



# UL 458

## STANDARD FOR SAFETY

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



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

Sixth Edition, Dated September 2, 2015

### **Summary of Topics**

***This reaffirmation of ANSI/UL 458 dated January 31, 2025 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.***

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The requirements are substantially in accordance with Proposal(s) on this subject dated November 22, 2024.

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## **UL 458**

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

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## INTRODUCTION

### 1 Scope

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

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

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

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

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

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

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

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

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

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

### 2 Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

- a) An inherently limiting Class 2 transformer;
- b) A non-inherently limiting Class 2 transformer and an overcurrent protective device that is:
  - 1) Not of the automatic reclosing type;

2) Trip-free from the reclosing mechanism; and

3) Not readily interchangeable with a device of a different rating;

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

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

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

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

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

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

**2.19 PRESSURE TERMINAL CONNECTOR** – A field wiring terminal that accomplishes the connection of one or more conductors by means of pressure without the use of solder. A pressure terminal connector may be the barrel and set screw type, crimp type barrel, or clamping plate and screw type.

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

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

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

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

**2.24 RISK OF ELECTRICAL ENERGY – HIGH CURRENT LEVELS** – The capability for damage to property or injury to persons, other than by electric shock, from available electrical energy is considered to exist, if between a live part and an adjacent dead metal part or between live parts of different polarity, there exists a potential of 2 V or more and either an available continuous power level of 240 VA or more, or a reactive energy level of 20 J or more. For example, a tool, or other metal short circuiting a component may cause a burn or a fire if enough energy is available at the component to vaporize, melt, or more than warm the metal.

**2.25 RISK OF ELECTRIC SHOCK** – A risk of electric shock is considered to exist at any part if the potential between the part and earth ground or any other accessible part is greater than 42.4 V<sub>peak ac</sub> or

60 V dc, and the continuous current flow through a 1500  $\Omega$  resistor connected across the potential exceeds 5 mA.

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

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

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

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

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

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

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

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

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

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

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

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

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

- a) The installation of accessories by means of attachment plugs and receptacles, or by means of separable connectors.
- b) The replacement of lamps and fuses, or the resetting of circuit breakers located in a user access area unless they are marked to indicate replacement or resetting by qualified personnel only.
- c) The making of routine operating adjustments necessary to adapt the unit for different intended functions.

d) Routine cleaning.

### 3 Components

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

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

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or
- b) Is superseded by a requirement in this standard.

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

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

### 4 Units of Measurement

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

### 5 Undated References

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

## PART I – POWER CONVERTERS AND INVERTERS

### CONSTRUCTION

#### 6 General

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

#### 7 Frame and Enclosure

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

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

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

**Table 7.1**  
**Minimum acceptable thicknesses of enclosure metal**

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

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

*Exception: A polymeric enclosure or polymeric part of an enclosure in accordance with [7.6](#) need not comply with this requirement.*

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

- a) Dimensional stability;
- b) Mechanical strength; and
- c) Resistance to creeping and distortion at temperatures to which the material may be subjected under conditions of intended use.

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

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

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

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

7.7 A conductive coating applied to a nonmetallic surface (such as the inside surface of a cover or an enclosure) shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

*Exception: If flaking or peeling of the coating will not result in a risk of fire or electric shock as a result of a reduction of spacings or the bridging of live parts, then the coating need not comply with UL 746C.*

7.8 Overtemperature and overcurrent protection shall be located within the unit enclosure. See [21.2.1](#) – [21.2.3](#).

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

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

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

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

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

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

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

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

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

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

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

7.17 For a unit having holes in the bottom of the enclosure, the requirements in [7.15](#) will necessitate the use of:

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

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

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

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

## 8 Enclosures Used For Protected Environments

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

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

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

- a) Hermetically sealed;
- b) Provided with gasketed, tight fitting joints and doors or covers;
- c) Welded, sonically welded, solvent cemented, or provided with tongue and groove joints and seams; or
- d) Encapsulated (potted); or
- e) Conformally coated with a compound that complies with the Standard for Polymeric Materials – Use in Electrical Evaluations, UL 746C, and with the intended application.

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

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

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

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

### 9.1 General

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

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



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

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

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

## 9.2 User servicing

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

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

- a) Recessed at least 1/8 in (3.2 mm) from the plane of the front of the fixed portion of an enclosure; or
- b) Recessed at least 1/8 in (3.2 mm) from the front edge of a wiring compartment, in the case of a device mounted to the face of a wiring compartment; or
- c) Afforded equivalent protection by projections or guards.

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

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

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

## 9.3 Serviceman servicing

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

9.3.2 The electrical components mentioned in [9.3.1](#) include a fuse and an adjustable control.

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

## 10 Assembly

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

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

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

- a) The switch is a plunger or other type that does not tend to rotate when operated—a toggle switch is considered to be subject to forces that tend to turn the switch;*
- b) The means for mounting the switch makes it unlikely that operation of the switch will loosen it;*
- c) Spacings are not reduced below the minimum acceptable values if the switch rotates; and*
- d) Normal operation of the switch is by mechanical means rather than by direct contact by persons.*

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

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

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

## 11 Protection Against Corrosion

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

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

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

## 12 Supply Connections

### 12.1 Permanently-connected converters or inverters

#### 12.1.1 General

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

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

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

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

**Table 12.1**  
**Knockout or hole sizes and dimensions of bushings**

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

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

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

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

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

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

- a) Sharp edges, including screw threads, burrs, fins, and the like that may abrade the insulation on conductors or otherwise damage the wiring;
- b) Terminals; and
- c) Other live parts.

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

## 12.1.2 Wiring terminals and leads

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

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

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

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

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

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

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

12.1.2.6 A wire-binding screw shall thread into metal.

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

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

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

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

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

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

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

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

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

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

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

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

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

## 12.2 Cord connection

### 12.2.1 General

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

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

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

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

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

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

## 12.2.2 Strain relief

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

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

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

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

## 12.3 Bushings

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

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

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

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

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

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

## 13 Low-Voltage DC Connections and Wiring

### 13.1 General

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

- a) A wiring compartment and terminals complying with the requirements in [13.1.2](#) – [13.1.5](#),
- b) A receptacle or attachment plug complying with the requirements in [13.1.6](#) – [13.1.12](#),
- c) Unenclosed individual leads complying with the requirements in [13.1.13](#) – [13.1.15](#).

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

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

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

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

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

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

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

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

13.1.10 An attachment-plug receptacle shall have recessed contacts.

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

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

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

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

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

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

## 13.2 Cigarette lighter inputs

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

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

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

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

**Table 13.1**  
**Cord sizes**

| Adapter input fuse rating<br>A | Minimum cord conductor size<br>AWG (mm <sup>2</sup> ) |
|--------------------------------|-------------------------------------------------------|
| 10 and less                    | 18 <sup>a</sup> (0.82)                                |
| 12                             | 17 (1.04)                                             |
| 13                             | 16 (1.31)                                             |
| 18                             | 14 (2.08)                                             |
| 20                             | 12 (3.31)                                             |

<sup>a</sup> Size not specified for conductors in Class 2 or Low Voltage Limited Energy Circuits.

## 14 Secondary Circuits

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

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

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

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

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

- a) Not more than 42.4 V<sub>peak</sub> ac or 60 Vdc; and
- b) The energy available at 1 min of operation is limited to:
  - 1) 8 A for 0-42.4 V<sub>peak</sub> ac or 0-30 Vdc; or
  - 2) 150/V<sub>max</sub> A for 30-60 Vdc.

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

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

**Table 14.1**  
**Rating for secondary fuse or circuit protector**

| Circuit voltage (V rms)                                                                                                                | Maximum overcurrent protection (A) |
|----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|
| 20 or less                                                                                                                             | 5                                  |
| More than 20 but less than 60                                                                                                          | 100/V <sup>a</sup>                 |
| <sup>a</sup> V is the maximum output voltage, regardless of load, with the primary energized in accordance with <a href="#">32.1</a> . |                                    |

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

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

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

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

## 14A Batteries

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

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

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

## 15 Live Parts

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

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

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

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

## 16 Internal Wiring

### 16.1 General

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

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

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

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

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

- a) The insulation on the individual conductors is equivalent to that required by [16.1.2](#);
- b) The individual conductors are supported in a manner positively separating them from live parts and dead metal parts; or
- c) Supplementary insulation equivalent to that required by [16.1.2](#) is reliably secured on each individual conductor.

### 16.2 Tubing

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

16.2.2 If the use of a short length of insulated conductor, such as a short coil lead, is not practical, electrical insulating tubing may be used on each conductor. The tubing shall not be subjected to sharp bends, tension, compression, or repeated flexing, or to contact with sharp edges, projections, or corners. Except as noted in [16.2.3](#), the wall thickness shall comply with the requirements for the tubing as a component.

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

### 16.3 Protection of wiring

16.3.1 Internal wiring shall be protected if, when judged in accordance with [9.1.2](#), it is accessible.

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

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

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

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

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

### 16.4 Electrical connections

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

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

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

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

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

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

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

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

## 16.5 Separation of circuits

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

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

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

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

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

## 16.6 Barriers

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

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