

# UL 508C

ISBN 0-7629-0093-8

## Power Conversion Equipment



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UL Standard for Safety  
for  
Power Conversion Equipment, UL 508C

Second Edition, Dated November 27, 1996

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**NOVEMBER 27, 1996**

**1**

**UL 508C**

**Standard for**

**Power Conversion Equipment**

Prior to the first edition, the requirements for the products covered by this standard were included in the Outline of Investigation for Power Conversion Equipment, UL 508C.

First Edition – December, 1993

**Second Edition**

**November 27, 1996**

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

Revisions of this standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard 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.

**ISBN 0-7629-0093-8**

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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 open or enclosed equipment that supplies power to control a motor or motors operating at a frequency or voltage different than that of the input supply. These requirements also cover power-supply modules, input/output modules, Silicon Controlled Rectifier (SCR) or Transistor output modules, dynamic braking units, and input/output accessory kits for use with power conversion equipment.

1.2 This equipment is for use in ordinary locations in accordance with Articles 430 and 440 of the National Electrical Code, NFPA 70-1996.

1.3 These requirements cover devices rated 1500 volts or less.

1.4 Equipment intended for use in hazardous locations as defined by the National Electrical Code, NFPA 70-1996, shall be evaluated to the Standard for Industrial Control Equipment for Use in Hazardous (Classified) Locations, UL 698.

1.5 A product that contains features, characteristics, components, materials, or systems new or different from those in use when the standard was developed, 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 in order to maintain the level of safety for the user of the product as originally anticipated by the intent of this standard.

### 2 Glossary

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

2.2 CONTROL CIRCUIT – A circuit that carries the electric signals directing the performance of a controller, and does not carry the main power circuit (see IEEE Standards Dictionary of Electrical and Electronic Terms). A control circuit is mostly limited to 15 amperes.

2.3 ENCLOSURE, OPEN DEVICE – Industrial control equipment with an incomplete or partial enclosure.

2.4 ENCLOSURE, ENCLOSED DEVICE – Industrial control equipment provided with a suitably rated enclosure. (See UL 50, the Standard for Enclosure for Electrical Equipment for details.)

2.5 POLLUTION DEGREE 1 – No pollution or only dry, nonconductive pollution occurs. The pollution has no influence. Pollution degree 1 is obtainable by the encapsulation or hermetic sealing of the product. Typical constructions that meet this requirement are:

- a) The use of conformal coating on printed wiring board foil traces that complies with the requirements for Conformal Coatings in the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C;
- b) The use of any potting material or encapsulation, such as epoxy;
- c) The use of silicone rubber at a thickness of at least 1/32 inch (0.79 mm);
- d) The use of a case or enclosure that is hermetically sealed against the entrance of an external atmosphere by means of fusion – such as from soldering, brazing, welding, or the fusion of glass to metal.

2.6 POLLUTION DEGREE 2 – Normally, only nonconductive pollution occurs; however, temporary conductivity is expected. Pollution degree 2 is obtainable by reducing possibilities of conductive pollution and reducing possibilities of condensation or high humidity at the creepage distances.

a) Typical constructions that reduce the possibility of conductive pollution are:

- 1) The use of an un-ventilated enclosure;
- 2) The use of a filtered ventilated enclosure when the ventilation is fan forced – that is, ventilation is accomplished by one or more blowers within the enclosure that provide a positive intake and exhaust; or
- 3) The use an un-filtered ventilated enclosure when the ventilation is not fan forced.

b) Typical constructions that reduce the effects of condensation or high humidity are:

- 1) The use of a ventilated enclosure;
- 2) The continuous application of heat through the use of heaters;
- 3) The application of heat through continuous energization of the equipment, with interruptions such that cooling to the point of condensation does not occur; or
- 4) The use of any coatings, such as solder masking, on printed wiring board foil traces.

2.7 POLLUTION DEGREE 3 – Conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation that is expected.

2.8 TRANSIENT SUPPRESSIVE DEVICE – A component or assembly that limits the transient voltage such as an overvoltage protective device, a transformer with isolated windings, or a damping impedance suitably located.

### 3 Units of Measurement

3.1 If a value for measurement is followed by a value in other units in parentheses, the first stated value is the requirement.

### 4 Components

4.1 Except as indicated in 4.2, 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 this standard.

4.2 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.

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

4.4 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.

## ENCLOSURE CONSTRUCTION

### 5 Frames and Enclosure

#### 5.1 General

5.1.1 An enclosure of power conversion equipment shall be constructed and assembled such that it has the strength and rigidity to resist the abuses to which it is subjected, without total or partial collapse resulting in a risk of fire, electric shock, or injury to persons due to reduction of spacings, loosening or displacement of parts, or other serious defects.

5.1.2 An enclosure shall be constructed so as to reduce the risk of unintentional contact with enclosed electrical devices, and to provide internal devices with protection from specified external conditions.

#### 5.2 Cast metal

5.2.1 A cast-metal enclosure shall be at least 1/8 inch (3.2 mm) thick at every point, more than 1/8 inch thick at reinforcing ribs and door edges, and at least 1/4 inch (6.4 mm) thick at tapped holes for conduit.

*Exception: Other than at plain or threaded conduit holes, malleable iron and die-cast or permanent mold cast aluminum, brass, bronze, or zinc shall be:*

- a) At least 3/32 inch (2.4 mm) thick for an area greater than 24 square inches (155 cm<sup>2</sup>) or having any dimension more than 6 inches (152 mm); and*
- b) At least 1/16 inch (1.6 mm) thick for an area of 24 square inches (155 cm<sup>2</sup>) or less having no dimension more than 6 inches (152 mm).*

*The area under evaluation is capable of being bounded by reinforcing ribs subdividing a larger area.*

#### 5.3 Sheet metal

5.3.1 The thickness of a sheet-metal enclosure shall not be less than that specified in Tables 5.1 and 5.2, except that at points to which a wiring system is to be connected, uncoated steel shall be at least 0.032 inch (0.81 mm) thick, zinc-coated steel at least 0.034 inch (0.86 mm) thick, and nonferrous metal at least 0.045 inch (1.14 mm) thick.

*Exception: Enclosure thickness at points other than where a wiring system is to be connected is not required to comply with these requirements when the enclosure complies with the Compression Test and Deflection Test in the Standard for Enclosures for Electrical Equipment, UL 50, as applicable.*

5.3.2 Tables 5.1 and 5.2 are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

5.3.3 With reference to Tables 5.1 and 5.2, a supporting frame is a structure of angle or channel or folded rigid section of sheet metal that is rigidly attached to and has the same outside dimensions as the enclosure surface and that has torsional rigidity to resist the bending moments that are applied by the enclosure surface when it is deflected. A structure that is as rigid as one built with a frame of angles or channels has equivalent reinforcing. Constructions without supporting frame include:

- a) A single sheet with single formed flanges – formed edges;
- b) A single sheet that is corrugated or ribbed;
- c) An enclosure surface loosely attached to a frame, for example, with spring clips; and
- d) An enclosure surface having an unsupported edge.

#### 5.4 Doors and covers

5.4.1 A part of an enclosure, such as a door or a cover, shall be provided with a means – such as latches, locks, interlocks, or screws – for firmly securing it in place.

*Exception: A snap-on cover that complies with Securement of Snap-On Cover Test, Section 10, is not required to have additional securing means.*

5.4.2 An enclosure cover shall be hinged when it gives access to a fuse or any other overload-protective device that requires renewal, or when it is required to be opened for normal operation of the device.

*Exception: A hinged cover is not required for an enclosure:*

- a) To which access is required only in the event of burnout of a current element or similar components on short circuit;*
- b) In which the only fuse enclosed is a control-circuit fuse, when the fuse and control-circuit load – other than a fixed control-circuit load, such as a pilot lamp – are within the same enclosure; or*
- c) In which a means is provided for resetting all overload-protective devices from outside the enclosure, or kits are available to provide a means for resetting all overload-protective devices from outside the enclosure and a marking is provided in accordance with Instructions and Markings Pertaining to Accessories, Section 59.*

5.4.3 Other than as noted in 5.4.4, a hinged cover provided in accordance with the requirement in 5.4.2 shall be provided with a snap latch or a captive multiturn or partial-turn fastener. Such securing means shall be located or used in multiple so as to hold the cover closed over its entire length. A captive fastener shall be operable by hand or by a simple hand tool such as a screwdriver.

5.4.4 A door more than 48 inches (1.2 m) long on the hinged side shall be provided with one of the following:

- a) A multipoint latch operated by a single knob or handle;
- b) Two or more snap latches or captive fasteners; or
- c) One knob-operated latch and one snap latch or captive fastener.

**Table 5.1**  
**Thickness of sheet metal for enclosures –**  
**carbon steel or stainless steel**

| Without supporting frame <sup>a</sup> |         | With supporting frame or equivalent reinforcement <sup>a</sup> |       | Minimum required thickness, |                    |
|---------------------------------------|---------|----------------------------------------------------------------|-------|-----------------------------|--------------------|
|                                       |         |                                                                |       | inches                      | (mm)               |
| Maximum width <sup>b</sup>            |         | Maximum length <sup>c</sup>                                    |       |                             |                    |
| Inches                                | (cm)    | Inches                                                         | (cm)  | Uncoated                    | Metal coated       |
| 4.0                                   | (10.2)  | Not limited                                                    | 6.25  | 0.020 <sup>d</sup>          | 0.023 <sup>d</sup> |
| 4.75                                  | (12.1)  | 5.75                                                           | 6.75  |                             |                    |
| 6.0                                   | (15.2)  | Not limited                                                    | 9.5   | 0.026 <sup>d</sup>          | 0.29d              |
| 7.0                                   | (17.8)  | 8.75                                                           | 10.0  |                             |                    |
| 8.0                                   | (20.3)  | Not limited                                                    | 12.0  | 0.032                       | 0.034              |
| 9.0                                   | (22.9)  | 11.5                                                           | 13.0  |                             |                    |
| 12.5                                  | (31.8)  | Not limited                                                    | 19.5  | 0.042                       | 0.045              |
| 14.0                                  | (35.6)  | 18.0                                                           | 21.0  |                             |                    |
| 18.0                                  | (45.7)  | Not limited                                                    | 27.0  | 0.053                       | 0.056              |
| 20.0                                  | (50.8)  | 25.0                                                           | 29.0  |                             |                    |
| 22.0                                  | (55.9)  | Not limited                                                    | 33.0  | 0.060                       | 0.063              |
| 25.0                                  | (63.5)  | 31.0                                                           | 35.0  |                             |                    |
| 25.0                                  | (63.5)  | Not limited                                                    | 39.0  | 0.067                       | 0.070              |
| 29.0                                  | (73.7)  | 36.0                                                           | 41.0  |                             |                    |
| 33.0                                  | (83.8)  | Not limited                                                    | 51.0  | 0.080                       | 0.084              |
| 38.0                                  | (96.5)  | 47.0                                                           | 54.0  |                             |                    |
| 42.0                                  | (106.7) | Not limited                                                    | 64.0  | 0.093                       | 0.097              |
| 47.0                                  | (119.4) | 59.0                                                           | 68.0  |                             |                    |
| 52.0                                  | (132.1) | Not limited                                                    | 80.0  | 0.108                       | 0.111              |
| 60.0                                  | (152.4) | 74.0                                                           | 84.0  |                             |                    |
| 63.0                                  | (160.0) | Not limited                                                    | 97.0  | 0.123                       | 0.126              |
| 73.0                                  | (185.4) | 90.0                                                           | 103.0 |                             |                    |
|                                       |         |                                                                | 127.0 |                             |                    |

<sup>a</sup> See 5.3.3.

<sup>b</sup> The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure are able to have supports in common and be made of a single sheet.

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

<sup>d</sup> Sheet steel for an enclosure intended for outdoor use – raintight or rainproof – shall not be less than 0.034 inch (0.86 mm) thick when zinc coated and not less than 0.032 inch (0.81 mm) thick when uncoated.

**Table 5.2**  
**Thickness of sheet metal for electrical enclosures –**  
**aluminum, copper, or brass**

| Without supporting frame <sup>a</sup> |                             | With supporting frame or equivalent reinforcement <sup>a</sup> |                | Minimum required thickness |
|---------------------------------------|-----------------------------|----------------------------------------------------------------|----------------|----------------------------|
| Maximum width <sup>b</sup>            | Maximum length <sup>c</sup> | Maximum width <sup>b</sup>                                     | Maximum length |                            |
| Inches (cm)                           | Inches (cm)                 | Inches (cm)                                                    | Inches (cm)    | Inches (mm)                |
| 3.0 (7.6)                             | Not limited                 | 7.0 (17.8)                                                     | Not limited    | 0.023 <sup>d</sup> (0.58)  |
| 3.5 (8.9)                             | 4.0 (10.2)                  | 8.5 (21.6)                                                     | 9.5 (24.1)     |                            |
| 4.0 (10.2)                            | Not limited                 | 10.0 (25.4)                                                    | Not limited    | 0.029 (0.74)               |
| 5.0 (12.7)                            | 6.0 (15.2)                  | 10.5 (26.7)                                                    | 13.5 (34.3)    |                            |
| 6.0 (15.2)                            | Not limited                 | 14.0 (35.6)                                                    | Not limited    | 0.036 (0.91)               |
| 6.5 (16.5)                            | 8.0 (20.3)                  | 15.0 (38.1)                                                    | 18.0 (45.7)    |                            |
| 8.0 (20.3)                            | Not limited                 | 19.0 (48.3)                                                    | Not limited    | 0.045 (1.14)               |
| 9.5 (24.1)                            | 11.5 (29.2)                 | 21.0 (53.3)                                                    | 25.0 (63.5)    |                            |
| 12.0 (30.5)                           | Not limited                 | 28.0 (71.1)                                                    | Not limited    | 0.058 (1.47)               |
| 14.0 (35.6)                           | 16.0 (40.6)                 | 30.0 (76.2)                                                    | 37.0 (94.0)    |                            |
| 18.0 (45.7)                           | Not limited                 | 42.0 (106.7)                                                   | Not limited    | 0.075 (1.91)               |
| 20.0 (50.8)                           | 25.0 (63.5)                 | 45.0 (114.3)                                                   | 55.0 (139.7)   |                            |
| 25.0 (63.5)                           | Not limited                 | 60.0 (152.4)                                                   | Not limited    | 0.095 (2.41)               |
| 29.0 (73.7)                           | 36.0 (91.4)                 | 64.0 (162.6)                                                   | 78.0 (198.1)   |                            |
| 37.0 (94.0)                           | Not limited                 | 87.0 (221.0)                                                   | Not limited    | 0.122 (3.10)               |
| 42.0 (106.7)                          | 53.0 (134.6)                | 93.0 (236.2)                                                   | 114.0 (289.6)  |                            |
| 52.0 (132.1)                          | Not limited                 | 123.0 (312.4)                                                  | Not limited    | 0.153 (3.89)               |
| 60.0 (152.4)                          | 74.0 (188.0)                | 130.0 (330.2)                                                  | 160.0 (406.4)  |                            |

<sup>a</sup> See 5.3.3.

<sup>b</sup> The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure are able to have supports in common and be made of a single sheet.

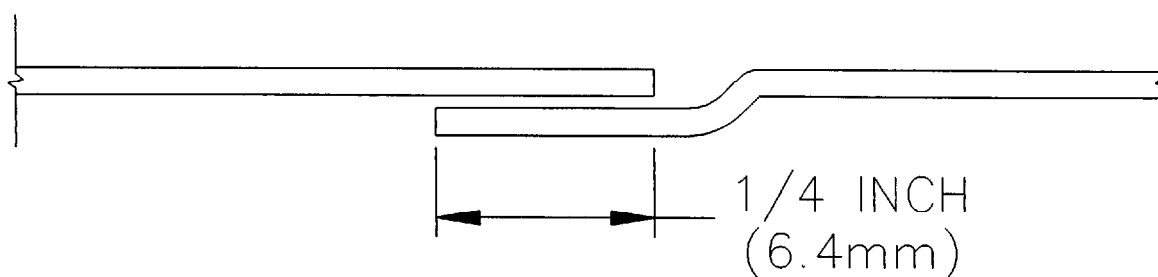
<sup>c</sup> Not limited applies only when the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

<sup>d</sup> Sheet copper, brass, or aluminum for an enclosure intended for outdoor use – raintight or rainproof – shall not be less than 0.029 inch (0.74 mm) thick.

5.4.5 Noncaptive fasteners are not prohibited for use on hinged cover enclosures that are not required to comply with 5.4.2

5.4.6 A door giving access to a fuse or any portion of a circuit breaker other than the operating handle shall shut closely against a 1/4-inch (6.4-mm) rabbet as illustrated in Figure 5.1 or the equivalent.

**Figure 5.1**  
**Rabbet**



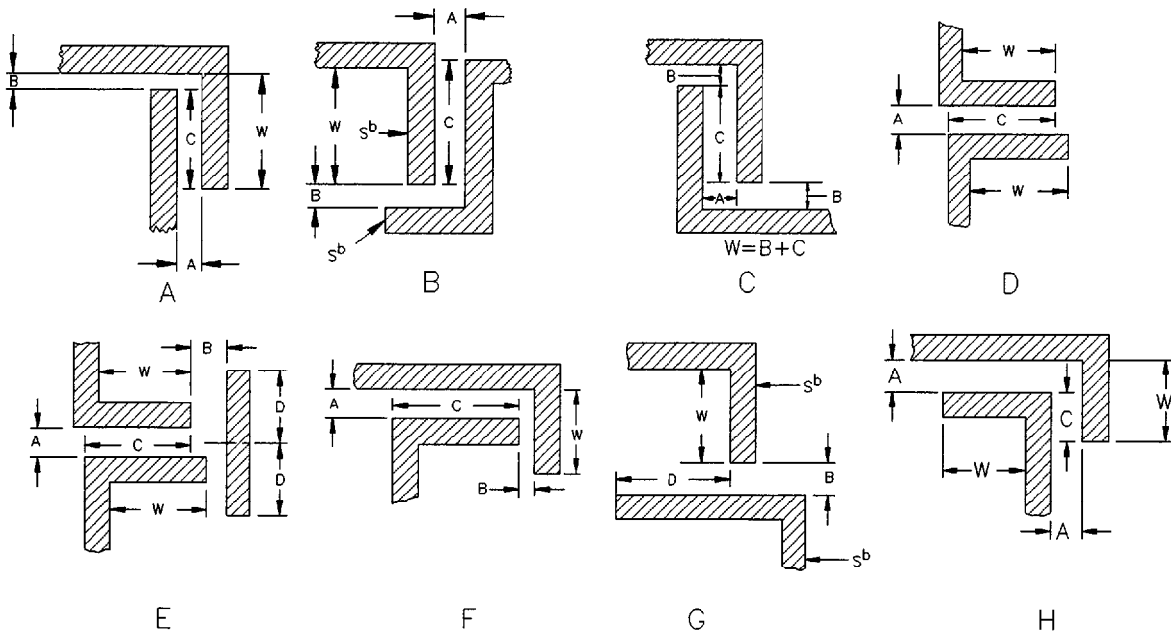
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5.4.7 A cover giving access to a fuse or any portion of a circuit breaker other than the operating handle shall have flanges for the full length of the four edges. Flanges on a cover shall fit closely with the outside walls of the enclosure, and shall comply with Figure 5.2 and Table 5.3. A combination of flange and rabbet is usable.

*Exception: The flange width is not required to be as specified when the construction complies with the Deflection Test in the Standard for Enclosures for Electrical Equipment, UL 50.*

5.4.8 To determine whether a flanged cover complies with the requirement in 5.4.7 regarding width of flange, the distance between the flat portion of the cover – clear of forming radii, beads, draws, and similar features – and a straight edge placed anywhere across any two flanges at any points is to be measured.

**Figure 5.2**  
**Flanged cover constructions<sup>a</sup>**



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- <sup>a</sup> See Table 5.3 for dimensions for sketches A – H.
- <sup>b</sup> The surfaces "S" are able to be in line with one another – not as shown.

**Table 5.3**  
**Dimensions for flanged cover constructions**

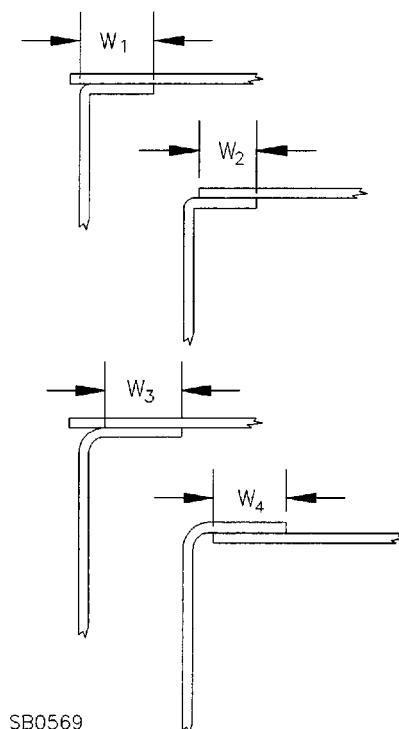
| Sketch – see<br>Figure 5.2 | Dimensions                           |      |                                |      |             |      |                 |      |                              |      |
|----------------------------|--------------------------------------|------|--------------------------------|------|-------------|------|-----------------|------|------------------------------|------|
|                            | W                                    |      | A                              |      | B           |      | C               |      | D                            |      |
|                            | Minimum flange<br>width <sup>a</sup> |      | Maximum space<br>between parts |      | Maximum gap |      | Minimum overlap |      | Minimum barrier<br>extension |      |
|                            | Inch                                 | (mm) | Inch                           | (mm) | Inch        | (mm) | Inch            | (mm) | Inch                         | (mm) |
| A                          | 1/2                                  | 12.7 | 1/8                            | 3.2  | 1/8         | 3.2  | 7/16            | 11.1 | -                            | -    |
| A                          | 3/4                                  | 19.1 | 3/16                           | 4.8  | 3/16        | 4.8  | 5/8             | 15.9 | -                            | -    |
| A                          | 1                                    | 25.4 | 1/4                            | 6.4  | 1/4         | 6.4  | 7/8             | 22.2 | -                            | -    |
| B                          | 1/2                                  | 12.7 | 1/8                            | 3.2  | 1/8         | 3.2  | 7/16            | 11.1 | -                            | -    |
| B                          | 3/4                                  | 19.1 | 3/16                           | 4.8  | 3/16        | 4.8  | 5/8             | 15.9 | -                            | -    |
| B                          | 1                                    | 25.4 | 1/4                            | 6.4  | 1/4         | 6.4  | 7/8             | 22.2 | -                            | -    |
| C                          | 1/2                                  | 12.7 | 3/16                           | 4.8  | 3/16        | 4.8  | 1/4             | 6.4  | -                            | -    |
| C                          | 3/4                                  | 19.1 | 1/4                            | 6.4  | 1/4         | 6.4  | 7/16            | 11.1 | -                            | -    |
| D                          | 1/2                                  | 12.7 | 3/32                           | 2.4  | -           | -    | 7/16            | 11.1 | -                            | -    |
| E                          | 1/2                                  | 12.7 | 1/8                            | 3.2  | 1/8         | 3.2  | 7/16            | 11.1 | 1/4                          | 6.4  |
| F                          | 1/2                                  | 12.7 | 1/8                            | 3.2  | 1/4         | 6.4  | 7/16            | 11.1 | -                            | -    |
| G <sup>b</sup>             | 1/2                                  | 12.7 | -                              | -    | 1/32        | 0.8  | -               | -    | 1/2                          | 12.7 |
| H                          | 1/4                                  | 6.4  | 1/8                            | 3.2  | -           | -    | 3/16            | 4.8  | -                            | -    |

<sup>a</sup> Tolerance: minus 1/16 inch (1.6 mm)

<sup>b</sup> Equipment within the enclosure must be located on the side of the barrier extension D that is opposite the gap B.

5.4.9 Figure 5.3 illustrates the method of determining the amount of overlap between a flat cover and a flanged box wall and the amount of overlap at a corner or box seam. When the radius of the flange bend is small, the flange width and overlap are designated  $W_1$  or  $W_2$ , based upon the actual construction, and shall be at least 1/2 inch (12.7 mm). When the radius of the flange bend is excessive or when the flat sheet is on the inside of the flange, the overlap,  $W_3$  or  $W_4$ , is to be measured over only that portion where the two pieces of metal are actually in contact with each other, and shall be at least 1/2 inch (12.7 mm).

**Figure 5.3**  
**Overlap between flat cover and box**  
**flange and at corner or box seam**



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5.4.10 To determine the overlap of a telescoping cover, the enclosure is to be placed on its back on a bench, with the cover in its normally closed position, and a mark is to be scribed on all walls of the box along the edge of the flange. The overlap is the measured distance between the scribe marks and the edges of the box walls, noted as  $W_4$  in Figure 5.3. In scribing the marks, the cover is to be held in a fixed position with firmness so as to prevent displacement of the cover by the scribing tool, and without bending or distorting any portion of the box, cover, or other part of the enclosure.

5.4.11 A flat strip used to provide a rabbet, or an angle strip fastened to the edges of a door giving access to a fuse or any portion of a circuit breaker, other than the operating handle, shall be at least 60 percent of the required thickness of the metal of the box proper, and not less than 0.042 inch (1.07 mm) when of uncoated steel, not less than 0.045 inch (1.14 mm) when of zinc-coated steel, and not less than 0.058 inch (1.47 mm) thick when of nonferrous metal. It shall be secured at no fewer than two points. There shall not be more than 1-1/2 inches (38 mm) between an end of the strip and a point at which it is secured, and the distance between adjacent points at which the strip is secured shall not be more than 6 inches (152 mm).

5.4.12 A construction involving a gasket that provides the intended tight fit, as verified by the environmental rating related performance tests in Section 8, General, is not required to comply with the rabbeting, flanging, or overlapping requirements in 5.4.6 – 5.4.11.

## 5.5 Polymeric

5.5.1 A polymeric electrical enclosure or a polymeric part of an electrical enclosure shall comply with the Polymeric Enclosures/Parts requirements in the Standard for Enclosures for Electrical Equipment, UL 50, and also with the additional requirements specified in this standard. See Section 8, General, for enclosure performance requirements.

5.5.2 A polymeric enclosure intended for connection to a rigid conduit system shall comply with Polymeric Enclosure Rigid Metallic Conduit Connection Tests in the Standard for Enclosures for Electrical Equipment, UL 50.

## 5.6 Bonding

5.6.1 An enclosure made of insulating material, either wholly or in part, shall have bonding means to provide continuity of grounding between all conduit openings. The bonding means shall be either completely assembled on the product or provided as separate parts for field installation. See 58.7.

*Exception No. 1: A bonding means is not required for the enclosure of a pushbutton station or a selector switch that is intended to be connected to a single conduit.*

*Exception No. 2: A bonding means is not required to be provided with each enclosure when such means is available in the form of a kit from the manufacturer and the equipment complies with the marking requirements in 59.1.*

5.6.2 The continuity of a conduit system shall be provided by metal-to-metal contact not relying on a polymeric material.

*Exception: The continuity of the grounding system is not prohibited from relying on the integrity of the polymeric enclosure when samples have been subjected to the creep test requirements in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. Overcurrent Tests shall be conducted at 200 percent of the rated current of the branch circuit-protective device.*

5.6.3 A separate bonding conductor whether in a plastic or metal enclosure shall be copper, a copper alloy, or other material determined to be usable as an electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. A separate bonding conductor shall:

- a) Be protected from mechanical damage or be located within the confines of the outer enclosure or frame; and
- b) Not be secured by a removable fastener used for any purpose other than bonding unless the bonding conductor is unable to be omitted after removal and replacement of the fastener.

5.6.4 The size of a separate component bonding conductor shall not be less than the applicable size specified in Table 5.4 or the size of the conductor supplying the component, whichever is smaller.

*Exception: A bonding conductor is not required to be as large as the specified size when:*

- a) *It does not open when carrying, for the time specified in Table 5.5, a current equal to twice the branch-circuit overcurrent-device rating – see 5.6.5 – and not less than 40 amperes; and*
- b) *None of three samples of the bonding conductor opens during a limited-short-circuit test with a current as specified in Table 5.6 when in series with a fuse as described in 5.6.5.*

**Table 5.4**  
**Size of bonding conductor**

| Maximum rating or setting of automatic overcurrent device in circuit ahead of equipment, amperes | Minimum size of bonding conductor <sup>a</sup> |                                               |
|--------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------|
|                                                                                                  | Copper wire AWG (mm <sup>2</sup> )             | Aluminum wire AWG or kcmil (mm <sup>2</sup> ) |
| 15                                                                                               | 14 (2.1)                                       | 12 (3.3)                                      |
| 20                                                                                               | 12 (3.3)                                       | 10 (5.3)                                      |
| 30                                                                                               | 10 (5.3)                                       | 8 (8.4)                                       |
| 40                                                                                               | 10 (5.3)                                       | 8 (8.4)                                       |
| 60                                                                                               | 10 (5.3)                                       | 8 (8.4)                                       |
| 100                                                                                              | 8 (8.4)                                        | 6 (13.3)                                      |
| 200                                                                                              | 6 (13.3)                                       | 4 (21.2)                                      |
| 300                                                                                              | 4 (21.2)                                       | 2 (33.6)                                      |
| 400                                                                                              | 3 (26.7)                                       | 1 (42.4)                                      |
| 500                                                                                              | 2 (33.6)                                       | 1/0 (53.5)                                    |
| 600                                                                                              | 1 (42.4)                                       | 2/0 (67.4)                                    |
| 800                                                                                              | 1/0 (53.5)                                     | 3/0 (85.0)                                    |
| 1000                                                                                             | 2/0 (67.4)                                     | 4/0 (107.0)                                   |
| 1200                                                                                             | 3/0 (85.0)                                     | 250 (127.0)                                   |

<sup>a</sup> Or equivalent cross-sectional area.

**Table 5.5**  
**Duration of current flow for bonding-conductor test**

| Overcurrent device rating, amperes | Minimum duration of current flow, minutes |
|------------------------------------|-------------------------------------------|
| 30 or less                         | 1                                         |
| 31 – 60                            | 4                                         |
| 61 – 100                           | 6                                         |

**Table 5.6**  
**Bonding conductor short-circuit test capacity**

| Controller rating |                 |           | Circuit capacity amperes |
|-------------------|-----------------|-----------|--------------------------|
| Horsepower        | (kW Output)     | Volts     |                          |
| 1/2               | (0.373)         | 0 – 250   | 200                      |
| 1/2               | (0.373)         | 251 – 600 | 1,000                    |
| over 1/2 to 1     | (0.374 – 0.746) | 0 – 600   | 1,000                    |
| 1 to 3            | (0.747 – 2.24)  | 0 – 250   | 2,000                    |
| over 3 to 7-1/2   | (2.25 – 5.59)   | 0 – 250   | 3,500                    |
| over 7-1/2 to 10  | (5.60 – 7.46)   | 0 – 250   | 5,000                    |
| over 10 to 50     | (7.47 – 37.3)   | 251 – 600 | 5,000                    |
| over 50 to 200    | (37.4 – 149)    | 0 – 600   | 10,000                   |
| over 200          | (over 150)      | 0 – 600   | a                        |

<sup>a</sup> See Table 44.1.

5.6.5 The circuit for the test required by the exception to 5.6.4 is to have a power factor of 0.9 – 1.0 and is to be limited to the current specified in Table 5.6. The open-circuit voltage of the test circuit is to be 100 to 105 percent of the specified voltage. The circuit is to be connected through a nonrenewable fuse that conducts twice its rated current for at least 12 seconds. The fuse rating is to be that of the branch-circuit overcurrent device to which the equipment is intended to be connected and not less than 20 amperes. One test is to be performed on each of three samples of the bonding conductor.

## 5.7 Resistance measurement

5.7.1 The resistance between two parts connected by a bonding conductor shall not be more than 0.1 ohm. The resistance is to be determined by a resistance measuring instrument, except that when unacceptable results are recorded, an alternating or direct current of at least 20 amperes from a power supply of not more than 12 volts is to be passed from the point of connection of the equipment grounding means to the metal part in the grounding circuit. The resulting drop in potential and the test current are to be measured between the two points. The resistance in ohms is to be determined by dividing the drop in potential in volts by the current in amperes.

## 5.8 Openings in enclosure

5.8.1 A 0.125 inch (3.18 mm) diameter rod shall not be able to enter an opening not used for ventilation. A 0.500 inch (12.70 mm) diameter rod shall not be able to enter an opening when the distance between the opening and the nearest live part is more than 4 inches (102 mm).

5.8.2 No covering is required across the top of an enclosure of a floor-mounted controller when the enclosure is 6 feet (1.83 m) high or more and when exposed live parts within the device are at least 6 inches (152 mm) below the lowest portion of the upper edge of the enclosure.

5.8.3 No covering is required across the bottom of an enclosure of a floor-mounted controller when the enclosure is within 6 inches (152 mm) of the floor or less and when exposed live parts within the device are at least 6 inches above the highest portion of the lower edge of the enclosure.

## 5.9 Ventilating openings

5.9.1 A ventilating opening is able to be provided in an enclosure that contains a resistance-type starter, autotransformer-type starter, or other equipment when the conditions of use necessitate such ventilation and it is shown by test that electrical disturbances within the enclosure are contained or when the ventilation opening complies with 5.9.2 – 5.10.2.

5.9.2 A ventilating opening in the top of the enclosure shall be covered by a hood or protective shield spaced above the opening to prevent the entry of water or objects falling vertically downward.

5.9.3 A rod having a diameter of 0.500 inch (12.7 mm) shall not be able to enter any ventilating opening in a Type 1, 2, or 3R enclosure.

*Exception: A rod having a diameter of 0.750 inch (19.05 mm) is usable for evaluating and opening when the distance between any uninsulated live part and the opening is more than 4 inches (102 mm).*

5.9.4 The diameter of the wires of a screen shall be at least 0.051 inch (1.30 mm) when the screen openings are 0.500 square inch (32.3 mm<sup>2</sup>) or less in area, and shall be at least 0.081 inch (2.06 mm) for larger screen openings.

5.9.5 Perforated sheet steel and sheet steel employed for expanded-metal mesh shall be at least 0.042 inch (1.07 mm) thick when uncoated and at least 0.045 inch (1.14 mm) thick when zinc-coated for mesh openings or perforations 0.500 square inch (3.2 cm<sup>2</sup>) or less in area, and shall be at least 0.080 inch (2.03 mm) thick when uncoated and at least 0.084 inch (2.13 mm) thick when zinc-coated for larger openings.

*Exception: In a small device where the indentation of a guard or enclosure does not alter the clearance between uninsulated, movable, live parts and grounded metal so as to adversely affect the performance or reduce the spacings below the minimum value specified in Table 35.1, expanded-metal mesh of uncoated steel not less than 0.020 inch (0.51 mm) thick and of zinc-coated steel not less than 0.023 inch (0.58 mm) thick are usable when:*

*a) The exposed mesh on any one side or surface of the device so protected has an area not more than 72 square inches (464 cm<sup>2</sup>) and has no dimension greater than 12 inches (304.8 mm); or*

*b) The width of the opening so protected is not greater than 3.50 inches (88.9 mm).*

## 5.10 Forced ventilation

5.10.1 When ventilation is fan forced – that is, ventilation is accomplished by one or more blowers within the enclosure that provide a positive intake and exhaust – the ventilation openings shall comply with the requirements in 5.10.2.

5.10.2 When operator controls are provided on the enclosure, the air outlet shall not direct exhaust air at the area occupied by the operator of the equipment.

## 5.11 Observation windows

5.11.1 Glass covering an observation opening and forming a part of the enclosure shall be reliably secured in such a manner that it is not readily displaced in service and shall provide mechanical protection of the enclosed parts. Glass for an opening not more than 4 inches (102 mm) in any dimension shall not be less than 0.055 inch (1.40 mm) thick; and glass for an opening having no dimension greater than 12 inches (305 mm) shall not be less than 0.115 inch (2.92 mm) thick. Glass used to cover a larger opening shall have the required mechanical strength and shall otherwise be usable for the purpose.

## 5.12 Wire bending space

5.12.1 The space between the end of the soldering lug or pressure wire connector for the connection of field-installed wire and the wall of the enclosure toward which the wire is directed upon leaving the lug or connector shall be at least that specified in Table 5.7.

5.12.2 The space specified in 5.12.1 is to be the length of a straight line extending from the end of the soldering lug or pressure wire connector where the wire is connected toward and perpendicular to the enclosure wall toward which the wire is initially directed.

5.12.3 When a wire is restricted by barriers or other means from being bent where it leaves the connector, the distance required by 5.12.1 and Table 5.7 is to be measured from the end of the barrier. A terminal lug or connector that is not prevented from turning as described in the exception to 18.2 is to be repositioned anywhere within the limits to obtain the shortest distance for measurement.

5.12.4 The wire size used to determine the wire bending space is based on 125 percent of the motor full-load current rating. See Tables 41.1 or 41.2 for the full-load current rating of horsepower rated motors.

**Table 5.7**  
**Wire bending space at the terminals of enclosed power conversion equipment**

| Size of wire <sup>a</sup> AWG or kcmil<br>(mm <sup>2</sup> ) | Minimum bending space, Terminal to wall, Inches (mm) |       |    |       |       |       |
|--------------------------------------------------------------|------------------------------------------------------|-------|----|-------|-------|-------|
|                                                              | Wires per terminal                                   |       |    |       |       |       |
|                                                              | 1                                                    |       | 2  |       | 3     |       |
| 14 – 10 (2.1 – 5.3)                                          | –                                                    |       | –  |       | –     |       |
| 8 – 6 (8.4 – 13.3)                                           | 1-1/2                                                | (38)  | –  |       | –     |       |
| 4 – 3 (21.2 – 26.7)                                          | 2                                                    | (51)  | –  |       | –     |       |
| 2 (33.6)                                                     | 2-1/2                                                | (64)  | –  |       | –     |       |
| 1 (42.4)                                                     | 3                                                    | (76)  | –  |       | –     |       |
| 1/0 (53.5)                                                   | 5                                                    | (127) | 5  | (127) | 7     | (178) |
| 2/0 (67.4)                                                   | 6                                                    | (152) | 6  | (152) | 7-1/2 | (191) |
| 3/0 (85.0)                                                   | 7                                                    | (178) | 7  | (178) | 8     | (203) |
| 4/0 (107.2)                                                  | 7                                                    | (178) | 7  | (178) | 8-1/2 | (216) |
| 250 (127)                                                    | 8                                                    | (203) | 8  | (203) | 9     | (229) |
| 300 (152)                                                    | 10                                                   | (254) | 10 | (254) | 11    | (279) |
| 350 (177)                                                    | 12                                                   | (305) | 12 | (305) | 13    | (330) |
| 400 (203)                                                    | 12                                                   | (305) | 12 | (305) | 14    | (356) |
| 500 (253)                                                    | 12                                                   | (305) | 12 | (305) | 15    | (381) |
| 600 (304)                                                    | 14                                                   | (356) | 16 | (406) | 18    | (457) |
| 700 (355)                                                    | 14                                                   | (356) | 16 | (406) | 20    | (508) |
| 750 – 800 (380 – 405)                                        | 18                                                   | (457) | 19 | (483) | 22    | (559) |
| 900 (456)                                                    | 18                                                   | (457) | 19 | (483) | 24    | (610) |

NOTE – Where provision for more than three conductors per terminals is provided, the bending space shall be in accordance with the appropriate tables for cabinets and boxes in Article 373 of the National Electrical Code, ANSI/NFPA 70-1996.

<sup>a</sup> The wire size is to be based on 26.5.1(b).

## ENVIRONMENTAL RATING RELATED ENCLOSURE CONSTRUCTION

### 6 General

6.1 An enclosure shall comply with the Environmental Related Constructional Features for Enclosure Types Table of the Standard for Enclosures for Electrical Equipment, UL 50, as they apply to the type number or numbers with which the enclosure is marked.

### 7 Protection Against Corrosion

7.1 An enclosure shall comply with the corrosion protection requirements in the Enclosures Types Table of the Standard for Enclosures for Electrical Equipment, UL 50, as they apply to the type number or numbers with which the enclosure is marked.

## ENVIRONMENTAL RATING RELATED ENCLOSURE PERFORMANCE

### 8 General

8.1 An enclosure shall comply with the environmental rating related performance requirements in the Enclosure Types Table of the Standard for Enclosures for Electrical Equipment, UL 50, as they apply to the type number or numbers with which the enclosure is marked.

*Exception: A Type 4X enclosure intended for indoor use only and marked in accordance with 12.2:*

- a) Is not required to be subjected to the Icing Test, in UL 50; and*
- b) For a polymeric enclosure, is not required to have a material which is resistant to ultraviolet light weathering in accordance with UL 50.*

8.2 A Type 12 enclosure employing filtered ventilation openings shall be subjected to either the Dust Test or the Atomized Water Test in UL 50, the Standard for Enclosures for Electrical Equipment.

## NON-ENVIRONMENTAL RATING RELATED ENCLOSURE PERFORMANCE

### 9 General

9.1 An enclosure shall comply with non-environmental rating related performance requirements in this standard and in the Standard for Enclosures for Electrical Equipment, UL 50.

### 10 Securement of Snap-On Cover Test

10.1 A snap-on cover providing part of the overall enclosure that gives access to uninsulated live parts and does not have a separate tool-operated fastener shall have no apparent means for removal such as an extending tab, and is to comply with the following:

- a) A cover that is able to be disengaged from the enclosure by a squeezing force applied with one hand shall not be released when a squeezing force of 14 pounds (62 N) or less is applied at any two locations not more than 5 inches (127 mm) apart. The distance is to be measured by a tape stretched tightly over that portion of the surface of the cover that is encompassed by the palm of the hand.
- b) A cover shall not disengage from the enclosure when a direct pull force of 14 pounds (62 N) is applied by gripping the cover at any two convenient locations; and
- c) A cover shall not be disengaged from the enclosure by an impact force of 1 foot-pound (1.4 J) applied to the accessible faces of the cover – one blow per face. The impact is to be applied by a steel ball having a diameter of not less than 2 inches (51 mm).

10.2 The tests described in 10.1(a) and (b) are to be conducted in the as-received condition and after the cover has been removed and replaced ten times.

## INSTRUCTIONS AND MARKINGS PERTAINING TO ENCLOSURES

### 11 Permanence of Marking

11.1 Any marking that is required to be permanent shall be molded, die-stamped, paint-stenciled, stamped or etched metal that is permanently secured, or indelibly stamped lettering on a pressure-sensitive label secured by adhesive. Usage, handling, storage, and similar conditions to which the product is exposed are to be evaluated in the determination of the permanency of a marking.

### 12 Details

12.1 An enclosure shall comply with the environmental rating related marking requirements in the Environmental Related Constructional Features for Enclosure Types Table of the Standard for Enclosures for Electrical Equipment, UL 50, as they apply to the type number or numbers with which the enclosure is marked.

12.2 With reference to 8.1, a Type 4X enclosure intended for indoor use only shall be marked "4X Indoor Use Only" in letters at least 5/32 inch (4.0 mm) high.

## DEVICE CONSTRUCTION

### 13 General

13.1 Power conversion equipment shall:

- a) Be constructed so that it complies with the rules for installation and use of such equipment as given in the National Electrical Code, ANSI/NFPA 70-1996; and
- b) Employ materials that are evaluated for the use.

### 14 Protection Against Corrosion

14.1 Iron and steel parts shall comply with the requirements in 7.1.

### 15 Provisions for Mounting

15.1 Provisions shall be made for securely mounting power conversion equipment to a supporting surface. A bolt, screw, or other part used to mount a component of the equipment shall not be used for securing the equipment to the supporting surface.

### 16 Insulating Material

16.1 A material that is used for the direct support of an uninsulated live part shall comply with the Relative Thermal Index (RTI), Hot Wire Ignition (HWI), High-Current Arc Resistance to Ignition (HAI), and Comparative Tracking Index (CTI) values indicated in Table 16.1. A material is in direct support of an uninsulated live part when:

- a) It is in direct physical contact with the uninsulated live part; and
- b) It serves to physically support or maintain the relative position of the uninsulated live part.

*Exception No. 1: No additional evaluation is required for the direct support of uninsulated live parts when the generic materials used comply with Table 16.2.*

*Exception No. 2: Materials without HWI Performance Level Category (PLC) values or with HWI PLC values higher (worse) than those required by Table 16.1 must comply with the end-product Abnormal Overload Test in accordance with the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C.*

*Exception No. 3: Materials without HAI Performance Level Category PLC values or with HAI PLC values higher (worse) than those required by Table 16.1 must comply with the end-product Arc Resistance Test in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.*

*Exception No. 4: Materials used in devices that do not incorporate contacts are not required to comply with the HAI Performance Level Category PLC requirements.*

*Exception No. 5: Materials that are used in devices that incorporate contacts and are not used within 1/2 inch (12.7 mm) of the contacts are not required to comply with the HAI Performance Level Category PLC requirements.*

*Exception No. 6: Materials without CTI Performance Level Category PLC values or with CTI PLC values higher (worse) than the CTI required by Table 16.1 must comply with the end-product Arc Resistance Test in accordance with the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C.*

*Exception No. 7: Materials without CTI Performance Level Category PLC values or with CTI PLC values higher (worse) than the CTI required by Table 16.1 comply with the intent of CTI PLC requirement when:*

- a) They have a High-Voltage-Arc Tracking (HVTR) PLC value of 1 or lower (better); or*
- b) The over surface spacings between the uninsulated live parts is 1/2 inch (12.7 mm) minimum.*

**Table 16.1**  
**Minimum material characteristics**  
**for the direct support of uninsulated live parts**

| UL 94 Flame Class | RTI Elec | HWI <sup>b</sup> | HAI <sup>b</sup> | CTI <sup>c</sup> |
|-------------------|----------|------------------|------------------|------------------|
| 94-HB             | a        | 2                | 1                | 4                |
| 94V-2             | a        | 2                | 2                | 4                |
| 94V-1             | a        | 3                | 2                | 4                |
| 94V-0             | a        | 4                | 3                | 4                |

<sup>a</sup> The electrical RTI value of a material is to be determined in accordance with the Standard for Polymeric Materials - Long Term Property Evaluations, UL 746B by test or by use of the generic RTI table. This material characteristic is dependent upon the minimum thickness at which the material is being used and shall not be exceeded during the Temperature Test, Section 39.

<sup>b</sup> The HAI and HWI Performance Level Category (PLC) value of a material is to be determined by test in accordance with the Standard for Polymeric Materials - Short Term Property Evaluations, UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used.

<sup>c</sup> The CTI PLC value of a material is to be determined by test in accordance with UL 746A. This material characteristic is not dependent upon the minimum thickness at which the material is being used.

**Table 16.2**  
**Generic materials for the**  
**direct support of uninsulated live parts**

| Generic material                            | Minimum thickness |           | RTI, °C  |
|---------------------------------------------|-------------------|-----------|----------|
| Any cold-molded composition (i.e. concrete) | No limit          |           | No limit |
| Ceramic, Porcelain and Slate                | No limit          |           | No limit |
| Diallyl Phthalate                           | 0.028 inch        | (0.71 mm) | 105      |
| Epoxy                                       | 0.028 inch        | (0.71 mm) | 105      |
| Melamine                                    | 0.028 inch        | (0.71 mm) | 130      |
| Melamine-Phenolic                           | 0.028 inch        | (0.71 mm) | 130      |
| Phenolic                                    | 0.028 inch        | (0.71 mm) | 150      |
| Unfilled Nylon                              | 0.028 inch        | (0.71 mm) | 105      |
| Unfilled Polycarbonate                      | 0.028 inch        | (0.71 mm) | 105      |
| Urea Formaldehyde                           | 0.028 inch        | (0.71 mm) | 100      |

NOTE: Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Test, Section 39.

16.2 An insulating material used as a barrier in lieu of the required spacings, shall comply with the requirements in 35.11.

16.3 A printed wiring board shall comply with the requirements of UL 796, the Standard for Printed-Wiring Boards.

## 17 Means for Switching

17.1 When a circuit breaker or switch is mounted such that movement of the operating handle, either vertically or rotationally, between the on and off positions results in one position being above the other position, the upper position shall be the on position. The requirement does not apply to a circuit breaker or switch that is operated horizontally or that is operated rotationally and the on and off positions are at the same level, nor to a switching device having two on positions, such as a transfer switch or a double throw switch.

## 18 Live Parts

18.1 A current-carrying part shall have mechanical strength and ampacity for the intended use and shall be of metal or other material that is intended for the application.

18.2 An uninsulated live part, including a terminal, shall be secured to its supporting surface by a method other than friction between surfaces so that it is prevented from turning or shifting in position when such motion results in a reduction of the required spacings.

*Exception: A pressure terminal connector is not required to be prevented from turning when no spacings less than those required result when the terminals are turned 30 degrees toward each other, or toward other uninsulated parts of opposite polarity, or toward grounded metal parts.*

18.3 A live screwhead or nut on the underside of an insulating base shall be prevented from loosening and shall be insulated or spaced from the mounting surface. This is accomplished by:

- a) Countersinking parts by at least 1/8 inch (3.2 mm) and covering them with a waterproof, insulating sealing compound that does not degrade at 15°C (27°F) higher than its normal operating temperature and not less than 65°C (149°F); or
- b) Securing such parts and insulating them from the mounting surface by a barrier, or the equivalent, or by through air or over surface spacings specified elsewhere in this standard.

## 19 Drive Protection

### 19.1 General

19.1.1 A drive rated more than 1 hp (745.7 w) shall comply with the Short Circuit Test, Section 44. This protection must be either integral to the drive or referenced in accordance with 44.8.9.

19.1.2 A drive that does not rely solely on solid-state short circuit protection shall also comply with the short circuit test power factor requirements in the Standard for Industrial Control Equipment, UL 508.

19.1.3 Drives shall be provided with one of the following means of motor overload protection:

- a) Mechanical overload relay that complies with the applicable requirements in the Standard for Industrial Control Equipment, UL 508; or
- b) Solid state overload protection that is subjected to the requirements in 61.1 – 61.3 and that complies with the Solid State Motor Overload Protection Test, Section 42.

*Exception: Drives marked in accordance with 54.1 and 54.2 are not required to be provided with motor overload protection.*

19.1.4 Polyphase drives shall be provided with input phase loss protection that complies with 40.3.1.

19.1.5 Drives incorporating blower motors, filters, or both, shall comply with 40.4.1 and 40.5.1.

19.1.6 Drives provided with current limiting protection shall comply with 40.6.1.

19.1.7 Drives provided with overspeed protection incorporating feedback shall operate to prevent over-speed upon loss of the feedback signal.

19.1.8 Drives provided with phase reversal protection shall interrupt and maintain the interruption of power in all of the circuit.

19.1.9 A DC drive shall not incorporate overcurrent protection in a motor field supply circuit unless the drive incorporates a detector that senses loss of field current or voltage and prevents over-speed upon field loss.

19.1.10 When a drive is provided with a fuse, not evaluated in accordance with one of the applicable standards in Appendix A of this Standard, other than a line or bus fuse, that is not relied upon for compliance with this Standard, the fuse shall be evaluated by simulating a fault downstream that opens the fuse.

## 19.2 Control circuit wiring

19.2.1 Primary and secondary circuit internal wiring shall be provided with additional protection that complies with 19.2.2 when it is:

- a) Connected to the load side of the branch circuit short circuit protection (see 19.1.1);
- b) Located in a circuit that incorporates the coil of an internal or external motor control contactor (such as for soft starting); and
- c) Sized from 22 – 12 AWG (0.643 – 2.052 mm).

*Exception No. 1: Wiring located in a Class 1 power-limited or Class 3 remote-control circuit or located in a Class 2 (see 31.3), Limited Voltage/Current (see 31.4), Limited Voltage (31.5), Limited Energy (31.6) or Limiting Impedance (see 31.7) secondary circuit is not required to be additionally protected.*

*Exception No. 2: Any wiring measuring a maximum of 12 inches (305 mm) long is not required to be additionally protected.*

*Exception No. 3: Any wiring connected to a printed wiring board having no connections external to the drive and having no more than casual contact with insulated or un-insulated parts of opposite polarity or with grounded parts is not required to be additionally protected.*

*Exception No. 4: When an instantaneous trip circuit breaker is used or intended for use as the branch circuit short circuit protection (see 19.1.1) and its rating or trip setting is not more than the applicable value specified in Table 19.1, then wiring is not required to be additionally protected when the drive is marked in accordance with 56.1.*

**Table 19.1**  
**Branch-circuit short-circuit protection**

| Control-circuit wire size, AWG (mm <sup>2</sup> ) |        | Maximum rating of branch-circuit-protective device, amperes |                              |
|---------------------------------------------------|--------|-------------------------------------------------------------|------------------------------|
|                                                   |        | Conductors within enclosure                                 | Conductors outside enclosure |
| 22                                                | (0.32) | 12                                                          | 3                            |
| 20                                                | (0.52) | 20                                                          | 5                            |
| 18                                                | (0.82) | 25                                                          | 7                            |
| 16                                                | (1.3)  | 40                                                          | 10                           |
| 14                                                | (2.1)  | 100                                                         | 45                           |
| 12                                                | (3.3)  | 120                                                         | 60                           |

19.2.2 The additional wiring protection required by 19.2.1 shall:

- a) Be located within the drive;
- b) Be rated in accordance with Table 19.2;
- c) Be provided in each ungrounded conductor;
- d) Be located no more than 12 inches (305 mm) from the point where the wiring is connected to its source of power;
- e) Either be a supplementary or a branch circuit type fuse or circuit breaker in accordance with the UL 198 series or the Standard for Molded Case Circuit Breakers and Circuit-Breaker Enclosures, UL 489 respectively; and
- f) Be provided with a marking in accordance with 56.2.

*Exception No. 1: This additional protection is not required to be included within the drive when it is shipped from the factory and meets the following:*

- a) The manufacturer makes available an accessory kit that complies with 19.2.2;*
- b) This accessory kit is evaluated for field installation; and*
- c) The drive is marked in accordance with 56.3.*

*Exception No. 2: This additional protection is not required to be shipped with the drive when the fuseholder is included within the drive and the unit is marked in accordance with 56.4.*

**Table 19.2**  
**Overcurrent protection**

| Control-circuit wire Size, AWG (mm <sup>2</sup> ) |        | Maximum protective device rating, amperes |
|---------------------------------------------------|--------|-------------------------------------------|
| 22                                                | (0.32) | 3                                         |
| 20                                                | (0.52) | 5                                         |
| 18                                                | (0.82) | 7                                         |
| 16                                                | (1.3)  | 10                                        |
| 14                                                | (2.1)  | 20                                        |
| 12                                                | (3.3)  | 25                                        |

19.2.3 For drives with a short circuit current rating in excess of 10,000 amperes, the additional wiring protection required by 19.2.1 shall comply with 19.2.2 and be rated greater than or equal to the marked short circuit current rating of the drive. When fuses are used for this protection, they shall be Class CC, J, R, or T and be provided with an appropriate branch circuit type fuse-holder.

### 19.3 Control circuit transformer

19.3.1 A transformer whose secondary supplies a circuit incorporating the coil of an internal or external motor control contactor (such as for soft starting) shall be provided with additional protection that complies with 19.3.2.

*Exception: A transformer shall not be additionally protected when:*

- a) The transformer secondary supplies a Class 1 power-limited or Class 3 remote-control circuit or supplies a Class 2 (see 31.3), Limited Voltage/Current (see 31.4), Limited Voltage (see 31.5), Limited Energy (see 31.6) or Limiting Impedance (see 31.7) secondary circuit;*
- b) The transformer secondary is rated less than 50 VA, is inherently protected and is an integral part of the drive;*
- c) The branch circuit protection provides the required additional protection; or*
- d) The additional protection is provided by other means that comply with the applicable requirements in the National Electrical Code, NFPA-70-1996.*

19.3.2 The additional transformer protection required by 19.3.1 shall either be a supplementary or a branch circuit type fuse or circuit breaker in accordance with the UL 198 series or the Standard for Molded Case Circuit Breakers and Circuit-Breaker Enclosures, UL 489, respectively and shall:

- a) For the primary:
  - 1) Be provided in each ungrounded conductor of the transformer primary and rated or set in accordance with Table 19.3;
  - 2) Be provided in the transformer primary and rated or set at a maximum of six times the rated transformer primary current when the transformer has no more than 6 percent impedance and coordinated thermal overload protection is arranged to interrupt the primary circuit;
  - 3) Be provided in the transformer primary and rated or set at a maximum of four times the rated transformer primary current when the transformer has more than 6 percent and less than 10 percent impedance and coordinated thermal overload protection is arranged to interrupt the primary circuit;
- b) For the primary and secondary:
  - 1) Be provided in the transformer primary and rated or set at not more than 250 percent of the rated transformer primary current and provided in the transformer secondary and rated or set at not more than 125 percent of the rated transformer secondary current; or
  - 2) Be provided in the transformer primary and rated or set at not more than 250 percent of the rated transformer primary current and provided in the transformer secondary and rated or set in accordance with line 2 of Table 19.3 when the rated transformer secondary current is 2 amperes or more.

**Table 19.3**  
**Maximum rating of overcurrent device**

| Rating primary current, amperes | Maximum rating of overcurrent protective device expressed as a percent of transformer primary current rating |
|---------------------------------|--------------------------------------------------------------------------------------------------------------|
| Less than 2                     | 500                                                                                                          |
| 2 to less than 9                | 167                                                                                                          |
| 9 or more                       | 125 <sup>a</sup>                                                                                             |

<sup>a</sup> When 125 percent of the current does not correspond to a standard fuse or nonadjustable circuit breaker rating, then the next higher standard rating shall be used. See Section 240-6 of the National Electrical Code, NFPA-70 – 1996.

## 19.4 Control circuit wiring and transformer combination

19.4.1 For a single phase transformer with only one 2-wire secondary, compliance with the additional wiring and transformer protection requirements of 19.2.1 and 19.3.1 is obtainable by protective devices in any ungrounded primary conductor. The protective devices shall:

- a) Be located in the primary of the transformer;
- b) Have its maximum rating or setting limit calculated by using the appropriate protective device value from Table 19.2 based on the AWG of the secondary wiring and multiplying this value by the secondary-to-primary voltage ratio of the transformer; and
- c) Have its actual rating or setting be within this maximum limit and also be in accordance with 19.3.2(a) and (b).

## 20 Capacitors

20.1 A bus capacitor shall be rated for the voltage and the temperature of the circuit involved. This rating shall be based on the continuous working voltage rating and the overvoltage surge rating.

20.2 An across-line capacitor shall be rated for the voltage (square root of 2 times the input value) and the temperature rating of the circuit involved and it shall comply with the Dielectric Voltage-Withstand Test, Section 43.

20.3 A means shall be provided to discharge each bus capacitor to a voltage level below 50 V DC within 1 minute.

*Exception: Drives are not required to comply with this discharge requirement when they are provided with instructions that read, "CAUTION - Risk of Electric Shock," followed by instructions to discharge the specific capacitor or indicating the time required for the capacitor to discharge to a level below 50 V DC.*