that center screw of outlet plate is grounded. The green-colored rigid ear or lug extending from adapter must be connected to a properly grounded outlet – make certain it is grounded. If necessary, replace original outlet cover plate screw with a longer screw that will secure adapter ear or lug to outlet cover plate and make ground connection to grounded outlet.

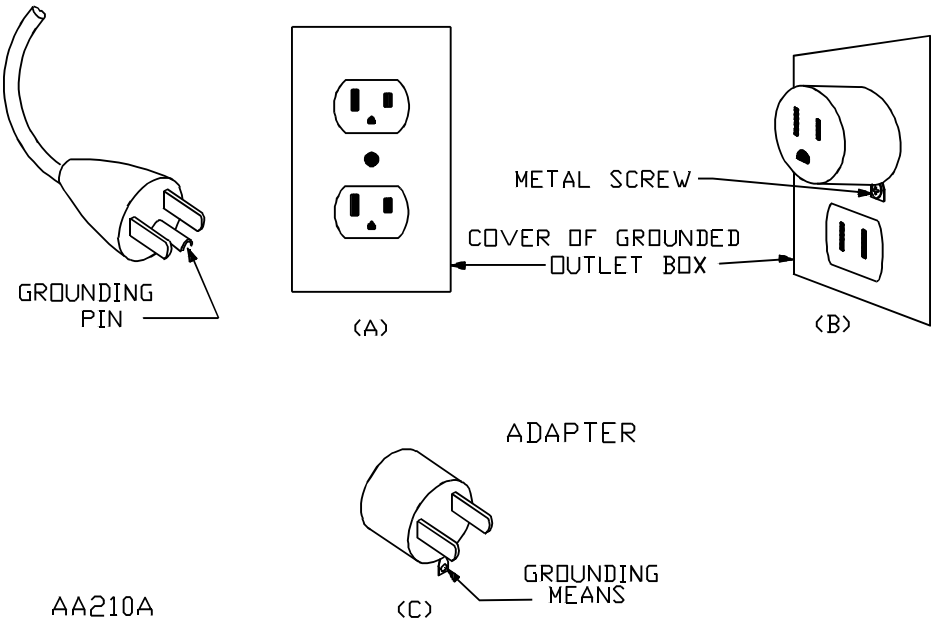
c) For all other grounded, cord-connected battery chargers:

This marine converter/inverter is for use on a circuit having a nominal rating more than 120 volts (or, "This appliance is rated more than 15 amperes and is for use on a circuit having a nominal rating of 120 volts") and is factory -equipped with a specific electric cord and plug to permit connection to an acceptable electric circuit. Make sure that the converter or inverter is connected to an outlet having the same configuration as the plug. No adapter should be used with this converter or inverter.

d) For a permanently connected marine converter or inverter:

GROUNDING INSTRUCTIONS – This marine converter or inverter should be connected to a grounded, metal, permanent wiring system; or an equipment-grounding conductor should be run with circuit conductors and connected to equipment-grounding terminal or lead on converter. Connections to converter should comply with all local codes and ordinances.

Figure SA27.1
Grounding method



SA28 Assembly Instructions

Section SA28 effective April 13, 1993

SA28.1 The assembly instructions, if applicable, shall contain all information needed for proper assembly of parts and shall be preceded by the heading "ASSEMBLY INSTRUCTIONS," or the equivalent.

SA29 Operating Instructions

Section SA29 effective April 13, 1993

SA29.1 The operating instructions shall contain all applicable information needed to operate a marine converter as intended, and shall be preceded by the heading "OPERATING INSTRUCTIONS," or the equivalent.

SA29.2 The operating instructions shall:

a) Warn that the marine converter or inverter must be properly assembled in accordance with the assembly instructions before it is used.

b) Explain and describe the location, function, and operation of each control of the marine converter, including all user-operated devices intended to reduce the risk of fire, electric shock, or injury to persons; and warn against tampering with such devices.

c) Operating instructions for marine converter or inverter provided with a battery charging circuit shall include a description of the function of an automatic or semiautomatic battery charging circuit, whichever is applicable.

SA30 Maintenance Instructions

Section SA30 effective April 13, 1993

SA30.1 The instructions for user maintenance shall include explicit instructions for all cleaning and mino r servicing – lubrication, external adju stments, and the like – that should be performed by the user; and shall warn the user that all other servicing should be perform ed by qualified service personnel. User maintenance instructions shall be preceded by the heading "MAINTENANCE INSTRUCTIONS," or the equivalent.

SA30.2 The user-maintena nce instructions, as described in SA30.1, shall not include operations that would require disassembly of the marine converter or inverter to accomplish.

APPENDIX A

Standards for Components

Standards under which components of the products covered by this standard are evaluated include the following:

Title of Standard – UL Standard Designation

Fuseholders – UL 512
Panelboards – UL 67
Transformers, Class 2 and Class 3 – UL 1585
Transformers, Specialty – UL 506

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