UL 508C

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Power Conversion Equipment

Underwriters Laboratories Inc. (UL)
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UL Standard for Safety for Power Conversion Equipment, UL 508C

Third Edition, Dated May 3, 2002

Revisions: This Standard contains revisions through and including November 5, 2004.

Summary of Topics

These revisions to ANSI/UL 508C are being issued to include requirements for Branch Circuit Protection by Self-Protected Combination Motor Controllers, Marking and Installation Information provided in Electronic Read-Only Digital Media Format (such as a CD-rom, diskette, or other media provided with the device), and other miscellaneous revisions.

Text that has been changed in any manner is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The following table lists the future effective dates with the corresponding reference.

Future Effective Dates	References
July 16, 2005	Paragraphs 27.6.1.1, 27.6.1.2, 27.6.1.3, 27.6.2, 27.6.5, 55.7, Table 27.1, Table 39.2, Section 53A, Section 53B, Section 53C, Section 64A, Section 64B, Section 64C

The new and revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated March 9, 2004 and August 10, 2004. The bulletin(s) is now obsolete and may be discarded.

The revisions dated November 5, 2004 include a reprinted title page (page1) for this Standard.

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

The UL Foreword is no longer located within the UL Standard. For information concerning the use and application of the requirements contained in this Standard, the current version of the UL Foreword is located on ULStandardsInfoNet at: http://ulstandardsinfonet.ul.com/ulforeword.html

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

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

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

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

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MAY 3, 2002
(Title Page Reprinted: November 5, 2004)

UL 508C

Standard for Power Conversion Equipment

First Edition – December, 1993
Second Edition – November, 1996

Third Edition

May 3, 2002

The most recent designation of ANSI/UL 508C as an American National Standard (ANSI) occurred on October 27, 2004.

This ANSI/UL Standard for Safety, which consists of the Third Edition with revisions through November 5, 2004, is under continuous maintenance, whereby each revision is ANSI approved upon publication. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Written comments are to be sent to UL-RTP Standards Department, 12 Laboratory Drive, P.O. Box 13995, Research Triangle Park, NC 27709-3995.

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.

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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.

1.2 revised November 5, 2004

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, shall be evaluated to the Standard for Industrial Control Equipment for Use in Hazardous (Classified) Locations, UL 698.

1.4 revised November 5, 2004

1.5 Deleted November 5, 2004

2 Glossary

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

2.2 AMBIENT TEMPERATURE – The temperature of the room or chamber in which the equipment under test is located.

2.3 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.

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

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

2.5.1 INSULATED LIVE PART – An electrically live part that is provided with complete protection against electric shock and does not rely upon other parts for insulation.

2.5.1 added July 16, 2003

2.6 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.

2.7 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.

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

2.8.1 SOLID STATE MOTOR OVERLOAD PROTECTION – Circuitry integral to the power conversion equipment that acts to protect a motor under overload conditions by reducing current flow to the motor output terminals. This protection is typically achieved through an algorithm based on the I^2t of the current to the motor. The protection circuitry is usually comprised of hardware, firmware and software components.

2.8.1 added November 5, 2004

2.8.2 SOLID STATE SHORT CIRCUIT PROTECTION – Circuitry integral to power conversion equipment that acts to suspend current flow to the motor output terminals upon sensing a preset or predetermined condition such as a rapid rate of change in output current or bus voltage. The protection circuitry may be comprised of hardware, firmware and software components.

2.8.2 added November 5, 2004

2.9 SURROUNDING AIR TEMPERATURE RATING – A rating assigned to open type equipment that refers to the maximum ambient temperature of air immediately surrounding the equipment inside of the ultimate enclosure.

2.10 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.

2.11 TRIP CURRENT – Current level above rated output motor current at which the motor overload protection circuitry will function. May be provided as a percent of motor current or as an actual stated current value.

2.11 added July 16, 2003

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3 Units of Measurement

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

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 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 rating established for the intended conditions of use.

4.4 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.

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.

ENCLOSURE CONSTRUCTION

6 Frames and Enclosure

6.1 General

6.1.1 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.

6.1.2 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.

6.2 Cast metal

6.2.1 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^2) 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^2) or less having no dimension more than 6 inches (152 mm).

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

6.3 Sheet metal

6.3.1 The thickness of a sheet-metal enclosure shall not be less than that specified in Tables 6.1 and 6.2, 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 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.

6.3.1 revised November 5, 2004

6.3.2 Tables 6.1 and 6.2 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.

6.3.3 With reference to Tables 6.1 and 6.2, 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.

See Figure 6.0 for supported and unsupported enclosure surfaces.

6.3.3 revised November 5, 2004

Table 6.1
Thickness of sheet metal for enclosures – carbon steel or stainless steel

Table 6.1 revised November 5, 2004

Without supporting frame[a]				With supporting frame or equivalent reinforcement[a]				Minimum required thickness, uncoated	
								inches	(mm)
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length			
Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)		
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020[d]	(0.51)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)		
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited		0.026[d]	(0.66)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)		
8.0	(20.3)	Not limited		12.0	(30.5)	Not limited		0.032	(0.81)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)		
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited		0.042	(1.07)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)		
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited		0.053	(1.35)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)		
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited		0.060	(1.52)
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)	43.0	(109.2)		
25.0	(63.5)	Not limited		39.0	(99.1)	Not limited		0.067	(1.70)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)		
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited		0.080	(2.03)
38.0	(96.5)	47.0	(119.4)	54.0	(137.2)	66.0	(167.6)		
42.0	(106.7)	Not limited		64.0	(162.6)	Not limited		0.093	(2.36)
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)	84.0	(213.4)		
52.0	(132.1)	Not limited		80.0	(203.2)	Not limited		0.108	(2.74)
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)		
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123	(3.12)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)		

[a] See 6.3.3.

[b] 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.

[c] 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.

[d] Sheet steel for an enclosure intended for outdoor use – raintight or rainproof – shall not be less than 0.032 inch (0.81 mm) thick when uncoated.

Table 6.2
Thickness of sheet metal for electrical enclosures – aluminum, copper, or brass

Without supporting frame[a]				With supporting frame or equivalent reinforcement[a]				Minimum required thickness	
Maximum width[b]		Maximum length[c]		Maximum width[b]		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[d]	(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)		

[a] See 6.3.3.

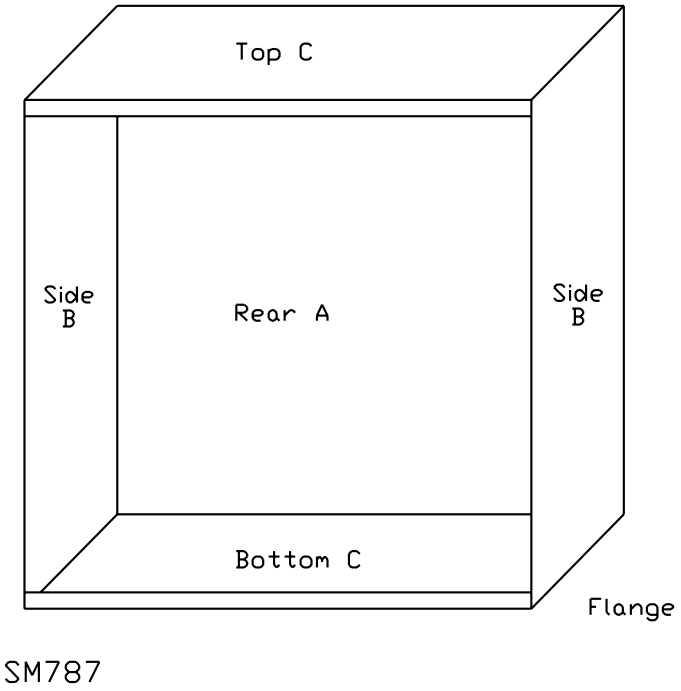
[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure are able to have supports in common and be made of a single sheet.

[c] 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.

[d] 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.

Figure 6.0
Determination of required metal thickness from Tables 6.1 and 6.2 for supported and unsupported enclosure surfaces

Figure 6.0 added November 5, 2004



NOTES:

Each enclosure surface is evaluated individually based on the length and width dimensions. For each set of surface dimensions, A, B or C, the width is the smaller dimension regardless of its orientation to other surfaces. In Tables 6.1 and 6.2, there are two sets of dimensions that correspond to a single metal thickness requirement and the following describes the applicable procedure for determining the minimum metal thickness for each surface:

1. For a supported surface, all of the table dimensions, including the ″not limited″ lengths, are able to be applied. The rear surface ″A″, top and bottom surfaces ″C″, are supported either by adjacent surfaces of the enclosure or by a 1/2 inch (12.7 mm) wide flange. To determine required metal thickness for supported surfaces, the width is to be measured and compared with the table value in the maximum width column that is equal to or greater than the measured width. When the corresponding length in the maximum length column is ″Not limited″, the minimum thickness in the far right column is to be used. When the corresponding length in the maximum length column is a numerical value, and the measured length of the side does not exceed this value, the minimum thickness from the far right column is to be used. When the measured length of the side exceeds the numerical value, the next line in the table is to be used.

2. For an unsupported surface, only the table dimensions that include a specific length requirement are applied. The dimensions with a ″not limited″ length do not apply. The front edge of the left and right surfaces ″B″, are not supported by an adjacent surface or by a flange. An edge that is rabbeted , as shown in Figure 6.1, is also evaluated as an unsupported surface. To determine the required metal thickness for unsupported surfaces, the length is to be measured and compared with the table value in the maximum length column that is not less than the measured length, ignoring the ″not limited″ entries. When the corresponding width in the maximum width column is not less than the measured width, the minimum thickness from the far right column is to be used. When the measured width of the surface exceeds the value in the maximum width column, the next line in the table is to be used.

6.4 Doors and covers

6.4.1 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 11, is not required to have additional securing means.

6.4.2 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 62.

6.4.3 Other than as noted in 6.4.4, a hinged cover provided in accordance with the requirement in 6.4.2 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.

6.4.4 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;

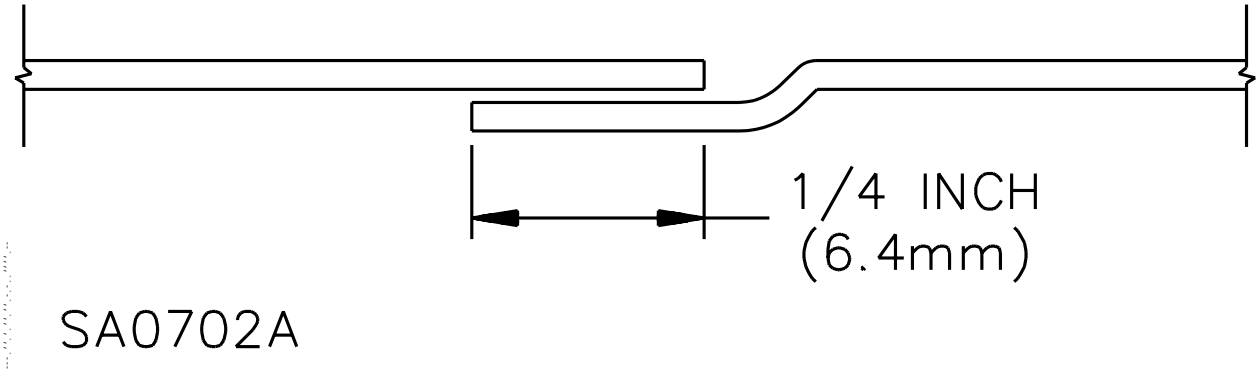
b) Two or more snap latches or captive fasteners; or

c) One knob-operated latch and one snap latch or captive fastener.

6.4.5 Noncaptive fasteners are not prohibited for use on hinged cover enclosures that are not required to comply with 6.4.2.

6.4.6 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 6.1 or the equivalent.

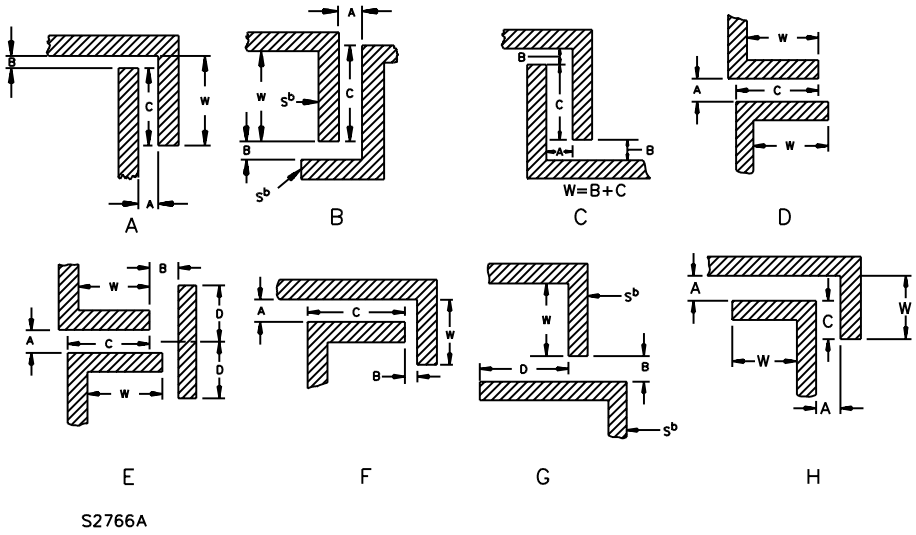
Figure 6.1
Rabbet



6.4.7 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 6.2 and Table 6.3. 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.

Figure 6.2
Flanged cover constructions[a]



[a] See Table 6.3 for dimensions for sketches A – H.

[b] The surfaces ″S″ are able to be in line with one another – not as shown.

Table 6.3
Dimensions for flanged cover constructions

Sketch – see Figure 6.2	Dimensions									
	W Minimum flange width[a]		A Maximum space between parts		B Maximum gap		C Minimum overlap		D Minimum barrier 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	–	–

Table 6.3 Continued on Next Page

Table 6.3 Continued

Sketch – see Figure 6.2	Dimensions									
	W Minimum flange width[a]		A Maximum space between parts		B Maximum gap		C Minimum overlap		D Minimum barrier extension	
	Inch	(mm)	Inch	(mm)	Inch	(mm)	Inch	(mm)	Inch	(mm)
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[b]	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	–	–

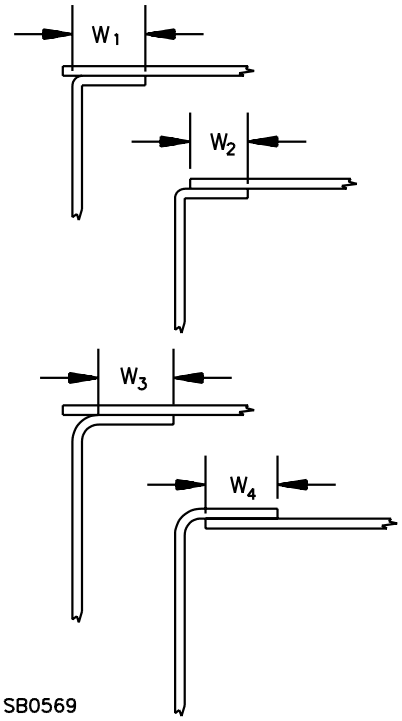
[a] Tolerance: minus 1/16 inch (1.6 mm).

[b] Equipment within the enclosure must be located on the side of the barrier extension D that is opposite the gap B.

6.4.8 To determine whether a flanged cover complies with the requirement in 6.4.7 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.

6.4.9 Figure 6.3 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 6.3
Overlap between flat cover and box flange and at corner or box seam



6.4.10 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 6.3. 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.

6.4.11 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, 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).

6.4.11 revised November 5, 2004

6.4.12 A construction involving a gasket that provides the intended tight fit, as verified by the environmental rating related performance tests in Section 9, General, is not required to comply with the rabbeting, flanging, or overlapping requirements in 6.4.6 – 6.4.11.

6.5 Polymeric

6.5.1 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 9, General, for enclosure performance requirements. With respect to the criteria of Flammability – 127 mm (5 Inch) Flame Test of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, referenced by the Polymeric Enclosures/Parts requirements in UL 50, only criteria (a) and (b) must be met following the application of the Flammability – 127 mm (5 inch) Flame Test to enclosures incorporating openings, such as ventilation openings:

a) The material shall not continue to burn for more than 1 minute after the fifth 5-second application of the test flame, with an interval of 5 seconds between applications of the flame.

b) Flaming drops or flaming or glowing particles that ignite surgical cotton 305 mm (12 inch) below the test specimen shall not be emitted by the test sample at any time during the test.

See 6.5.1.1 for criteria for enclosures with no openings.

6.5.1 revised May 25, 2004

6.5.1.1 Application of the Flammability – 127 mm (5 inch) Flame Test to enclosures with no openings must meet criteria (a), (b), and (c):

a) The material shall not continue to burn for more than 1 minute after the fifth 5-second application of the test flame, with an interval of 5 seconds between applications of the flame.

b) Flaming drops or flaming or glowing particles that ignite surgical cotton 305 mm (12 inch) below the test specimen shall not be emitted by the test sample at any time during the test.

c) Not have any area exhibit burn-through.

6.5.1.1 added May 25, 2004

6.5.2 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.

6.6 Bonding

6.6.1 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 61.7.

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 62.1.

6.6.2 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 – Use in Electrical Equipment Evaluations, UL 746C. Overcurrent Tests shall be conducted at 200 percent of the rated current of the branch circuit-protective device.

6.6.2 revised November 5, 2004

6.6.3 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.

6.6.4 The size of a separate component bonding conductor shall not be less than the applicable size specified in Table 6.4 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 6.5, a current equal to twice the branch-circuit overcurrent-device rating – see 6.6.5 – 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 6.6 when in series with a fuse as described in 6.6.5.

Table 6.4
Size of bonding conductor

Maximum rating or setting of automatic overcurrent device in circuit ahead of equipment, amperes	Minimum size of bonding conductor[a]			
	Copper wire AWG (mm^2)		Aluminum wire AWG or kcmil (mm^2)	
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)

[a] Or equivalent cross-sectional area.

Table 6.5
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 6.6
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

[a] See Table 45.1.

6.6.5 The circuit for the test required by the Exception to 6.6.4 is to have a power factor of 0.9 – 1.0 and is to be limited to the current specified in Table 6.6. 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

No Text on This Page

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.

6.7 Resistance measurement

6.7.1 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.

6.8 Openings in enclosure

6.8.1 A 0.500 inch (12.70 mm) diameter rod shall not be able to enter an opening not used for ventilation. All such openings shall comply with the requirements in 6.9, Accessibility of live parts.

6.8.2 No covering is required across the bottom of a Type 1, 2, 3R, or 3RX enclosure of a floor-mounted controller when the enclosure is within 6 inches (152 mm) of the floor or less and when live parts within the device are at least 6 inches above the highest portion of the lower edge of the enclosure.

6.8.2 revised November 5, 2004

6.9 Accessibility of live parts

6.9.1 To reduce the risk of unintentional contact that may involve a risk of electric shock or injury, the probe illustrated in Figure 6.4 shall not contact an uninsulated live part or wire, electrical energy – high current levels, or moving parts when inserted through any opening in an enclosure.

Exception: As an alternative to 6.9.1, the probe illustrated in Figure 6.5 may be used to determine accessibility.

6.9.1 revised July 16, 2003

Figure 6.4
Articulate probe with web stop

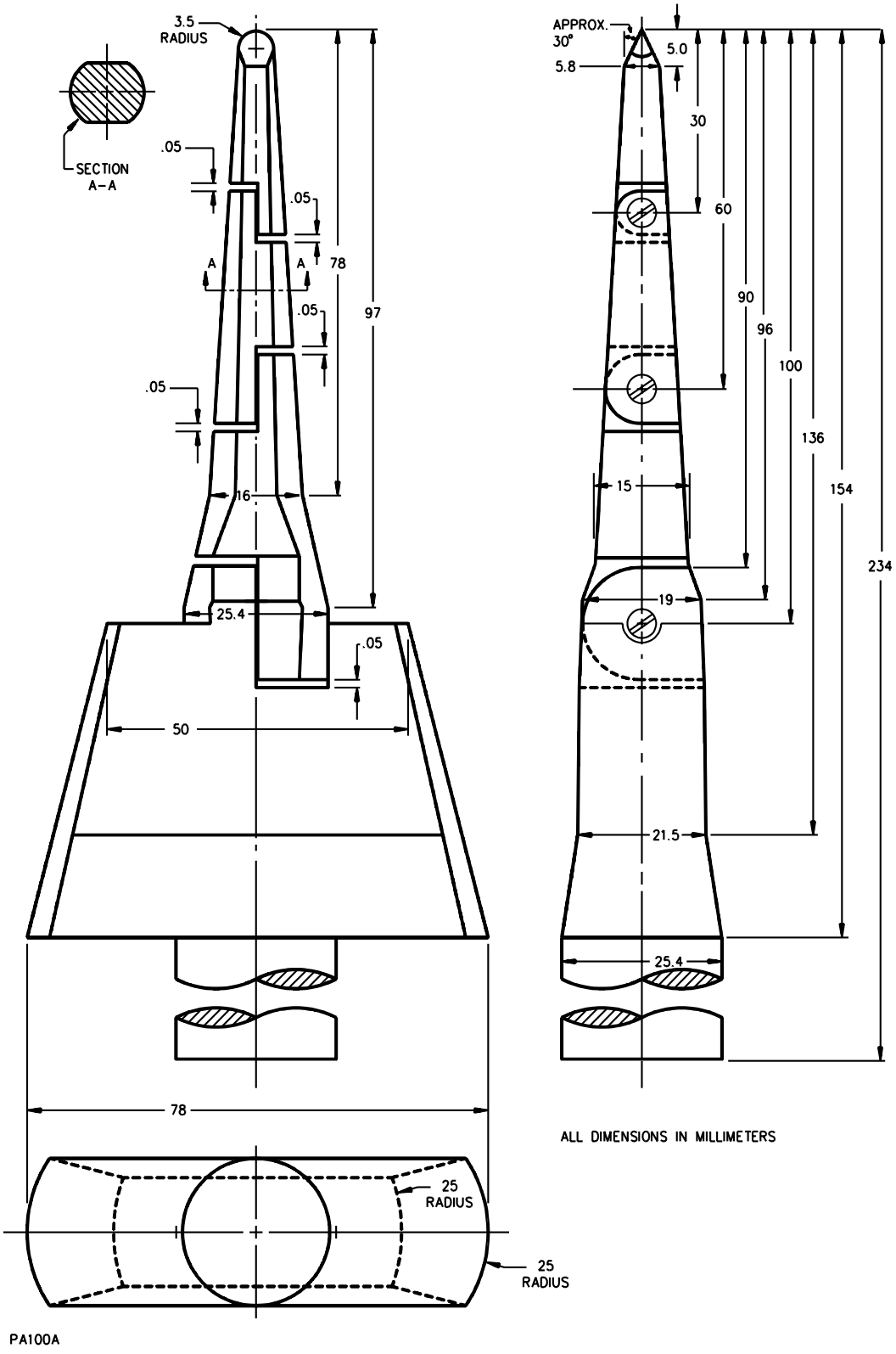
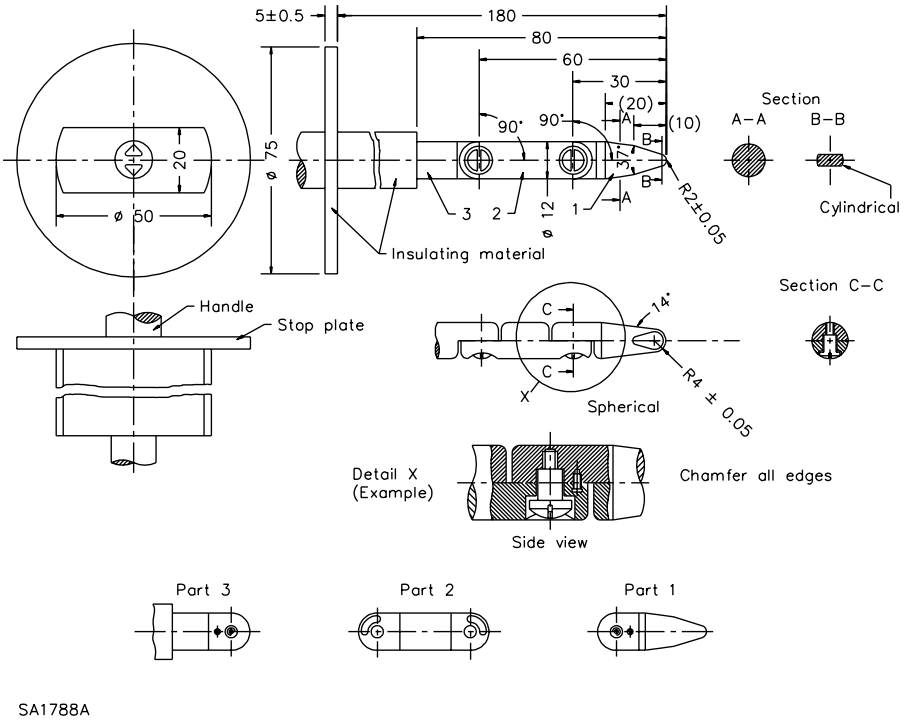


Figure 6.5
IEC articulate probe



6.9.2 The probe specified in 6.9.1 shall be applied in any possible configuration; and, if necessary, the configuration shall be changed after insertion through the opening.

6.9.3 The probe specified in 6.9.1 is to be applied with a force not to exceed 2.2 pounds (10 N). The probe is to be used to determine the accessibility provided by an opening, and not as an instrument to determine the strength of a material.

6.9.4 The probe specified in 6.9.1 is to be inserted as described in 6.9.2 into all openings, including those in the bottom of the unit. The unit is to be moved in whatever way necessary to make the entire bottom accessible for insertion of the probe.

Exception: For a floor-standing unit, the probe is to be inserted into all openings in the bottom that are accessible without tipping, turning over, or otherwise moving the unit from its intended installed position.

6.10 Ventilating openings

6.10.1 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 6.10.2 – 6.11.2.

6.10.2 A ventilating opening in the top of a Type 1 enclosure shall be covered by a hood or protective shield spaced above the opening when there are uninsulated live components below the opening. The ventilation opening shall also be in accordance with 6.10.3.

6.10.3 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 diamter 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).

6.10.4 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^2) or less in area, and shall be at least 0.081 inch (2.06 mm) for larger screen openings.

6.10.5 Perforated sheet steel and sheet steel employed for expanded-metal mesh shall be at least 0.042 inch (1.07 mm) thick for mesh openings or perforations 0.500 square inch (3.2 cm^2) or less in area, and shall be at least 0.080 inch (2.03 mm) thick 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 36.1, expanded-metal mesh of uncoated steel not less than 0.020 inch (0.51 mm) thick is 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^2) 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).

6.10.5 revised November 5, 2004

6.11 Forced ventilation

6.11.1 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 6.11.2.

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

6.11.3 The area occupied by the operator shall be 30 inches (762 mm) wide (horizontal) centered on any operator control, display, or disconnect handle over the entire (vertical) height of the enclosure for wall mounted equipment or up to 6-1/2 feet (1.98 m) above the floor for floor mounted equipment.

6.12 Observation windows

6.12.1 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.

6.13 Wire bending space

6.13.1 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 6.7.

Table 6.7
Wire bending space at the terminals of enclosed power conversion equipment

Table 6.7 revised November 5, 2004

Size of wire[a] AWG or kcmil (mm^2)		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)

Table 6.7 Continued on Next Page

Table 6.7 Continued

Size of wire[a] AWG or kcmil (mm^2)		Minimum bending space, Terminal to wall, inches (mm)					
		Wires per terminal					
		1		2		3	
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 312 of the National Electrical Code, ANSI/NFPA 70.

[a] The wire size is to be based on 27.5.1(b).

6.13.2 The space specified in 6.13.1 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.

6.13.3 When a wire is restricted by barriers or other means from being bent where it leaves the connector, the distance required by 6.13.1 and Table 6.7 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 19.2 is to be repositioned anywhere within the limits to obtain the shortest distance for measurement.

6.13.4 The wire size used to determine the wire bending space is based on 125 percent of the motor full-load current rating. See Table 42.1 or 42.2 for the full-load current rating of horsepower rated motors.

ENVIRONMENTAL RATING RELATED ENCLOSURE CONSTRUCTION

7 General

7.1 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.

8 Protection Against Corrosion

8.1 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

9 General

9.1 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 13.2:

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.

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

9.3 Equipment marked Type 12 is able to employ a Type 12 rated primary enclosure, enclosing both uninsulated and insulated live parts, with insulated live parts external to the primary enclosure or portions of insulated live parts projecting though the wall of the primary enclosure. In all cases, the primary enclosure must satisfy all requirements referenced in the Standard for Enclosures for Electrical Equipment, UL 50, for a Type 12 enclosure.

9.3 added May 25, 2004

9.4 The enclosure enclosing insulated live parts or portions of insulated live parts which extend through a Type 12 primary enclosure must comply with all requirements for a Type 1 enclosure.

9.4 added May 25, 2004

9.5 Power conversion equipment employing a construction as noted in 9.3 and 9.4 must be submitted to the Indoor Circulating Airborne Dust Test or the Atomized Water Test – Method A and the Drip Test as referenced in the Standard for Enclosures for Electrical Equipment, UL 50. Where provided, these tests must be conducted separately on equipment employing cooling fans with the fans energized and unenergized.

9.5 added May 25, 2004

9.6 Insulated live parts or portions of insulated live parts which extend through a primary Type 12 enclosure must be protected from dripping non-corrosive liquids and circulating dust by either of the following methods:

a) If protection from dripping non-corrosive liquids is provided by electrical insulation integral to the insulated live part, the insulation material must meet the requirements for Insulating Material, Section 17, and additionally the requirements for Volume Resistivity and Dielectric Strength, both of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, following exposure to water per Water Exposure and Immersion of UL 746C.

b) If protection from dripping liquids is provided by mechanical means such as a cavity, channel, hood, or guard, the construction must inhibit contact with dripping liquids when the assembly including primary enclosure is subjected to the Drip Test of the Standard for Enclosures for Electrical Equipment, UL 50 with the enclosure mounted in all orientations allowed.

c) Protection from circulating dust must be verified by either the Dust Test or the Atomized Water Test of UL 50. At the conclusion of either the Dust Test or Atomized Water Test, no contaminants (cement particles or water droplets) are allowed to be in contact with uninsulated live parts. Water droplets or cement particles are allowed to contact insulating material. Verification of contaminant ingress is to be accomplished by disassembly and visual inspection immediately following the conclusion of the test.

Exception: At the conclusion of either the Dust or Atomized Water Test in (c), contaminants are allowed in contact with uninsulated live parts in limited voltage/current circuits, Section 32.3, that might be exposed in places such as the windings of a cooling fan supplied by a limited voltage/current source.

9.6 added May 25, 2004

NON-ENVIRONMENTAL RATING RELATED ENCLOSURE PERFORMANCE

10 General

10.1 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.

11 Securement of Snap-On Cover Test

11.1 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).

11.2 The tests described in 11.1 (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

12 Permanence of Marking

12.1 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.

13 Details

13.1 An enclosure shall be marked with its environmental type rating number and 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.

13.2 With reference to 9.1, a Type 4X enclosure intended for indoor use only shall be marked ″Type 4X Indoor Use Only ″ in letters that are legible and of the same font and height.

DEVICE CONSTRUCTION

14 General

14.1 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; and

b) Employ materials that are evaluated for the use.

14.1 revised November 5, 2004

15 Protection Against Corrosion

15.1 Iron and steel parts shall comply with the requirements in 8.1.

16 Provisions for Mounting

16.1 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.

16.2 When the temperature on the back of equipment exceeds 90°C (194°F) per Table 40.2, when operated under normal conditions, the construction shall be such that only the points of support are in contact with a plane mounting surface with the remainder of the equipment spaced at least 1/4 inch (6.4 mm) from the mounting surface. In addition, the mounting surface shall not attain a temperature higher than 90°C during the temperature test.

16.2 revised July 16, 2003

17 Insulating Material

17.1 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 17.1. 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 17.2.

Exception No. 2: Materials without HWI Performance Level Category (PLC) values or with HWI PLC values higher (worse) than those required by Table 17.1 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 17.1 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 17.1 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 17.1 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 17.1
Minimum material characteristics for the direct support of uninsulated live parts

Table 17.1 revised November 5, 2004

UL 94 Flame Class	RTI Elec	HWI[b]	HAI[b]	CTI[c]
HB	a	2	1	3
V-2	a	2	2	3
V-1	a	3	2	3
V-0	a	4	3	3

[a] 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 40.

[b] 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.

[c] 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 17.2
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 40.

17.2 For equipment rated 601 – 1500 volts, an insulating material used as direct or indirect support of an uninsulated live part shall comply with 17.1, except for the CTI requirement specified in 17.1.

17.3 For equipment rated 601 – 1500 volts, an insulating material used as direct or indirect support of an uninsulated live part shall comply with The Inclined-Plane Tracking Test of the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C.

Exception: The Inclined-Plane Tracking Test of the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C, may be conducted at the application (rated) voltage.

17.4 An insulating material used as a barrier in lieu of the required spacings, shall comply with the requirements in 36.11.

17.5 A printed wiring board shall comply with the requirements of the Standard for Printed-Wiring Boards, UL 796 and shall be rated with a minimum flammability rating of V-2.

18 Means for Switching

18.1 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.

19 Live Parts

19.1 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.

19.2 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.

19.3 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.

20 Drive Protection

20.1 General

20.1.1 A drive rated more than 1 hp (745.7 w) shall comply with the Short Circuit Test – Standard Fault Currents, Section 45. This protection must be either integral to the drive or referenced in accordance with 45.8.9.

20.1.2 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.

20.1.3 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 64.1 – 64.3 and that complies with the Solid State Motor Overload Protection Test, Section 43.

Exception: Drives marked in accordance with 56.1 and 56.2 are not required to be provided with motor overload protection.

20.1.4 Polyphase drives shall be provided with input phase loss protection that complies with 41.3.1.

20.1.5 Drives incorporating blower motors, filters, or both, shall comply with 41.4.1 and 41.5.1.

20.1.6 Drives provided with current limiting protection shall comply with 41.6.1.

20.1.7 Deleted July 16, 2003

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

20.1.9 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.

20.1.10 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.

20.2 Control circuit wiring

20.2.1 Primary and secondary circuit internal wiring shall be provided with additional protection that complies with 20.2.2 when it is:

a) Connected to the load side of the branch circuit short circuit protection (see 20.1.1);

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 32.2), Limited Voltage/Current (see 32.3), Limited Voltage (see 32.4), Limited Energy (see 32.6) or Limiting Impedance (see 32.7) 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 20.1.1) and its rating or trip setting is not more than the applicable value specified in Table 20.1, then wiring is not required to be additionally protected when the drive is marked in accordance with 58.1.

Table 20.1
Branch-circuit short-circuit protection

Control-circuit wire size, AWG (mm^2)		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

20.2.2 The additional wiring protection required by 20.2.1 shall:

a) Be located within the drive;

b) Be rated in accordance with Table 20.2;

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 in accordance with the UL 248 series or a branch circuit breaker in accordance with the Standard for Molded Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures, UL 489; and

f) Be provided with a marking in accordance with 58.2.

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 20.2.2;

b) This accessory kit is evaluated for field installation; and

c) The drive is marked in accordance with 58.3.

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 58.4.

Table 20.2
Overcurrent protection

Control-circuit wire Size, AWG (mm^2)		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

20.2.3 For drives with a short circuit current rating in excess of 10,000 amperes, the additional wiring protection required by 20.2.1 shall comply with 20.2.2 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, G, J, L, R, or T and be provided with an appropriate branch circuit type fuseholder.

20.3 Control circuit transformer

20.3.1 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 20.3.2.

Exception: A transformer is not required to be additionally protected when any of the following conditions exist:

a) The transformer secondary supplies a Class 1 power-limited or Class 3 remote-control circuit or supplies a Class 2 (see 32.2), Limited Voltage/Current (see 32.3), Limited Voltage (see 32.4), Limited Energy (see 32.6) or Limiting Impedance (see 32.7) 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.

20.3.1 revised November 5, 2004

20.3.2 The additional transformer protection required by 20.3.1 shall either be a supplementary or a branch circuit type fuse or circuit breaker in accordance with the UL 248 series or the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, 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 20.3;

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 20.3 when the rated transformer secondary current is 2 amperes or more.

Table 20.3
Maximum rating of overcurrent device

Table 20.3 revised November 5, 2004

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[a]
[a] 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.	

20.4 Control circuit wiring and transformer combination

20.4.1 For a single phase transformer with only one 2-wire secondary, compliance with the additional wiring and transformer protection requirements of 20.2.1 and 20.3.1 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 20.2 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 20.3.2 (a) and (b).

21 Capacitors

21.1 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.

21.2 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 44.

21.3 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.

21.4 A motor starting capacitor employing a liquid dielectric medium more combustible than askarel shall comply with the protected oil filled capacitor requirements, contained in the Standard for Capacitors, UL 810, including faulted overcurrent conditions based on the branch circuit in which it is used (see the Short Circuit Test – Standard Fault Currents, Section 45). A motor starting capacitor and any associated solid state component shall be evaluated in accordance with the Breakdown of Components Test, Section 50.

Exception: When the available fault current is limited by other components in the circuit such as a motor-start winding, the capacitor is able to be tested using a fault current less than the value specified in Table 45.1, and not less than the current established by dividing the rated circuit voltage by the impedance of the other components.

No Text on This Page

21.5 A non-motor starting capacitor employing a liquid dielectric medium more combustible than askarel, and any associated solid-state component, is only required to be evaluated in accordance with the Breakdown of Components Test, Section 50.

22 Fuseholders

22.1 A fuseholder shall be of the cartridge type.

22.2 A cartridge fuseholder shall be constructed for use with a branch-circuit fuse.

Exception: When a supplementary fuse is used, the fuseholder shall be constructed for use with the supplementary fuse.

22.3 Power conversion equipment incorporating a fuseholder and the location of fuses, the normal function of which requires renewal, shall be so constructed that the fuses are readily accessible when the switch contacts are open so that a person is not required to touch any live part to replace any fuse. The electrical arrangement of a single-throw switch shall be such that when it is connected as intended and the contacts are open, the fuse terminals are dead.

Exception: A control-circuit fuse arrangement is not required to comply with this requirement when the fuse and control-circuit load – other than a fixed control-circuit load, such as a pilot lamp – are within the same enclosure.

23 Internal Wiring

23.1 General

23.1.1 The wiring and connections between parts of the equipment shall be protected from mechanical damage during installation.

23.1.2 The insulation on all internal wires of the equipment shall be rated for the voltage and the temperature conditions of use. It shall also be evaluated with respect to other conditions of service to which it is intended to be subjected. The voltage rating shall cover an RMS voltage and the peak equivalence (square root of 2 multiplied by the RMS value) voltage. Insulation shall be at least 1/32 inch (0.8 mm) thick when the internal wiring is subjected to movement, flexing, handling, or manipulation during its intended use, or during mechanical maintenance.

23.2 Routing

23.2.1 A hole through which insulated wires pass in a sheet metal wall within the enclosure of the equipment shall be provided with a smooth, well-rounded bushing or shall have smooth, well-rounded surfaces upon which the wires bear to reduce the risk of abrasion of the insulation.

23.2.2 Wires shall be routed away from sharp edges, screw threads, burrs, fins, moving parts, drawers, and similar parts, that abrade the wire insulation.

23.2.3 Clamps and guides, either metallic or nonmetallic, used for routing stationary internal wiring shall be provided with smooth, well-rounded edges. The clamping action and bearing surface shall be such that abrasion or cold flow of the insulation does not occur. Auxiliary nonconducting mechanical protection shall be provided under a metallic clamp that exerts pressure on a conductor having thermoplastic insulation less than 1/32 inch (0.8 mm) thick and having no overall braid.

23.3 Flexing

23.3.1 Wiring that is subject to flexing during servicing such as that from a stationary part to a part mounted on a hinged door shall be provided with additional insulation at any point where it is flexed, unless the wiring is flexible cord.

Exception: Additional insulation is not required when damage to the wiring is not evident and the wiring withstands the Dielectric Voltage-Withstand Test, Section 44 applied between conductors and between conductors and ground, after the wiring is mounted on a door and tested by opening the door as far as possible and then closing it for 500 cycles of operation (restraints such as a chain are to remain in place).

23.3.2 Additional insulation, when used, shall be insulating sleeving, tubing, or a wrapping of not less than two layers of insulating tape. The insulation shall be made of materials rated for the temperature and voltage involved.

23.4 Color coding

23.4.1 Insulated grounding and bonding conductors shall be identified by the color green with or without one or more yellow stripes throughout the entire product. No other leads shall be so identified.

Exception No. 1: Insulated conductors sized 4 AWG or larger are able to be identified at each termination point by a green marking, such as green tape wrapped around the conductor.

Exception No. 2: This requirement does not apply to a green or green/yellow conductor provided in a wiring harness, ribbon cable, or similar prefabricated wiring assembly which is not likely to be mistaken for a grounding conductor.

23.4.1 revised November 5, 2004

23.5 Splices and connections

23.5.1 All splices and connections shall be mechanically secure and shall provide electrical continuity.

23.5.2 Electrical connections shall be soldered, welded, crimped, or otherwise securely connected. A soldered joint shall be mechanically secure before soldering.

Exception: Printed wiring board joints are not required to be mechanically secure before soldering.

23.5.3 A lead is mechanically secure when it is:

a) Wrapped at least halfway (180 degrees) around a terminal;

b) Provided with at least one right angle bend when passed through an eyelet or opening; or

c) Twisted with other conductors.

23.5.4 When stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire do not contact:

a) Other uninsulated live parts not always of the same polarity as the wire; and

b) De-energized metal parts.

Means, that meet the intent of the requirement, include machine- or tool-applied pressure terminal connectors, soldering lugs, crimped eyelets, or the soldering of all strands of the wire together.

23.6 Splice insulation

23.6.1 A splice shall be provided with insulation equivalent to that of the wires involved.

23.6.2 In determining when splice insulation consisting of coated-fabric, thermoplastic, or other types of tubing is usable, electrical and mechanical properties including dielectric voltage-withstand ability, heat resistance, and moisture resistance shall be evaluated. See 23.3.2. Thermoplastic tape shall not be wrapped over a sharp edge or connection.

24 External Interconnections

24.1 Open equipment

24.1.1 The means provided for the interconnection of open equipment shall be evaluated on the basis of the interconnecting cable, cord, or harness being evaluated as internal wiring in accordance with the requirements in Internal Wiring, Section 23.

24.2 Enclosed equipment

24.2.1 The means provided for the interconnection of enclosed equipment shall comply with the requirements of 24.3.1 – 24.3.4, except that equipment with field wiring provisions to facilitate interconnection by means of permanently installed field wiring shall comply with the requirements in Supply Connections, Section 27.

24.3 Interconnecting cords and cables

24.3.1 Cable assemblies and flexible cords provided for interconnection between sections of equipment or between units of a system shall be of a type that is evaluated for the service or use involved and shall be provided with bushings and strain relief.

24.3.2 Misalignment of male and female connectors, insertion of a multipin male connector in a female connector other than the one intended to receive it, and other manipulations of parts that are accessible to the operator shall not result in mechanical damage or a risk of fire, electric shock, or injury to persons.

24.3.3 When either or each end of an external interconnecting cable terminates in a connector external to the enclosure on which there are one or more exposed contacts, risk of electric shock shall not exist between earth ground and any contact that is exposed on either the connector or its receptacle mounted on an enclosure surface while the connector is out of its receptacle.

24.3.4 An interlock circuit in the cable to de-energize the exposed contacts whenever an end of the cable is disconnected meets the intent of the requirement in 24.3.3.

25 Transformers

25.1 A transformer employed in industrial control equipment shall comply with the appropriate standard for transformers, unless the load is part of the equipment, in which case the transformer shall comply with the Temperature Test, Section 40, and the Dielectric Voltage-Withstand Test, Section 44.

Exception: Pulse and current transformers constructed in a manner other than required by the applicable UL transformer Standard are in compliance with this requirement when they withstand, without breakdown, a dielectric voltage withstand potential in accordance with the Dielectric Voltage-Withstand Test, Section 44, applied between the primary and secondary windings. An example of transformer constructions for which this exception applies are those that rely upon magnet wire coating to provide isolation instead of interwinding tape.

26 Blower Motors

26.1 Each blower motor shall be provided with:

a) Locked rotor protection in accordance with 26.2;

b) A fire and shock enclosure in accordance with Frames and Enclosure, Section 6; and

c) An environmental enclosure in accordance with General, Section 9.

Exception: A blower motor located in a Class 2 (see 32.2), Limited Voltage/Current (see 32.3) or Limiting Impedance (see 32.7) secondary circuit is not required to be subjected to these requirements.

26.2 The locked rotor protection required by 26.1 shall:

a) Comply with the thermal protection requirements in the Standard for Overheating Protection for Motors, UL 2111;

b) Comply with the impedance protection requirements in the Standard for Overheating Protection for Motors, UL 2111; or

c) Involve an alternative protection means that is shown by test to be equivalent to the protection specified in (a).

26.3 Regarding 26.2(c), an example of an alternative protection means is the use of fusing to limit the locked rotor temperature of the blower motor windings in accordance with the thermal protection requirements in the Standard for Overheating Protection for Motors, UL 2111. The fusing in this example shall be branch circuit or supplementary types in accordance with the UL 248 series.

26.4 Regarding 26.1(b), when a polymeric blower motor body is accessible due to openings in the drive, the blower motor body shall comply with the polymeric enclosure tests required by 6.5. Accessibility is to be determined in accordance with 6.8 – 6.10.

26.5 Regarding 26.1(c), when openings in the drive expose a blower motor body (either metal or polymeric) to water or dust during any testing in accordance with General, Section 9, the blower motor body shall protect the blower motor windings from exposure to this water or dust. The ability of the body to protect the windings shall be determined with and without the blower motor operating.

Exception: Openings for a blower motor enclosure is not required to meet the requirements for water or dust testing in accordance with Section 9 when:

a) The overall drive enclosure is divided into two separate parts – one part housing primarily the blower motor and the other part housing the majority of the electrical parts; and

b) The part of the overall enclosure housing the blower motor is marked with a "Type 1" environmental rating regardless of the environmental rating of the other part of the overall enclosure.

27 Supply Connections

27.1 General

27.1.1 Supply connections are those electrical connections that are made in the field when the equipment is installed.

27.2 Permanently connected equipment

27.2.1 Power conversion equipment intended for permanent connection to the power supply shall have provision for connection of one of the applicable wiring systems in accordance with the National Electrical Code, ANSI/NFPA 70.

Exception: An enclosure is not required to have provision for the connection of a wiring system, such as a conduit hub, a knockout or a fitting, when it is intended to be drilled or punched in the field to accommodate a wiring system and is provided with appropriate installation instructions.

27.2.1 revised November 5, 2004

27.3 Tapped holes for conduit

27.3.1 A tapped hole in a cast metal enclosure for the attachment of threaded rigid conduit shall be provided with:

a) An integral bushing having a smooth, rounded inlet hole with a diameter the same as the internal diameter of a standard bushing to provide protection for the conductors equivalent to that provided by such a bushing, or shall be located so that a standard bushing is able to be attached to the end of the conduit; and

b) At least three full threads when tapped all the way through the wall of an enclosure, or with at least 3-1/2 full threads when used with an integral bushing.

27.4 Knockouts

27.4.1 A knockout in a sheet-metal enclosure shall be reliably secured and capable of being removed without undue deformation of the enclosure.

27.4.2 A knockout shall be provided with a flat surrounding surface for proper seating of a conduit bushing, and shall be located so that installation of a bushing at any knockout used during installation does not result in spacings between uninsulated live parts and the bushing that are less than the minimum values specified in this standard.

27.5 Wiring terminals and leads

27.5.1 Except as noted in 27.5.2, the line and load terminals of power conversion equipment shall each be provided with wiring terminals or leads for connection of conductors having an ampacity not less than the largest of the following:

a) 125 percent of maximum rated current.

b) 125 percent of the full-load motor current specified in Table 42.1 or 42.2 for output horsepower ratings.

c) For equipment controlling a direct-current motor intended to be operated from a rectified single-phase power supply.

1) One-hundred ninety percent of full load current when a half wave rectifier is used.

2) One-hundred fifty percent of full load current when a full wave rectifier is used.

Exception: This does not apply when the product is marked in accordance with 61.9.

27.5.2 A pressure terminal connector, including one that is compression tool applied, for field connection to line or load is not required to be provided for equipment with field wiring larger than 10 AWG (5.3 mm^2) when the construction complies with the following conditions:

a) Component terminal connectors are available from the equipment manufacturer and one or more are specified for field installation on the equipment.

b) A fastening device, such as a stud, nut, bolt, spring or flat washer, or similar device, that is required for installation is:

1) Provided as part of the component terminal assembly; or

2) Mounted on or separately packaged with the equipment.

c) The installation of the terminal assembly does not involve the loosening or disassembly of a part other than a cover or other part giving access to the terminal location. The means for securing the terminal connectors shall be accessible for tightening before and after installation of the conductor.

d) When the pressure connector provided in a component terminal assembly requires the use of a special tool for securing the conductor, instructions referencing use of the tool shall be included with the component assembly or with the equipment.

e) Installation of a pressure terminal connector in the intended manner shall result in a product that complies with the requirements in this standard.

f) The equipment is marked in accordance with 60.10.

27.5.2 revised November 5, 2004

27.5.3 It is assumed that power conversion equipment having a current rating or a horsepower rating with a full-load motor current as specified in Table 42.1 or 42.2 is intended to be connected with wire of a size determined in accordance with Table 310-16 of the National Electrical Code, ANSI/NFPA 70. Unless marked for use only with wire rated 75°C (167°F), the size is to be based upon wire rated for a temperature 60°C (140°F) for equipment rated 100 amperes or less; and upon wire rated for 75°C for equipment rated greater than 100 amperes. The type of insulation is not specified.

27.5.3 revised November 5, 2004

27.5.4 When a wiring terminal is able to receive the next larger size conductor than that required in 27.5.1, the terminal shall comply with secureness and pullout requirements with that size conductor, unless the equipment is marked to restrict its use to only the smaller size conductor.

27.5.5 A lead that is intended to be spliced in the field to a circuit conductor shall not be smaller than 18 AWG (0.82 mm^2) and the insulation, when of rubber or thermoplastic, shall not be less than 1/32 inch (0.8 mm) thick.

27.5.5 revised November 5, 2004

27.5.6 A terminal to which field wiring is to be connected shall be a soldering lug or pressure wire connector.

Exception: A terminal to which 10 AWG (5.3 mm^2) or smaller wiring connection is to be made, is not prohibited from consisting of a clamp or binding screw with a terminal plate having upturned lugs or the equivalent to hold the wire in position.

27.5.6 revised November 5, 2004

27.5.7 A field-wiring pressure wire connector provided with or specified for use with power conversion equipment shall comply with one or more of the following, as applicable:

a) The performance requirements in the Standard for Wire Connectors, UL 486A-486B; or

b) The performance requirements in the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

27.5.7 revised November 5, 2004

27.5.8 The tightening torque for a field-wiring terminal shall be as specified by the power conversion equipment manufacturer and shall be marked as specified in 60.11. The specified tightening torque shall not be less than 90 percent of the value employed in the static heating test as specified in the requirements in the Standard for Wire Connectors, UL 486A-486B or the Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E, for that wire size corresponding to the ampere rating of the power conversion equipment.

Exception No. 1: The value of tightening torque is not required to be 90 percent of the value specified when the connector is investigated in accordance with UL 486A-486B or UL 486E, with the lesser assigned torque value.

Exception No. 2: A field-wiring terminal intended only for the connection of a control circuit conductor is not required to be marked with a value of tightening torque when tested in accordance with the applicable requirements in UL 486A-486B or UL 486E, with a value of tightening torque of 7 pound-inches (0.8 N·m).

27.5.8 revised November 5, 2004

27.5.9 A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch wide quick-connect terminal shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310. Other sizes of quick-connect terminals shall be investigated with respect to such areas as crimp pullout, engagement-disengagement forces of the connector and tab, and temperature rises in accordance with UL 310.

27.5.10 A wire-binding screw to which field-wiring connections are made shall be No. 8 (0.164 in) or larger.

Exception: A No. 6 (0.138 in) screw is usable at a terminal intended only for connection of a 14 AWG (2.1 mm^2) conductor.

27.5.10 revised November 5, 2004

27.5.11 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.030 inch (0.76 mm) thick for a 14 AWG (2.1 mm^2) or smaller wire, and not less than 0.050 inch (1.27 mm) thick for a wire larger than 14 AWG (2.1 mm^2). There shall be at least two full threads in the plate.

Exception: Two full threads are not required when fewer threads result in a secure connection in which the threads do not strip upon application of a 20 pound-inch (2.3 N·m) tightening torque.

27.5.11 revised November 5, 2004

27.5.12 A terminal plate formed from stock having the required thickness specified in 27.5.11 is able to have the metal extruded at the tapped hole for the binding screw to provide two full threads.

27.5.13 A wire-binding screw shall thread into metal.

27.5.14 A pressure wire terminal shall comply with the Verification of the Performance of Terminal Assemblies Test of the Standard for Terminal Blocks, UL 1059.

27.5.14 added November 5, 2004

27.6 Cord-connected equipment

27.6.1 Power conversion equipment intended to be cord connected to the power supply shall be provided with a length, size, and type of hard-service or junior hard-service flexible cord, such as Type S, SJ, or the equivalent, evaluated for the use conditions, that is terminated in an attachment plug and rated for the temperature and voltage involved.

27.6.1.1 Equipment is able to be cord-connected to the power supply when the equipment is:

a) Portable;

b) Free standing or stationary (not permanently connected to building wiring);

c) As described in 27.6.7.

Revised 27.6.1.1 effective July 16, 2005

27.6.1.2 The cord ampacity, as specified in Table 27.1, shall not be less than the ampacity required for the equipment in 27.5.1.

Added 27.6.1.2 effective July 16, 2005

Table 27.1
Ampacity of flexible cord

Added Table 27.1 effective July 16, 2005

Conductor size, AWG	Number of conductors	
	2	3[a]
18	10	7
16	13	10
14	18	15
12	25	20
10	30	25
8	40	35
6	55	45
4	70	60
2	95	80

[a] Where more than three current-carrying conductors are provided, the ampacity of each of the conductors shall be: 80 percent of these values for 4 – 6 conductors; 70 percent of these values for 7 – 9 conductors; 50 percent of these values for 10 – 20 conductors; 45 percent of these values for 21 – 30 conductors; 40 percent of these values for 31 – 40 conductors; and 35 percent of these values for 41 or more conductors.

27.6.1.3 Cord-connected equipment provided with a standard attachment plug whose ampere rating exceeds the ampacity of the power supply cord shall be provided with an integral overcurrent protective device rated not more than the ampacity of the conductors. Cord-connected equipment provided with a multi-pin connector or without any attachment plug or connector shall be:

a) Provided with integral overcurrent protection rated not more than the ampacity of the conductors; or

b) Marked as in 55.7 to indicate the ratings of the overcurrent protection required to be installed in the field.

Added 27.6.1.3 effective July 16, 2005

27.6.2 Strain relief shall be provided on power supply or signal multicable cords.

27.6.2 revised and separated into 27.6.2 and 53A.1 effective July 16, 2005

27.6.3 At the point at which the cord passes through the enclosure wall, protection shall be provided to prevent cord abrasion.

27.6.4 When a knot serves as strain relief in an attached flexible cord, any surface that the knot contacts shall be free from projections, sharp edges, burrs, fins and similar irregularities, that abrade insulation on the conductors.

27.6.5 Means shall be provided to prevent the supply cord from being pushed into the enclosure of the equipment through the cord entry hole when such displacement results in:

a) Subjecting the supply cord to mechanical damage;

b) Exposing the supply cord to a temperature higher than that for which it is rated;

c) Reducing spacings, such as to a metal strain-relief clamp, below the minimum required values; or

d) Damaging internal connections or components.

To determine compliance, the supply cord shall be tested in accordance with Section 53B, Push-Back Relief Test.

Revised 27.6.5 effective July 16, 2005

27.6.6 A power-supply or signaling connecting cord, used on equipment having a:

a) Type 3, 3R, 3S, 4, 4X, 6, or 6P enclosure shall be evaluated for outdoor use;

b) Type 6 or 6P enclosure shall be water resistant; and

c) Type 12, 12K, or 13 enclosure shall be oil resistant (such as SO, SJO, or STO).

27.6.7 For a device that is intended to provide a signaling function, an attachment plug is not required.

28 Cord-Connected Programming and Diagnostic Units

28.1 Auxiliary units such as portable programmers intended to be used only on a temporary basis, to diagnose or program industrial controls shall comply with the requirements for Safety of Information Technology Equipment, UL 1950. These units shall be evaluated as a subsystem of the industrial electronic control equipment.

29 Risk of Electric Shock

29.1 A risk of electric shock exists within a circuit unless that circuit meets one of the following criteria:

a) The circuit is supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V ac or 42.4 V peak; or

b) The circuit is supplied by an isolating source such that the current available through a 1500 ohm resistor connected across any potential in the circuit (including to ground) does not exceed 5.0 mA.

29.2 The secondary circuits that do not involve a risk of electric shock are:

a) A Class 2 circuit;

b) A Limited Voltage/Current circuit;

c) A Limited Voltage circuit;

d) A Limited Energy circuit that involves open circuit potentials less than or equal to 30 V ac or 42.4 V peak; or

e) A Limiting Impedance circuit that complies with 29.1.

No Text on This Page

30 Risk of Fire

30.1 A risk of fire exists in a circuit unless one of the following criteria is met:

a) The circuit is supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V ac or 42.4 V peak and the current available is limited to a value not exceeding 8 amperes measured after 1 minute of operation; or

b) The circuit is supplied by an isolating source such that the power available to the circuit is limited to a value less than 15 watts.

30.2 Secondary circuits that do not involve a risk of fire are:

a) A Class 2 circuit;

b) A Limited Voltage/Current circuit; and

c) A Limiting Impedance circuit.

31 Lithium Battery Circuits

31.1 A lithium battery circuit is a primary or secondary circuit that obtains power from lithium batteries.

31.2 A lithium battery circuit shall comply with the following:

a) The requirements in the Standard for Lithium Batteries, UL 1642; and

Exception: A circuit that obtains power solely from a lithium battery (i.e a circuit in which the lithium battery is serving as the sole power source as opposed to serving as a back-up power source) is not required to meet the requirements in the Standard for Lithium Batteries, UL 1642.

b) The primary circuit requirements in this Standard or with the secondary circuit requirements in Isolated Secondary Circuits, Section 32.

32 Isolated Secondary Circuits

32.1 General

32.1.1 An isolated secondary circuit is a control circuit that is isolated at all points from the primary branch circuit. This isolation shall be provided by means such as a transformer, optical isolator, limiting impedance, or electro-mechanical relay.

32.1.2 In addition to the requirements for Separation of Circuits, Section 34, a secondary circuit shall comply with the requirements for a primary circuit or with the isolated secondary circuit requirements in 32.1 and the applicable requirements for one of the following types of secondary circuits:

a) A Class 2 circuit (see 32.2);

b) A Limited Voltage/Current circuit (see 32.3);

c) A Limited Voltage circuit (see 32.4);

d) An Isolated Power Supply circuit (see 32.5);

e) A Limited Energy circuit (see 32.6); or

f) A Limiting Impedance circuit (see 32.7).

32.1.3 The construction and performance requirements for various isolated secondary circuits described in 32.1.2 shall be in accordance with Table 32.1.

Table 32.1
Summary of the evaluation required for each type of secondary circuit

Section		Type of secondary circuit:								
		Class 2	Limited voltage/ current	Limited voltage	Limited energy		Limiting impedance			Isolated power supply
29	Risk of electric shock	No	No	No	No	Yes	No	No	Yes	Yes
30	Risk of fire	No	No	Yes	Yes	Yes	No	No	No	Yes
Electrical characteristics of isolated secondary source (ISC):										
32	Maximum voltage,ac	x[b]	30	30	30	100	–	30	–	150
	Maximum voltage, peak	x[b]	42.4	42.4	42.4	–	–	42.4	–	–
	Max. secondary current, A	x[b]	8	–	–	–	0.005[a]	–	–	–
	Max. secondary power, VA	x[b]	100	–	200	200	15 W	15 W	15 W	10,000
Component requirements within isolated secondary circuit (ISC):										
31	Lithium batteries	x	x	x	x	x	x	x	x	x
17	Printed wiring boards	–	–	x[c]	x[c]	x[c]	–	–	–	x[c]

Table 32.1 Continued on Next Page

Table 32.1 Continued

Section		Type of secondary circuit:								
		Class 2	Limited voltage/ current	Limited voltage	Limited energy		Limiting impedance			Isolated power supply
23	Internal wiring	–	–	x	x	x	–	–	–	x
26	Blower motors	–	–	–	–	x	–	–	–	x
27	Field wiring terminals	x	x	x	x	x	x	x	x	x
	All other components	x[d]	x[d]	x[d]	x[d]	x[d]	x[d]	x[d]	x[d]	x[d]
Spacing requirements for isolated secondary circuit (ISC):										
36	Within ISC	–	–	–	–	–	–	–	–	–
	Between ISC and ground	–	–	–	–	x	–	–	x	x[e]
	Between ISC and enclosure or accessible parts	–	–	–	–	x	–	–	x	x[e]
	Between ISC and other isolated circuits	x	x	x	x	x	x	x	x	x
Enclosure requirements for isolated secondary circuit (ISC):										
6	ISC must be enclosed	–	–	x	x	x	–	–	x	x
Performance requirements[f] **Isolating source such as a transformer, power supply, limiting impedance, or battery:**										
40	Temperature[d]	x	x	x	x	x	x	x	x	x
44	Dielectric	x	x	x	x	x	x	x	x	x
53	Secondary circuit	x[b]	53.2	53.5	53.3	53.3	53.6	53.6	53.6	53.4
50	Breakdown of components	x[b]	x	x	x	x	x	x	x	x
48	Transient voltage surge suppression	–	–	–	–	–	–	–	–	x
Isolation components such as an optical isolator, relay, or power switching semiconductor:										
40	Temperature[d]	x	x	x	x	x	x	x	x	x
44	Dielectric	x	x	x	x	x	x	x	x	x

NOTE – ″x″ indicates the requirement applies whereas ″–″ indicates the requirement does not apply.

[a] See 29.1(b).

[b] See the Standard for Class 2 Power Units, UL 1310, or the Standard for Class 2 and Class 3 Transformers, UL 1585, for maximum electrical characteristics and performance requirements.

[c] Printed-wiring boards shall comply with 17.5 and shall be rated V-2, V-1 or V-0.

[d] No evaluation required except the effect of heat generating components in the isolated secondary circuit on adjacent components such as printed wiring boards and wiring shall be evaluated during the temperature test.

Table 32.1 Continued on Next Page

Table 32.1 Continued

Section		Type of secondary circuit:					
		Class 2	Limited voltage/ current	Limited voltage	Limited energy	Limiting impedance	Isolated power supply
[e] Spacings comply with 32.5.1(c). [f] Tests specified in this table evaluate isolating components for use with secondary circuits and does not indicate all tests applicable to the isolating components.							

32.2 Class 2 circuits

32.2.1 A Class 2 circuit shall be supplied by an isolating source that complies with the requirements in the Standard for Class 2 Power Units, UL 1310, or the requirements in the Standard for Class 2 and Class 3 Transformers, UL 1585.

Exception: A circuit intended to be supplied from an isolating source that complies with 32.2 in the field shall be marked in accordance with 59.3.

32.3 Limited voltage/current circuits

32.3.1 A limited voltage/current circuit shall be supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V ac or 42.4 V peak, and the current available is limited to a value not exceeding 8 amperes measured after 1 minute of operation.

32.3.2 The secondary winding of an isolating type transformer or power supply tested in accordance with 53.2 may be used to comply with 32.3.1. For a device (circuit) that is intended to be supplied by an isolating source that complies with 32.3.1 and that is intended to be supplied as an accessory in the field, the device shall be marked in accordance with 62.1 – 62.3.

32.3.3 A secondary fuse or other such secondary circuit protective device used with an isolating source to limit the available current in accordance with 32.3.1, shall be rated at not more than the values specified in Table 32.2. When a secondary fuse that complies with UL 248 series of standards is used, the test specified in 53.2 is not required. Other types of protective devices and protective devices with a rating higher than in Table 32.2 shall be evaluated as in 53.2.

Exception No. 1: When the protective device, that complies with Table 32.2, and isolating source are intended to be supplied in the field, the device shall be marked in accordance with 59.4.

Exception No. 2: When the protective device and isolating source, that have been found to comply with 53.2, are intended to be supplied in the field, the device shall be marked in accordance with 62.1 – 62.3.

Table 32.2
Rating for fuse or circuit protective device

Open circuit volts (peak)	Amperes
0 – 20	5
Over 20 – 30	100/V[a]
[a] V is defined as the peak open circuit voltage.	

32.3.4 The secondary circuit protective device referenced in 32.3.3 may be provided in the primary circuit. When provided in the primary circuit, there are no restrictions on the current rating of the protective device as long as it limits the available secondary current in accordance with Table 32.2.

32.3.5 When a protective device is used as specified in 32.3.3 or 32.3.4, this protective device shall comply with the requirements of this Standard and shall be provided with an adjacent replacement marking or replacement instructions that includes the required voltage and current rating. The printed wiring board, wiring, and spacings prior to the point at which the voltage and current are limited shall comply with the primary circuit requirements of this Standard.

32.3.6 A fixed impedance (such as a component or grouping of components in the same circuit) or a regulating network (such as used in a switching type power supply) that is used to limit the voltage and/or the available current shall comply with 32.3.1. Such a fixed impedance or regulating network shall be able to function under single component fault conditions.

32.4 Limited voltage circuits

32.4.1 A limited voltage circuit shall be supplied by an isolating source that complies with the following:

a) The maximum open circuit voltage potential available to the circuit shall not be more than 30 V ac or 42.4 V peak without any limitation on the available current or volt-ampere capacity;

b) All external secondary-circuit interconnecting cables and all secondary-circuit wiring between units shall be protected against burnout and damage to the insulation resulting from any overload or short-circuit condition that is able to occur during use of the equipment. Overcurrent protection shall be provided in the secondary circuit and comply with Table 20.2, or the isolated secondary circuit shall comply with the secondary circuit test of 53.5. Overcurrent protection provided in the primary circuit of the isolating source is able to serve as protection for the secondary circuit when it complies with 20.4.1 or the secondary circuit test of 53.5; and

c) These circuits are intended for use in a pollution degree 2 environment.

32.4.2 When the protective device, that complies with Table 20.2, and isolating source are intended to be supplied in the field, the device shall be marked in accordance with 59.4.

32.4.3 When the protective device and isolating source, that have been found to comply with 53.5, are intended to be supplied in the field, the device shall be marked in accordance with 62.1 – 62.3.

32.5 Isolated power supply circuits

32.5.1 An isolated power supply circuit shall comply with the following:

a) The secondary circuit shall be supplied from the secondary of an isolating source that complies with 53.4.

b) The construction or circuitry shall suppress internally and externally generated surges in the secondary circuit to at least 300 volts peak. See Transient Voltage Surge Suppression Test, Section 48.

c) Spacings shall not be less than 1/8 inch (3.2 mm) through air and over surface, between live parts of the secondary circuit and operator-accessible metal, or grounded dead metal including the enclosure.

Exception No. 1: For secondary circuits rated 50 volts or less, these spacings shall not be less than 1/16 inch.

Exception No. 2: When spacings are less than 1/8 inch (3.2 mm), the construction shall withstand, without breakdown or arc-over the application of an ac potential of twice the rated voltage plus 1000 V (or a dc potential of 1.4 times the sum of twice the rated voltage plus 1000 V) for 60 seconds between the secondary and accessible or grounded noncurrent carrying metal parts. During the test any component normally connected to ground is to be disconnected.

32.6 Limited energy circuits

32.6.1 A limited energy circuit shall be supplied by an isolating source such that the maximum volt-ampere capacity available to the circuit is 200 volt-amperes or less at a maximum open circuit voltage potential of 100 V ac. The isolating source shall comply with the test described in 53.3. For a device (circuit) that is intended to be supplied by an isolating source that complies with this requirement and that is intended to be supplied as an accessory in the field, the device shall be marked in accordance with 62.1 – 62.3.

32.6.2 A primary or secondary circuit fuse or other such circuit protective device may be used to limit the maximum available volt-ampere capacity in accordance with 32.6.1. There are no restrictions on the current rating of this protective device as long as it limits the available secondary volt-ampere limit in accordance with 32.6.1. The protective device shall comply with the requirements of this standard and shall be marked in accordance with 58.2.

32.7 Limiting impedance circuits

32.7.1 A limiting impedance circuit relied upon to reduce the risk of fire as defined in Section 30, Risk of Fire, shall be supplied by an impedance that complies with any of the following:

a) The calculated power dissipation of the impedance, as the result of a direct short applied across the circuit limited by the impedance, does not exceed the power rating of the impedance and the power dissipation is less than 15 watts; or

b) The impedance shall:

1) Be rated such that the calculated power dissipation of the impedance, as the result of a direct short applied across the circuit limited by the impedance, exceeds the power rating of the impedance and is still less than 15 watts; and

2) Not open or short when subjected to the effects of a direct short applied across the circuit limited by the impedance as described in 53.6.1; or

c) The circuit shall be evaluated as in 53.6.2 to determine the points where less than 15 watts are available and then subjected to the test described in 53.6.1.

32.7.2 The 15-watt power limitation of the impedance shall not be exceeded under single component fault conditions. A limiting impedance relied upon to reduce the risk of electric shock as in 29.1(b) shall comply with 29.1(b) under single component fault conditions.

Exception No. 1: When the circuit limited by the 15-watt impedance is enclosed, the effect of single component fault conditions is not evaluated.

Exception No. 2: A single resistor serving as a limiting impedance is considered to comply with this requirement without further investigation.

Exception No. 3: A single capacitor serving as a limiting impedance is considered to comply with this requirement without further investigation when the capacitor complies with requirements in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414.

32.7.3 A limiting impedance, relied upon to reduce the risk of electric shock as defined in Section 29, Risk of Electric Shock, shall comply with 32.7.5 and 53.6.1.2 under single component fault conditions as described in 53.6.1.3, and one of the following:

a) The limiting impedance is connected to the high potential side of, or as a voltage divider, across a grounded single phase supply voltage rated not more than 150V and serves to limit the voltage within the isolated secondary circuit to be less than 30V rms or 42.4V peak within the isolated secondary circuit and also with respect to ground as determined by circuit analysis; or

b) The limiting impedance is connected to each of two ungrounded supply voltage lines from a 120/240V supply or two or three ungrounded supply voltage lines from a three phase supply and serves to limit the voltage within the isolated secondary circuit to be less than 30V rms or 42.4V peak within the isolated secondary circuit and also with respect to ground as determined by circuit analysis. The circuit shall be evaluated for voltage to ground present while connected to any primary voltage system supplying the equipment.

32.7.4 A limiting impedance circuit that does not comply with 32.7.3 shall:

a) Be insulated from or have spacings to grounded metal or accessible parts; and

b) Not have external connections from the limiting impedance circuit that leave the equipment enclosure; or

c) Be marked with a cautionary marking indicating the maximum voltage to ground that is able to be present on the low voltage output from the equipment; and

d) Comply with the test in 53.6.1.2 when performed between each of the field wiring terminals of outputs from the limiting impedance circuit to ground.

32.7.5 A circuit element relied upon to limit the voltage, current, or both to the values specified in Section 29, Risk of Electric Shock, shall not experience an electrical stress factor:

a) Greater than 0.5 during all conditions of normal operation; or

b) Greater than 1.0 after single component failure with respect to rated voltage, current and dissipated wattage.

The electrical stress factor is defined as ratio of applied electrical characteristic to rated electrical characteristic (applied current to rated ampacity).

33 Limited Voltage Circuit Overcurrent Protection

33.1 General

33.1.1 A limited voltage circuit (see 32.4.1) shall be provided with overcurrent protection in accordance with 33.2 – 33.3.

33.2 Primary overcurrent protection

33.2.1 All wiring including bus bars and interconnecting cables used in the distribution of primary electric energy within and between units of equipment and all transformers and other loading devices connected to the primary circuit shall be protected against burnout and damage to insulation resulting from any overload or short-circuit condition that occurs during operation of the equipment.

33.2.2 The protection referenced in 33.2.1 is obtainable from overcurrent devices included as integral parts of the control equipment or, when rated in accordance with 33.2.4, from the protection associated with the branch circuit to which the equipment is connected.

33.2.3 Overcurrent protective devices that are provided within the equipment and are types that set the requirements for branch-circuit protection in accordance with the National Electrical Code, ANSI/NFPA 70 – for example, circuit breakers or Class CC, J, T, G, H, K, L, RK1, or RK5 cartridge fuses or Type S fuses – comply with the requirement in 33.2.2. Other types of overcurrent protection devices are to be investigated to determine their acceptability for the application.

33.2.3 revised November 5, 2004

33.2.4 The ratings of an overcurrent device in series with connecting wiring shall not exceed the following:

a) For motor loads alone – 300 percent of the motor full-load current observed during the maximum normal operation of the system.

b) For resistive loads, and for combination resistive and reactive loads, with or without motor loads – 250 percent of the full-load current of the circuit under evaluation.

33.2.5 A device providing overcurrent protection shall be of a type that is intended for use when supplied directly by the branch circuit to which the equipment is connected unless additional protection intended for the use is provided in the equipment.

33.2.6 An overcurrent protective device shall be connected between the ungrounded branch-circuit supply conductor and the load.

33.3 Secondary overcurrent protection

33.3.1 All external secondary-circuit interconnecting cables and all secondary-circuit wiring between units shall be protected against burnout and damage to the insulation resulting from any overload or short-circuit condition that occurs during use of the equipment.

Exception No. 1: This requirement does not apply to Class 2 circuits.

Exception No. 2: The overcurrent protection provided in the primary circuit of the transformer provides protection for the secondary circuit, when it operates to protect the circuit under all overload conditions including short circuit.

33.3.2 A conductor provided with overcurrent protection complying with the National Electrical Code, ANSI/NFPA 70, complies with 33.3.1.

33.3.2 revised November 5, 2004

33.3.3 Secondary circuits that are derived from power supplies or other sources are not prohibited from being used when the output wiring carries the maximum current available from the power supply without discoloration or softening of insulation, and when the power supplies or other sources:

a) Are inherently limited; or

b) Include sensing devices whose operation achieves the same result (prevention of burnout and damage to insulation resulting from overload) or de-energizes the equipment.

34 Separation of Circuits

34.1 Factory installed secondary circuits that have not been found to comply with the requirements in Section 32, Isolated Secondary Circuits, shall be separated from all other circuits in accordance with 34.2. Insulated conductors shall be separated from wiring and uninsulated live parts connected to other circuits.

Exception: Wiring and components provided with insulation rated for the highest voltage involved are not required to be separated from each other.

34.2 Separation of insulated conductors shall be accomplished by clamping, routing, or equivalent means that provides permanent separation from insulated or uninsulated live parts of a different circuit.

34.3 Field installed Class 2 conductors of secondary circuits shall be separated from all other circuits by a permanent barrier.

Exception No. 1: This requirement does not apply when Class 1 or power conductors introduced solely to connect to equipment connected to a Class 2 circuit and:

a) The Class 1 or power circuit conductors are routed to maintain a minimum 1/4-inch (6.35 mm) separation from the conductors of the Class 2 circuit; or

b) The Class 1 or power circuit conductors operate at 150 volts or less to ground and also comply with one of the following:

1) The Class 2 circuits are installed using Types CL3, CL3R, CL3P, or equivalent cables, and the cable conductors extending beyond the jacket are separated by a minimum of 1/4 inch or by a nonconductive sleeve or nonconductive barrier from all other conductors; or

2) The Class 2 conductors are installed as a Class 1 circuit in accordance with Section 725-21 of the National Electrical Code, ANSI/NFPA 70.

Exception No. 2: This requirement does not apply to Class 2 conductors entering compartments, enclosures, device boxes, or similar fittings, where Class 1 or power circuit conductors are introduced solely to connect the equipment connected to Class 2 circuits to which the other conductors in the circuit are connected. When the conductors enter an enclosure that is provided with a single opening, they are able to enter through a single fitting (such as a tee), when the conductors are separated from the other circuit conductors by a continuous and firmly fixed type conductor, such as flexible tubing.

34.3 revised November 5, 2004

34.4 Field and factory installed conductors of two or more Class 2 circuits are able to be routed within the same cable, enclosure, or raceway.

35 Isolation Devices

35.1 Optical isolators that provide isolation between primary and secondary circuits shall be constructed in accordance with the Standard for Optical Isolators, UL 1577. The rated isolation voltage of the optical isolator shall be at least the minimum dielectric voltage withstand rating test voltage required by Section 44, Dielectric Voltage-Withstand Test.

Exception No. 1: An optical isolator is not required to be subjected to the requirements in the Standard for Optical Isolators, UL 1577, when the internal insulation is of such a material and at such a thickness that it complies with 36.11.3.

Exception No. 2: An optical isolator that is constructed in accordance with the requirements in the Standard for Optical Isolators, UL 1577, and rated at a dielectric potential less than that required by the Dielectric Voltage-Withstand Test, Section 44, complies with 35.1 when the internal insulation is at such thickness that it also complies with 36.11.3(b).

35.1 revised July 16, 2003

35.2 Power switching semiconductor devices that provide isolation to ground shall be constructed in accordance with the Standard for Electrically Isolated Semiconductor Devices, UL 1557. The dielectric voltage withstand tests required by UL 1557 shall be conducted at a dielectric potential in accordance with the Dielectric Voltage-Withstand Test, Section 44.

Exception No. 1: A power switching semiconductor is not required to be subjected to the requirements in UL 1557 when the internal insulation is of such material and at such a thickness that it complies with 36.11.3.

Exception No. 2: A power switching semiconductor that is constructed in accordance with UL 1557 and rated at a dielectric potential less than that required by the Dielectric Voltage-Withstand Test, Section 44, complies with 35.2 when the internal insulation is at such thickness that it also complies with 36.11.3(b).

36 Spacings

36.1 General

36.1.1 Spacings shall comply with the requirements in 36.1.2 – 36.9.4.

Exception No. 1: Spacings are not required to comply with these requirements when they comply with testing in lieu of spacings, 36.10, Insulating material used as a barrier in lieu of spacings, 36.11, or Clamped insulating joints in lieu of spacings, 36.12.

Exception No. 2: Spacings of only 1/32 inch on a printed wiring board complies with 36.1.1 when the printed wiring board spacings are:

a) Covered by a layer of silicone rubber at least a 1/32 inch (0.79 mm) thick; or

b) Encapsulated by epoxy or potting material, without air bubbles.

The silicone rubber and the potting material, when used, shall comply with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, or the Standard for Polymeric Materials – Long Term Property Evaluations UL 746B, or the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 3: Spacings on the inner layers of multi-layer printed wiring boards are not required to be measured.

36.1.2 In an open-type drive, the spacings between live parts and metal parts that are able to be grounded, such as the heads of mounting screws that pass through an insulating panel, shall be evaluated as grounded parts within an enclosure.

36.1.3 For evaluating the spacing between uninsulated live parts and the surface on which the device is mounted, the mounting surface is evaluated as part of an enclosure.

Exception: The mounting surface is not required to be evaluated as part of the enclosure when deformation of the enclosure does not reduce the spacings between the mounting surface and any uninsulated live part. See footnote (d) of Table 36.1 and footnote b of Table 36.3.

Table 36.1
Minimum spacings

Potential involved in volts rms ac or dc		Minimum spacing, inch (mm)							
		A			B		C		D
		General industrial control equipment			Devices having limited ratings[a]		Other devices[b]		All circuits[e]
		51 – 150	151 – 300	301 – 600	51 – 300	301 – 600	51 – 150	151 – 300	0 – 50
Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[g,h]	Through air or oil	1/8[c]	1/4	3/8	1/16[c]	3/16[c]	1/8[c]	1/4	1/16[c]
		(3.2)	(6.4)	(9.5)	(1.6)	(4.8)	(3.2)	(6.4)	(1.6)
	Over surface	1/4	3/8	1/2	1/8[c]	3/8	1/4	1/4	1/16
		(6.4)	(9.5)	(12.7)	(3.2)	(9.5)	(6.4)	(6.4)	(1.6)
Between any uninsulated live part and the walls of a metal enclosure including fittings for conduit or armored cable[d,f]	Shortest distance	1/2	1/2	1/2	1/4	1/2	1/4	1/4	1/4
		(12.7)	(12.7)	(12.7)	(6.4)	(12.7)	(6.4)	(6.4)	(6.4)

NOTES

1 A slot, or groove, 0.013 inch (0.33 mm) wide or less in the contour of insulating material is to be disregarded.

2 An air space of 0.013 inch (0.33 mm) or less between a live part and an insulating surface is to be disregarded for the purpose of measuring over surface spacings.

[a] See 36.5.1.

[b] See 36.6.1.

[c] The spacing between field wiring terminals of opposite polarity and the spacing between a field wiring terminal and a grounded dead metal part shall be at least 1/4 inch (6.4 mm) when short-circuiting or grounding of such terminals results from projecting strands of wire. For circuits involving no potential greater than 50 volts rms ac or dc, spacings at field wiring terminals are able to be 1/8 inch (3.2 mm) through air and 1/4 inch (6.4 mm) over surface.

[d] For the purpose of this requirement, a metal piece attached to the enclosure is a part of the enclosure when deformation of the enclosure reduces the spacings between the metal piece and uninsulated live parts.

Table 36.1 Continued on Next Page

Table 36.1 Continued

Potential involved in volts rms ac or dc		Minimum spacing, inch (mm)							
		A			B		C		D
		General industrial control equipment			Devices having limited ratings[a]		Other devices[b]		All circuits[e]
		51 – 150	151 – 300	301 – 600	51 – 300	301 – 600	51 – 150	151 – 300	0 – 50

[e] Spacings apply as indicated, except as specified in 36.8.1 and the spacings between the low-potential circuit are in accordance with the requirements that are applicable to the high-potential circuit.

[f] Applicable to devices with sheet metal enclosures regardless of wall thickness and cast metal enclosures with a wall thickness of less than 1/8 inch (3.2 mm).

Table 36.1 Continued on Next Page

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Table 36.1 Continued

Potential involved in volts rms ac or dc		Minimum spacing, inch (mm)							
		A			B		C		D
		General industrial control equipment			Devices having limited ratings[a]		Other devices[b]		All circuits[e]
		51 – 150	151 – 300	301 – 600	51 – 300	301 – 600	51 – 150	151 – 300	0 – 50

[g] These spacings are also applicable between any uninsulated live parts and the walls of a cast metal enclosure with a wall thickness of minimum 1/8 inch (3.2 mm) for devices without a short circuit rating and complying with 36.5.1 or 36.6.1.

[h] These spacings are also applicable between an insulated live part and the wall of a metal enclosure to which the component is mounted. Deformation of the enclosure shall not reduce spacings and result in a risk of shock.

36.1.4 Film-coated wire is an uninsulated live part in determining compliance with the spacing requirements in this standard.

36.1.5 In a series circuit, the spacings between resistor terminals, transformer taps, and similar parts are to be based on the normal operating voltage existing between such parts.

36.1.6 The spacings at fuses and fuseholders are to be measured with the fuses having maximum standard dimensions in place, and shall be at least the spacings specified in column A of Table 36.1.

36.1.7 To assist in determining the adequacy of opposite polarity spacings on printed wiring boards, a color coded voltage map layout is able to be used. This layout shall utilize different colors to identify potential differences on the printed wiring board.

Table 36.2
Minimum spacings

Potential involved, in volts	Location	Minimum spacings, inches (mm)			
		601 – 1000 V		1001 – 1500 V	
Between any uninsulated live part and an uninsulated live part of opposite polarity, an uninsulated grounded part other than the enclosure, or an exposed metal part	Through air	0.55	(14.0)	0.70	(17.8)
	Through oil	0.45	(11.4)	0.60	(15.2)
	Over surface air	0.85	(21.6)	1.20	(30.5)
	Over surface oil	0.62	(15.7)	0.70	(17.8)
Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable	Through air or oil	0.80	(20.3)	1.20	(30.5)
	Over surface	1.00	(25.4)	1.65	(41.9)

Table 36.3
Minimum spacings for products with known and controlled transient voltages

Maximum supplied short-circuit power[a]	Peak working voltage[d]	Minimum spacing, inch (mm)							
		Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part				Between any uninsulated live part and the walls of a metal enclosure including fittings for conduit or armored cable[b]			
		Through air or oil		Over surface		Through air		Over surface	
More than 10 kVA, for use where transient voltages are known and controlled	0 – 50	0.030	(0.76)	0.030	(0.76)	0.500[c]	(12.70)	0.250	(6.35)
	51 – 225	0.075	(1.91)	0.100	(2.54)	0.500	(12.70)	0.500	(12.70)
	226 – 450	0.150	(3.81)	0.200	(5.08)	0.500	(12.70)	0.500	(12.70)
	451 – 900	0.300	(7.62)	0.400	(10.16)	0.500	(12.70)	0.500	(12.70)
More than 500 VA and not more than 10 kVA	0 – 50	0.030	(0.76)	0.030	(0.76)	0.500[c]	(12.70)	0.250	(6.35)
	51 – 225	0.060	(1.52)	0.060	(1.52)	0.500	(12.70)	0.500	(12.70)
	226 – 450	0.100	(2.54)	0.100	(2.54)	0.500	(12.70)	0.500	(12.70)
	451 – 900	0.200	(5.08)	0.200	(5.08)	0.500	(12.70)	0.500	(12.70)
500 VA or less	0 – 36	0.012	(0.30)	0.012	(0.30)	0.500[c]	(12.70)	0.250	(6.35)
	37 – 72	0.016	(0.40)	0.016	(0.40)	0.500[c]	(12.70)	0.250	(6.35)
	73 – 100	0.030	(0.76)	0.030	(0.76)	0.500[c]	(12.70)	0.250	(6.35)
	101 – 225	0.045	(1.14)	0.045	(1.14)	0.500	(12.70)	0.500	(12.70)
	226 – 450	0.060	(1.52)	0.060	(1.52)	0.500	(12.70)	0.500	(12.70)
	451 – 900	0.100	(2.54)	0.100	(2.54)	0.500	(12.70)	0.500	(12.70)

[a] Maximum short-circuit power is the product of the open-circuit voltage and the short circuit current available at the supply terminals when protective devices are bypassed.

[b] A metal piece attached to the enclosure is part of the enclosure when deformation of the enclosure reduces spacings between the metal piece and uninsulated live parts. Spacings specified for parts other than enclosure walls are applicable to metal walls of a subassembly mounted inside another enclosure when spacings in the subassembly are rigidly maintained.

[c] Where deflection of an enclosure wall does not reduce the through-air spacing to the enclosure wall, the spacing through air is able to be 0.250 inch (6.35 mm).

[d] The peak working voltage is the maximum peak voltage (negative or positive peak) measured under normal load conditions.

36.2 Spacings other than at field-wiring terminals

36.2.1 Spacings other than at field-wiring terminals, and other than between uninsulated live parts and conduit bushings shall comply with one of the following:

a) Spacings for drives having general ratings (see 36.4, and Columns A and D of Table 36.1 or Table 36.2);

b) Spacings for drives having limited ratings (see 36.5, and Columns B and D of Table 36.1);

c) Spacings for drives having other ratings (see 36.6, and Columns C and D of Table 36.1);

d) Spacings for drives having known and controlled transient voltages (see 36.7, and Table 36.3);

e) Spacings for drives used in pollution degree 2 environments (see 36.8, and Table 36.4); or

f) Spacings for drives used in accordance with UL 840, (see 36.9).

36.2.2 Spacings between uninsulated live parts and conduit openings shall comply with 36.13, Table 36.6 and one of the following:

a) Table 36.1, column A, B, C, or D, or Table 36.2; or

b) Table 36.3.

36.3 Spacings at field-wiring terminals for pollution degree 2 environments

36.3.1 Spacings at field-wiring terminals shall comply with 36.3.2 and one of the following:

a) Column A, B, C or D of Table 36.1, including footnote c, or Table 36.2;

b) Table 36.5; or

c) The exception to 36.9.3.

36.3.2 The spacing at a field-wiring terminal is to be measured with wire connected to the terminal as in service. The connected wire is to be the next larger size than is normally required for the equipment rating when the terminal accommodates it or when the equipment is not marked to restrict its use.

Table 36.4
Spacings other than at field-wiring terminals for pollution degree 2 environment

Potential involved in volts		Minimum spacings[a], inch (mm)			
rms	Peak	Over surface		Through air	
0 – 50	0 – 70.7	3/64	(1.2)	3/64	(1.2)
51 – 125	72.1 – 176.8	1/16	(1.6)	1/16	(1.6)
126 – 250	178.2 – 353.6	3/32	(2.4)	3/32	(2.4)
251 – 600	355.0 – 848.5	1/2	(12.7)[b]	3/8	(9.5)[b]

[a] On printed-wiring boards, their connectors, and board-mounted electrical components, wired on the load side of line filters of similar voltage peak reduction networks and components, a minimum spacing of 0.0230 inch (0.584 mm) plus 0.0002 inch (0.005 mm) per volt peak shall be maintained over surface and through air between uninsulated live parts and any other uninsulated live or dead conductive parts not of the same polarity. See 36.1.7.

[b] Film-coated wire is identified as an uninsulated live part. However, a spacing of not less than 3/32 inch (2.4 mm) over surface and through air is required between a dead metal part and film-coated wire that is rigidly supported and held in place on a coil.

Table 36.5
Spacings at field-wiring terminals for pollution degree 2 environments

Potential involved, in volts	Minimum spacings[a], inch (mm)					
	Between field-wiring terminals		Between field-wiring terminals and other uninsulated parts not always of the same polarity			
	Through air or over surface		Oversurface		Through air	
0 – 50	1/8	(3.2)	1/8	(3.2)	1/8	(3.2)
51 – 250	1/4	(6.4)	1/4	(6.4)	1/4	(6.4)
251 – 600	1/2	(12.7)	1/2	(12.7)	3/8	(9.5)

[a] These spacings apply to the sum of the spacings involved wherever an isolated dead metal part is interposed.

Table 36.6
Dimensions of bushings

Trade size of conduit, inches	Bushing dimensions, inches (mm)			
	Maximum overall diameter		Height	
1/2	1	(25.4)	3/8	(9.5)
3/4	1-15/64	(31.4)	27/64	(10.7)
1	1-19/32	(40.5)	33/64	(13.1)
1-1/4	1-15/16	(49.2)	9/16	(14.3)
1-1/2	2-13/64	(56.0)	19/32	(15.1)
2	2-45/64	(68.7)	5/8	(15.9)
2-1/2	3-7/32	(81.8)	3/4	(19.1)
3	3-7/8	(98.4)	13/16	(20.6)
3-1/2	4-7/16	(113)	15/16	(23.8)
4	4-31/32	(126)	1	(25.4)
5	6-7/32	(158)	1-3/16	(30.2)
6	7-7/32	(183)	1-1/4	(31.8)

36.4 Spacings for drives having general ratings for pollution degree 2 environments

36.4.1 A drive rated more than 1 horsepower (746 W output) at 51 – 150 volts that complies with the spacings specified in column A of Table 36.1 for such rating is not prohibited from having an additional rating of 1 horsepower or less at 51 – 300 volts. See also 36.4.2 for multipole products.

36.4.2 A drive rated more than 1 horsepower (746 W output) at 151 – 300 volts that complies with the spacings specified in column A of Table 36.1 for such rating is not prohibited from having an additional rating of 1 horsepower or less at 301 – 600 volts. See also 36.6.1 for multipole products.

36.5 Spacings for drives having limited ratings

36.5.1 The spacings specified in column B of Table 36.1 are applicable to non-motor circuits in equipment:

a) Rated 720 volt-amperes break pilotduty or less; or not more than 15 amperes at 51 – 150 volts, 10 amperes at 151 – 300 volts, or 5 amperes at 301 – 600 volts.

b) Of the type described in (a) which controls more than one load provided the total load connected to the line at one time does not exceed 1440 volt-amperes, or have a current rating greater than 30 amperes at 51 – 150 volts, 20 amperes at 151 – 300 volts, or 10 amperes at 301 – 600 volts.

36.6 Spacings for drives having other ratings

36.6.1 The spacings specified in column C of Table 36.1 apply only to equipment rated at 300 volts or less, and 1 horsepower (746 W output) or less or 2000 volt-amperes or less per pole and to a device that has a current rating per pole of 15 amperes or less at 51 – 150 volts, 10 amperes at 151 – 300 volts, or both.

36.6.1 revised November 5, 2004

36.7 Spacings for products with known and controlled transient voltages

36.7.1 The spacing in industrial control equipment in which transient voltages are known and controlled by a transient suppressive device or circuit shall not be less than those specified in Table 36.3 except that spacings at a field-wiring terminal shall be in accordance with 36.3.1.

36.7.2 Transient suppression devices, such as a varistor or transient voltage surge protector, shall be evaluated to the component requirements in the Standard for Transient Voltage Surge Suppressors, UL 1449.

36.7.3 The transient suppressive circuits other than those specified in 36.7.2 shall prevent peak transient voltages from exceeding 300 percent of the instantaneous peak working voltage or 300 volts, whichever is greater, in accordance with the Transient-Voltage-Surge Suppression Test, Section 48.

36.7.4 With reference to the requirements in 36.7.1, industrial control equipment shall have provision for the maintenance of clean, dry electrical surfaces, such as a coating on a printed wiring board, or other equivalent means.

36.8 Spacings for drives used in pollution degree 2 environments

36.8.1 The primary circuit spacings intended for use in a pollution degree 2 environment shall be at least those specified in Tables 36.4 and 36.5.

36.9 Spacings for drives evaluated in accordance with UL 840

36.9.1 Other than as noted in 36.9.2 and 36.9.3, clearances and creepage distances are able to be evaluated in accordance with the requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840. See 36.9.4 for details on applying UL 840.

36.9.2 Clearances between an uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable, shall be in accordance with 36.2.2. The clearances shall be determined by physical measurement.

36.9.3 The clearance and creepage distance at field wiring terminals shall be in accordance with the requirements in 36.3.1.

Exception: When the design of the field wiring terminals precludes the possibility of reduced spacing due to stray strands or improper wiring installation, then clearance and creepage distances at these terminals are able to be evaluated in accordance with the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840.

36.9.4 In conducting evaluations in accordance with the requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, the following shall be used:

a) While the macro-environment in which a drive is installed is typically pollution degree 3, the macro-environment shall be identified as pollution degree 2, when:

1) Instructions are provided with the drive indicating that it shall be installed in a pollution degree 2 macro-environment; or

2) The specific installation application of the drive is known to be a pollution degree 2 macro-environment.

b) When the macro-environment in which a drive is installed is actually pollution degree 3, a pollution degree 2 micro-environment is attainable within the drive by incorporating one of the constructions defined in 2.7.

c) Drives covered under this standard shall be evaluated as Overvoltage Category III;

d) Any printed wiring board which complies with the requirements in the Standard for Printed Wiring Boards, UL 796, provides a Comparative Tracking Index (CTI) of 100. When it further complies with the requirements for direct support in the Standard for Printed-Wiring Boards, UL 796, then it provides a CTI of 175;

e) Evaluation of clearances, only, to determine equivalence with required through air spacings is able to be conducted in accordance with Section 4, Clearance A (Equivalency) of UL 840. An impulse test potential having a value as determined in UL 840 is to be applied across the same points of the device as are required for the Dielectric Voltage-Withstand Test, Section 44;

f) Evaluation of clearances and creepage distances shall be conducted in accordance with the requirements in Section 5, Clearance B (Controlled Overvoltage), and Section 7, Creepage Distances of UL 840;

g) The Phase-to-Ground Rated System Voltage used in the determination of Clearances shall be the equipment rated supply voltage rounded to the next higher value (in the table for determining clearances for equipment) for all points on the supply side of an isolating transformer or the entire product when no isolating transformer is provided. The System Voltage used in the evaluation of secondary circuitry is not prohibited from being interpolated with interpolation continued across the table for the Rated Impulse Withstand Voltage Peak and Clearance; and

h) Determination of the dimensions of clearance and creepage distances shall be conducted in accordance with the requirements for Measurement of Clearance and Creepage Distances of UL 840.

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

36.10 Testing in lieu of spacings

36.10.1 For other than providing isolation between different circuits or in a safety circuit, spacings between traces of different potential on a printed wiring board are not required to comply with 36.1.1 when:

a) The printed wiring board has a flammability rating of V-0;

b) The printed wiring board base material has a minimum Comparative Tracking Index (CTI) of 100 volts; and

c) The equipment complies with the Printed Wiring Board Abnormal Operation Test, Section 52.

36.11 Insulating material used as a barrier in lieu of spacings

36.11.1 Insulating material is not prohibited from being used as a barrier in lieu of the spacings required in 36.1.1.

36.11.2 Insulating material used as a barrier shall comply with the requirements in 36.11.3 when:

a) The material is in direct physical contact with an uninsulated live part;

b) The material serves to physically support, or maintain the relative position of the uninsulated live part; and

c) The material is used as a barrier in lieu of the required over surface or through air spacings.

36.11.3 An insulating material used as noted in 36.11.1 shall:

a) Comply with 17.1; and

b) Be at least 0.028 inch (0.71 mm) thick.

Exception No. 1: A material that complies with 17.1 and does not comply with the thickness limit in (b) is able to alternatively be subjected to a 5000 V ac Dielectric Voltage Withstand Test in accordance with the Internal Barrier requirements in the Standard for Polymeric Materials– Electrical Equipment Evaluations, UL 746C.

Exception No. 2: A material that complies with 17.1 and is used in addition to not less than one-half the required through air spacings is able to be less than 0.028 inch (0.71 mm) thick, and shall be at least 0.013 inch (0.33 mm) thick. This material shall:

a) Have the required mechanical strength when exposed or otherwise subjected to mechanical damage;

b) Be held in place; and

c) Be located so that it is not adversely affected by operation of the equipment in service.

36.11.4 The two requirements noted in 36.11.2 are independent of each other. For example, even when a material complies with 17.1 at a thickness less than the 0.028 inch (0.71 mm) limit, then the material still is required to be provided at a thickness at least equal to this 0.028 inch (0.71 mm) limit or at a thickness as specified by the exceptions to 36.11.3.

36.11.5 An insulating material shall also comply with the requirements in 36.11.3 when:

a) The material is in direct physical contact with an uninsulated live part;

b) The material does not serve to physically support or maintain the relative position of that uninsulated live part; and

c) The material is used as a barrier in lieu of the required over surface, or through air spacings.

Exception: The generic insulating materials in Table 36.7 meet the intent of the requirements for this application without additional evaluation.

36.11.6 An insulating material shall also comply with the requirements in 36.11.3 when:

a) The material is not in direct physical contact with an uninsulated live part;

b) The material does not serve to physically support, or maintain the relative position of that uninsulated live part; and

c) The material is used as a barrier in lieu of the required through air spacings.

Exception No. 1: The generic insulating materials in Table 36.7 meet the intent of the requirements for this application without additional evaluation.

Exception No. 2: Materials that are located at least 1/32 inch (0.8 mm) from uninsulated live parts are not required to comply with the Hot Wire Ignition (HWI), High – Current Arc Resistance to Ignition (HAI) or Comparative Tracking Index (CTI) Performance Level Category (PLC) requirements.

Exception No. 3: Materials that are located at least 1/2 inch (12.7 mm) from uninsulated live parts are not required to comply with the Hot Wire Ignition (HWI), High – Current Arc Resistance to Ignition (HAI) or Comparative Tracking Index (CTI) Performance Level Category (PLC) requirements and also are not required to comply with the RTI requirements.

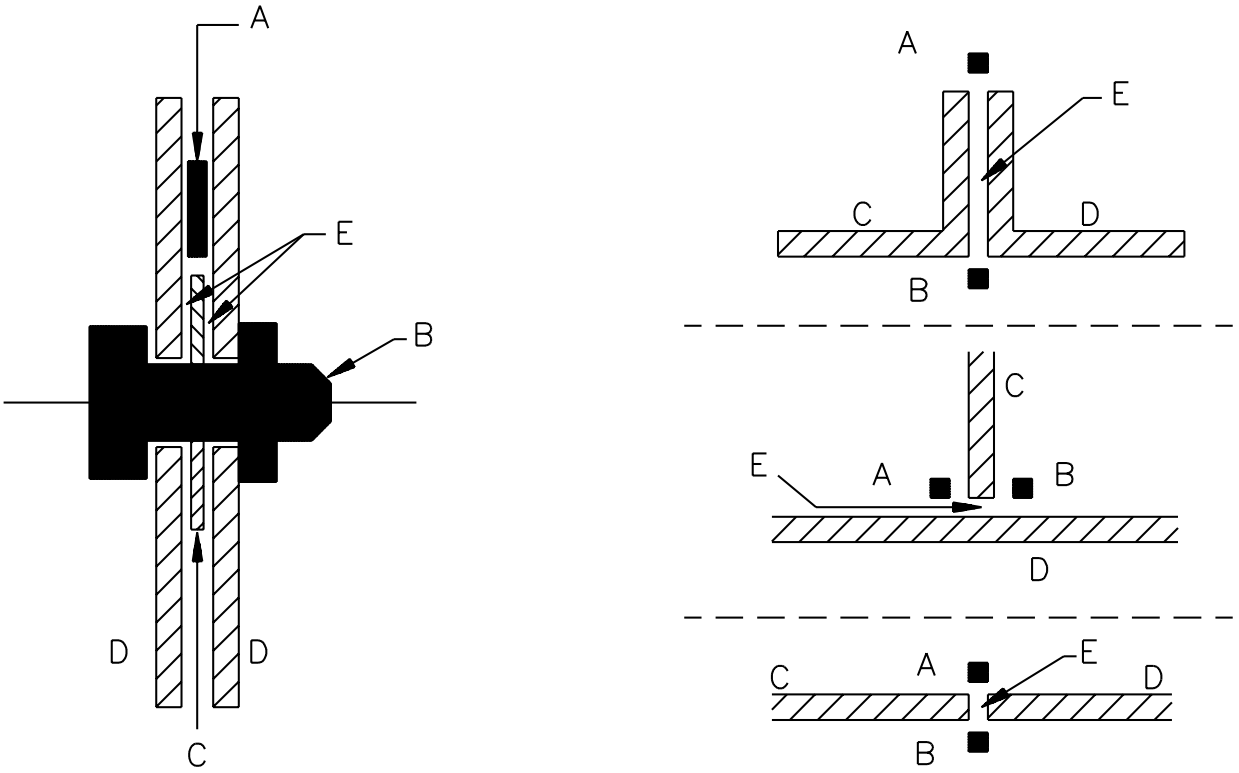
Table 36.7
Generic materials for barriers per 36.11.5 and 36.11.6

Generic Material	Minimum thickness	RTI, °C
Aramid Paper	0.010 inch (0.25 mm)	105
Cambric	0.028 inch (0.71 mm)	105
Electric Grade Paper	0.028 inch (0.71 mm)	105
Epoxy	0.028 inch (0.71 mm)	105
Mica	0.006 inch (0.15 mm)	105
Mylar (PETP)	0.007 inch (0.18 mm)	105
RTV	0.028 inch (0.71 mm)	105
Silicone	0.028 inch (0.71 mm)	105
Treated Cloth	0.028 inch (0.71 mm)	105
Vulcanized Fiber	0.028 inch (0.71 mm)	105
NOTE – Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Tests, Section 40.		

36.12 Clamped insulating joints in lieu of spacings

36.12.1 In the case of a clamped insulating joint, spacings are to be measured through cracks in accordance with 36.1.1 unless a clamped joint has passed the test described in 44.2.1. A clamped joint is a joint between two pieces of insulation that are under pressure, as shown in Figure 36.1. Adhesives, cements, and similar materials, when used to effect a seal in place of a tightly mated joint, shall comply with the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C.

Figure 36.1
Clamped joint



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Parts A, B – Live parts of opposite polarity, or a live part and grounded metal part with spacing through the crack between C and D less than required in 36.1 or 36.3.

Parts C, D – Insulating barriers clamped tightly together so that the dielectric strength between A and B is greater than the equivalent air spacing.

Part E – The clamped joint.

36.13 Spacings between live parts and conduit openings

36.13.1 For an enclosure without conduit openings or knockouts, spacings not less than the minimum specified in 36.3.2 shall be provided between uninsulated live parts and a conduit bushing installed at any location to be used during installation. A permanent marking on the enclosure, a template, or a full-scale drawing furnished with the equipment is usable to identify such locations.

36.13.2 For the spacing between an uninsulated live part and a bushing installed in a knockout, it is to be assumed that a bushing having the dimensions specified in Table 36.6 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

37 Grounding

37.1 Portable equipment intended for use on circuits involving a potential of more than 150 volts to ground and all fixed equipment shall have provision for grounding all noncurrent carrying metal parts that are exposed or that are likely to be contacted by persons during normal operation or adjustment of the equipment and that have the potential to become energized.

37.2 Means for grounding shall be provided as follows:

a) Fixed equipment shall be provided with a means of attachment of a terminal or the equivalent for connecting an equipment grounding conductor. The terminal shall be sized to receive a grounding conductor as specified in Section 250-122 and Table 250-122 of the National Electrical Code, ANSI/NFPA 70;

b) Portable equipment shall be provided with a power-supply cord with a grounding conductor. The grounding conductor shall be connected to the grounding blade of a grounding attachment plug and shall be connected to the frame or enclosure of the equipment. The surface of the insulation on the grounding conductor shall be green with or without one or more yellow stripes.

The grounding means is able to be in the form of a kit. See 60.10.

37.2 revised November 5, 2004

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

37.4 A pressure wire connector intended for connection of a field-installed equipment grounding conductor shall be plainly identified, such as being marked ″G,″ ″GR,″ ″GRD,″ ″Ground ,″ ″Grounding,″ or similar designation, or with the grounding symbol ⏚ (IEC Publication 417, Symbol 5019).

38 Accessories

38.1 Equipment having provision for the use of an accessory to be attached in the field shall comply with the requirements in this standard, and shall comply with the requirements for the equipment for which it is intended. See Instructions and Marking Pertaining to Accessories, Section 62.

38.2 As part of the investigation, an accessory shall be tested and trial-installed. The accessory shall be capable of being installed, and the instructions shall be detailed and accurate. The installation shall be capable of being accomplished using tools that are readily available unless a special tool is provided with the accessory.

DEVICE PERFORMANCE

39 General

39.1 The performance of industrial power conversion equipment shall be investigated by subjecting a representative sample or samples in commercial form to the tests described in Sections 40 – 53. Table 39.1 specifies the tests and indicates those tests to be conducted in sequence.

Table 39.1
Sequence of tests for power conversion equipment

Test reference	Test	Sample number							
		1	2	3	4	5	6	7	8
		Sequence	Sequence	Sequence	Sequence	Sequence	Sequence	Sequence	Sequence
Paragraph or section									
40	Temperature	1							
41.2	Contactor Overload		1						
41.3	Single Phasing		2						
41.4	Inoperative Blower Motor			1					
41.5	Clogged Filter				1				
41.6	Current Limiting Control					1			
44	Dielectric Voltage Withstand	2	3	2	2				
45	Short Circuit						1		
43	Solid State Motor Overload Protection							1	
50	Breakdown of Components								1

39.2 Temperature or current sensitive devices or systems that result in termination of a test shall be additionally evaluated to determine their suitability for the application.

39.3 Tests are to be conducted at rated frequency and a test potential not less than 120, 208, 240, 277, 480, or 600 volts as appropriate for the voltage ratings. See Table 39.2. The Temperature Test shall be conducted at a potential between 90 – 110 percent of the potential specified when the load current is adjusted to produce the maximum normal heating.

Revised 39.3 effective July 16, 2005

Table 39.2
Values of voltage for tests

Revised Table 39.2 effective July 16, 2005

Voltage rating of equipment[a]					
110 – 120	**220– 240**	**254 – 277**	**380 – 415**	**440 – 480**	**560 – 600**
120	240	277	415	480	600
[a] If the rating of the equipment does not fall within any of the indicated voltage ranges, it is to be tested at its rated voltage.					

39.4 Unless indicated otherwise, the tests are to be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F). The ambient temperature is to be determined using either thermometers or thermocouples placed adjacent to the equipment being tested.

39.5 An open type device shall be mounted in an enclosure representative of the intended use. The maximum enclosure dimensions are to be determined by one of the following methods:

a) An enclosure that is 150 percent of the dimensions of the device (i.e., length, width, and height);

b) An enclosure dimensioned to meet the wire-bending space specified in Table 6.7;

c) The intended enclosure, such as a standard outlet box; or

d) The intended enclosure, larger than indicated in (a) – (c) when the dimensions are specified in the manufacturer's installation instructions.

39.6 Open type power conversion equipment is not required to be tested in an enclosure when marked with a surrounding air temperature rating. See 55.6.

39.7 During the tests, equipment shall be mounted and wired so as to represent the intended use. Except as indicated in the Terminal Torque Test, Section 51, all field wiring terminal blocks or wire connectors shall be tightened to the value of torque marked on the product.

39.8 Power conversion equipment intended to control a variable speed motor load is to be tested controlling:

a) A load equivalent to that of a motor with voltage, frequency, and current ratings corresponding to the marked rating;

b) A test motor capable of being loaded to the values specified; or

c) A simulation of the test motor by a passive load consisting of resistive or inductive loads.

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40 Temperature Test

40.1 Power conversion equipment tested under the conditions described in 40.2 – 40.12 shall not attain a temperature at any point so high as to constitute a risk of fire or to adversely affect any materials employed in the equipment, and shall not exceed the values specified in Table 40.1 and Table 40.2.

Table 40.1
Maximum temperatures for internal parts

Table 40.1 revised November 5, 2004

Materials and components	°C	°F
1. Rubber- or thermoplastic-insulated conductors[a,b]	75	167
2. Field-wiring terminals[c,j]	g,h,i	g,h,i
3. Buses and connecting straps or bars[d]	k	k
4. Insulation systems		
Class 105(A) insulation system[e]		
Thermocouple method	105	221
Resistance method	125	257
Class 105(A) insulation systems on single-layer series coil with exposed surfaces either uninsulated or enameled, thermocouple method	130	266
Class 120(E) insulation systems[e,n]		
Thermocouple	120	248
Resistance	135	275
Class 130(B) insulation systems[e,n]		
Thermocouple method	125	257
Resistance method	145	293
Class 155(F) insulation systems[e,n]		
Thermocouple method	135	275
Resistance method	155	311
Class 180(H) insulation systems[e,n]		
Thermocouple method	155	311
Resistance method	175	347
Class 220(R) insulation systems[e,n]		
Thermocouple method	195	383
Resistance method	215	419
5. Phenolic composition[a]	165	329
6. *Deleted*		
7. On bare resistor material, thermocouple method	415	779
8. Capacitor	f	f
9. Power switching semiconductors	l	l
10. Printed-wiring boards	m	m
11. Liquid cooling medium	70	158

[a] The limitation on phenolic composition and on rubber and thermoplastic insulation does not apply to compounds that have been investigated and found to meet the requirements for a higher temperature.

[b] For standard insulated conductors other than those specified in item 1, reference shall be made to the National Electrical Code (NEC), ANSI/NFPA 70, and the maximum temperature shall not exceed the maximum operating temperature specified in the NEC for the wires.

[c] The temperature on a wiring terminal or lug is measured at the point most at risk of being contacted by the insulation of a conductor installed as in actual service.

[d] The limit does not apply to connections to a source of heat, such as a resistor and a current element of an overload relay.

Table 40.1 Continued on Next Page

Table 40.1 Continued

Materials and components	°C	°F
[e] See 40.9 – 40.12.		
[f] The maximum operating temperature of the capacitor is in accordance with the manufacturer's specifications.		
[g] In equipment marked for 60°C (140°F) supply wire, the terminal temperature shall not exceed 75°C (167°F).		
[h] In equipment marked for 75°C (167°F) supply wire, the terminal temperature shall not exceed 90°C (194°F). When the measured temperature is 75°C (167°F) or less and an aluminum bodied connector is used or aluminum wire is intended, the connector shall be marked AL7CU or AL9CU; when the terminal temperature exceeds 75°C and does not exceed 90°C, the connector shall be marked AL9CU.		
[i] Equipment marked for 60/75°C supply wires shall comply with both notes g and h of this table.		
[j] See 60.12.		
[k] The limit applies only to bus bars and connecting straps used for distribution of power to industrial control devices. The limit does not apply to short pieces of copper located within industrial control devices and used for the support of stationary contact assemblies or factory or field wiring terminations. The maximum temperatures for this type of construction are determined by the temperature limitations on the support material, adjacent part material, or 140°C (284°F) maximum temperature on the copper material, whichever is the lowest. There shall be no structural deterioration of the assembly, loosening of parts, cracking or flaking of material, loss of temper of spring, annealing of parts, or other visible damage.		
[l] The maximum temperature on the case shall be the maximum case temperature for the applied power dissipation specified by the semiconductor manufacturer.		
[m] The maximum operating temperature of the printed-wiring board shall not be exceeded.		
[n] The electrical insulation system shall meet the requirements of the Standard for Systems of Insulating Materials – General, UL 1446.		

Table 40.2
Maximum enclosure surface temperatures

Table 40.2 revised July 16, 2003

	Surface	°C	(°F)
1.	Inaccessible parts of the enclosure	90[a]	(194)
2.	Accessible parts of the enclosure subject to casual contact		
	Nonmetallic	80[b]	(176)
	Metal	70[b]	(158)
3.	Parts intended to be touched (i.e. power switches and similar parts)		
	Nonmetallic	65	(149)
	Metal	55	(131)

[a] See 16.2.

[b] The temperature noted is able to be exceeded, with a maximum temperature of 150°C, when provided with the marking indicated in 61.10.

40.2 Open and enclosed type equipment shall be tested with an assumed minimum environmental ambient of 40°C (104°F) unless the equipment is marked for a higher or lower end use ambient. When the equipment is tested in an ambient other than the end use temperature rating, the maximum measured temperatures shall be linearly extrapolated for the intended end use ambient (for example, in a 25°C ambient, 15°C would be added to each temperature measurement where the maximum intended end use ambient is 40°C).

40.3 To determine whether power conversion equipment complies with the temperature test requirements, it is to be operated at the voltage specified in 39.3 until thermal stabilization occurs under normal conditions as follows:

a) For continuous operation, according to the continuous ratings;

b) For intermittent operation, according to the rated duty cycle; or

c) For short-time operation, for the rated operating time.

The rated current for equipment rated only in horsepower and not in current is to be as specified in Tables 42.1 and 42.2. When the equipment is rated in current and horsepower, and the current rating is not the same as specified in Table 42.1 and Table 42.2 for the rated horsepower, the load current shall be the greater of the two current values. No protective devices or circuitry shall trip during the test

Exception: Instead of the voltages specified, a low voltage source of supply is able to be used for temperature tests on parts other than voltage rated coils.

40.4 Temperatures are to be measured with all parts operating simultaneously, as the heating of one part is able to affect the heating of another part.

40.5 Power conversion equipment is to be tested with 4 feet (1.2 m) of wire attached to each field-wiring terminal. The wire is to be of the smallest size having an ampacity of at least 125 percent of the test current. The wire size is to be in accordance with Table 40.3 based on the wire temperature rating marked on the equipment. The type of insulation is not specified. The temperature test is not prohibited from being conducted with conductors having other than black insulation, however referee temperature measurements are to be conducted with black-insulated conductors.

Exception No. 1: When there is only provision for the connection of bus bars to power conversion equipment rated at 450 amperes or more, copper bus bars 1/4 inch (6.4 mm) thick of the width specified in Table 40.4 and at least 4 feet (1.2 m) in length are to be used. The spacing between multiple bus bars is to be 1/4 inch (6.4 mm) with no intentional wider spacing except as required at the individual terminals of the equipment

Exception No. 2: Where there is provision only for the connection of bus bars to power conversion equipment, copper bus bars specified in the manufacturer's installation instructions are able to be used for the test.

Table 40.3
Ampacities of insulated conductors

Wire size AWG (mm^2)		60°C (140°F)		75°C (167°F)	
		Copper	Aluminum	Copper	Aluminum
24	(0.2)	2	–	–	–
22	(0.3)	3	–	–	–
20	(0.5)	5	–	–	–
18	(0.8)	7	–	–	–
16	(1.3)	10	–	–	–
14	(2.1)	15	–	15	–
12	(3.3)	20	15	20	15
10	(5.3)	30	25	30	25
8	(8.4)	40	30	50	40
6	(13.3)	55	40	65	50
4	(21.2)	70	55	85	65
3	(26.7)	85	65	100	75
2	(33.6)	95	75	115	90
1	(42.4)	110	85	130	100
1/0	(53.5)			150	120
2/0	(67.4)			175	135
3/0	(85.0)			200	155
4/0	(107.2)			230	180
kcmil					
250	(127)			255	205
300	(152)			285	230
350	(177)			310	250
400	(203)			335	270
500	(253)			380	310
600	(304)			420	340
700	(355)			460	375
750	(380)			475	385
800	(405)			490	395
900	(456)			520	425
1000	(506)			545	445
1250	(633)			590	485
1500	(760)			625	520
1750	(887)			650	545
2000	(1013)			665	560

NOTES

1 For multiple-conductors of the same size (1/0 AWG or larger) at a terminal, the ampacity is equal to the value in Table 40.3 for that conductor multiplied by the number of conductors that the terminal accommodates.

2 These values of ampacity apply only when not more than three conductors are to be field-installed in the conduit. When four or more conductors, other than a neutral that carries the unbalanced current, are to be installed in a conduit (as occurs because of the number of conduit hubs provided in outdoor equipment, the number of wires required in certain polyphase systems, or other reasons), the ampacity of each of the conductors shall be 80 percent of these values when 4 – 6 conductors are involved, 70 percent of these values when 7 – 24 conductors, 60 percent of these values when 25 – 42 conductors, and 50 percent of these values when 43 or more conductors.

Table 40.4
Width of copper bus bars

Product rating, amperes	Bus bars per terminal	Width of bus bars,	
		Inches	(mm)
450 – 600	1	2	(51)
601 – 1000	1	3	(76)
1001 – 1200	1	4	(102)
1201 – 1600	2	3	(76)
1601 – 2000	2	4	(102)
2001 – 2500	2	5	(127)
	4	2-1/2	(64)
2501 – 3000	3	5	(127)
	4	4	(102)

40.6 When referee measurements of ambient temperatures are required, several thermometers are to be placed at different points around the equipment at a distance of 3 to 6 feet (0.9 to 1.8 m). The thermometers are to be located in the path of the cooling medium, and are to be protected from drafts and abnormal heat radiation. The ambient temperature is to be the mean of the readings of the temperatures taken at equal intervals of time during the final quarter of the duration of the test.

40.7 The acceptability of insulating materials other than those specified in Table 40.1 is to be determined with respect to properties such as flammability, arc-resistance, and similar properties, based on an operating temperature equal to the measured temperature adjusted to the minimum anticipated end use ambient of 40°C (104°F), unless the equipment is marked for a higher end use ambient.

40.8 For the purpose of evaluating the temperature limit of the material, insulating material at the junction in lieu of required spacings is evaluated as being at the junction temperature. To determine the insulating material temperature, reference temperatures (case, tab, heat sink, or similar parts) are to be measured and the junction temperature is to be calculated based on the semiconductor manufacturer's power dissipation and thermal resistance data.

40.9 The thermocouple method for temperature measurement as specified in Table 40.1 consists of the determination of temperature by use of a potentiometer type instrument and thermocouples that are applied to the hottest accessible parts. The thermocouples are to be made of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). The thermocouples and related instruments are to be accurate and calibrated in accordance with standard laboratory practice. The thermocouple wire is to conform with the requirements specified in the Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA MC96.1.

40.9 revised November 5, 2004

40.10 A thermocouple junction and adjacent thermocouple lead wire are to be securely held in thermal contact with the surface of the material of which the temperature is being measured. In most cases, adequate thermal contact results from securely taping or cementing the thermocouple in place; however, when a metal surface is involved, brazing or soldering the thermocouple to the metal is often required.

40.11 The resistance method for temperature measurement as specified in Table 40.1 consists of the calculation of the temperature rise of a winding using the equation:

$$\Delta t = \frac{r_2}{r_1}(k + t_1) - (k + t_2)$$

in which:

Δt is the temperature rise of the winding in degrees C.

r_2 is the resistance of the coil at the end of the test in ohms.

r_1 is the resistance of the coil at the beginning of the test in ohms.

t_1 is the room temperature in degrees C at the beginning of the test.

t_2 is the room temperature in degrees C at the end of the test.

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors are to be determined.

40.12 Thermal stabilization has been reached when three successive readings, that are taken at intervals of 10 percent of the previously elapsed duration of the test and not less than 10 minute intervals, indicate no change in temperature, defined as ±1°C between any of the three successive readings, with respect to the ambient temperature.

41 Abnormal Operation Tests

41.1 General

41.1.1 Completion of the abnormal operations tests is achieved when the following occurs:

a) Thermal stabilization occurs;

b) A protective device opens;

c) An internal component opens or shorts; or

d) A thermistor operates in conjuction with solid state circuitry so as to disable the drive output.

In all tests, there shall be no evidence of a risk of fire or electric shock. The wire specified in 41.1.2 shall not open and the surgical cotton specified in 45.7.1 shall not glow or flame.

41.1.1 revised July 16, 2003

41.1.2 To assess the risk of electric shock, the outer enclosure (when provided) and grounded or exposed dead metal parts are to be connected through a four foot maximum length of solid wire, sized per 37.2 to the supply circuit pole least at risk of arcing to ground. For grounded control circuits, the enclosure and grounded or exposed dead metal parts are to be connected through the ground wire to ground. To assess the risk of fire, the procedures specified in 45.5.1 – 45.7.1 are to be followed.

41.1.2 revised July 16, 2003

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41.1.3 Before all abnormal operation tests, the test sample is to be mounted, connected, and operated as described in the Temperature Test, Section 40.

41.2 Contactor overload

41.2.1 A contactor having the coil circuit interlocked or sequenced such that in normal operation the contactor does not make or break load current is to be tested at the maximum current the current limiting control is capable of handling without activating. The current is to be at least 150 percent of full-load current. Five operations are to be conducted.

41.3 Single phasing

41.3.1 Three-phase power conversion equipment is to be operated with one line disconnected at the input. The line disconnected is to be the one in which any protective devices are the least responsible. The test is to be conducted by disconnecting one line with the power conversion equipment operating at maximum normal load and is to be repeated by initially energizing the device with one lead disconnected.

41.4 Inoperative blower motor

41.4.1 Power conversion equipment having forced ventilation is to be operated at rated load with each blower motor disabled one at a time. Following this test, when the equipment incorporates more than one blower motor, all blowers are to be disabled concurrently.

41.5 Clogged filter

41.5.1 Enclosed power conversion equipment having filtered ventilation openings shall be operated with the openings blocked to represent clogged filters. The test is to be conducted initially with the ventilation openings blocked 50 percent. The test is then to be repeated under a full blocked condition.

41.6 Current limiting control

41.6.1 Power conversion equipment incorporating a current limiting control is to be operated with the load increased such that the current limit mode is reached. When the current limiting control is adjustable, it is to be adjusted to result in the most severe condition. The duration of the test is not to exceed the maximum time required for operation of the overload protective device on the system supplied or specified on the marking required by 56.4.

42 Full-Load Motor-Running Current Tables

Table 42.1
Full-load motor-running currents in amperes corresponding to various a-c horsepower ratings

HP	110 – 120 Volts			220 – 240 Volts[a,b]			360 – 380 Volts		440 – 480 Volts			550 – 600 Volts		
	Single phase	Two phase	Three phase	Single phase	Two phase	Three phase	Single phase	Three phase	Single phase	Two phase	Three phase	Single phase	Two phase	Three phase
1/10	3.0	–	–	1.5	–	–	1.0	–	–	–	–	–	–	–
1/8	3.8	–	–	1.9	–	–	1.2	–	–	–	–	–	–	–
1/6	4.4	–	–	2.2	–	–	1.4	–	–	–	–	–	–	–
1/4	5.8	–	–	2.9	–	–	1.8	–	–	–	–	–	–	–
1/3	7.2	–	–	3.6	–	–	2.3	–	–	–	–	–	–	–
1/2	9.8	4.0	4.4	4.9	2.0	2.2	3.2	1.3	2.5	1.0	1.1	2.0	0.8	0.9
3/4	13.8	4.8	6.4	6.9	2.4	3.2	4.5	1.8	3.5	1.2	1.6	2.8	1.0	1.3
1	16.0	6.4	8.4	8.0	3.2	4.2	5.1	2.3	4.0	1.6	2.1	3.2	1.3	1.7
1-1/2	20.0	9.0	12.0	10.0	4.5	6.0	6.4	3.3	5.0	2.3	3.0	4.0	1.8	2.4
2	24.0	11.8	13.6	12.0	5.9	6.8	7.7	4.3	6.0	3.0	3.4	4.8	2.4	2.7
3	34.0	16.6	19.2	17.0	8.3	9.6	10.9	6.1	8.5	4.2	4.8	6.8	3.3	3.9
5	56.0	26.4	30.4	28.0	13.2	15.2	17.9	9.7	14.0	6.6	7.6	11.2	5.3	6.1
7-1/2	80.0	38.0	44.0	40.0	19.0	22.0	27.0	14.0	21.0	9.0	11.0	16.0	8.0	9.0
10	100	48.0	56.0	50.0	24.0	28.0	33.0	18.0	26.0	12.0	14.0	20.0	10.0	11.0
15	135	72.0	84.0	68.0	36.0	42.0	44.0	27.0	34.0	18.0	21.0	27.0	14.0	17.0
20	–	94.0	108	88.0	47.0	54.0	56.0	34.0	44.0	23.0	27.0	35.0	19.0	22.0
25	–	118	136	110	59.0	68.0	70.0	44.0	55.0	29.0	34.0	44.0	24.0	27.0
30	–	138	160	136	69.0	80.0	87.0	51.0	68.0	35.0	40.0	54.0	28.0	32.0
40	–	180	208	176	90.0	104	112	66.0	88.0	45.0	52.0	70.0	36.0	41.0
50	–	226	260	216	113	130	139	83.0	108	56.0	65.0	86.0	45.0	52.0
60	–	–	–	–	133	154	–	103	–	67.0	77.0	–	53.0	62.0
75	–	–	–	–	166	192	–	128	–	83.0	96.0	–	66.0	77.0
100	–	–	–	–	218	248	–	165	–	109	124	–	87.0	99.0
125	–	–	–	–	–	312	–	208	–	135	156	–	108	125
150	–	–	–	–	–	360	–	240	–	156	180	–	125	144
200	–	–	–	–	–	480	–	320	–	208	240	–	167	192
250	–	–	–	–	–	602	–	403	–	–	302	–	–	242
300	–	–	–	–	–	–	–	482	–	–	361	–	–	289
350	–	–	–	–	–	–	–	560	–	–	414	–	–	336
400	–	–	–	–	–	–	–	636	–	–	477	–	–	382
500	–	–	–	–	–	–	–	786	–	–	590	–	–	472

[a] To obtain full-load currents for 200 and 208 volt motors, increase corresponding 220 – 240 volt ratings by 15 and 10 percent, respectively.

[b] To obtain full-load currents for 265 and 277 volt motors, decrease corresponding 220 – 240 volt ratings by 13 and 17 percent, respectively.

Table 42.2
Full-load motor-running currents in amperes corresponding to various d-c horsepower ratings

HP	90 Volts	110 – 120 Volts	180 Volts	220 – 240 Volts	500 Volts	550 – 600 Volts
1/10	–	2.0	–	1.0	–	–
1/8	–	2.2	–	1.1	–	–
1/6	–	2.4	–	1.2	–	–
1/4[a]	4.0	3.1	2.0	1.6	–	–
1/3	5.2	4.1	2.6	2.0	–	–
1/2	6.8	5.4	3.4	2.7	–	–
3/4	9.6	7.6	4.8	3.8	–	1.6
1	12.2	9.5	6.1	4.7	–	2.0
1-1/2	–	13.2	8.3	6.6	–	2.7
2	–	17.0	10.8	8.5	–	3.6
3	–	25.0	16.0	12.2	–	5.2
5	–	40.0	27.0	20.0	–	8.3
7-1/2	–	58.0	–	29.0	–	12.2
10	–	76.0	–	38.0	–	16.0
15	–	110.0	–	55.0	27.0	24.0
20	–	148.0	–	72.0	34.0	31.0
25	–	184.0	–	89.0	43.0	38.0
30	–	220.0	–	106.0	51.0	46.0
40	–	292.0	–	140.0	67.0	61.0
50	–	360.0	–	173.0	83.0	75.0
60	–	–	–	206.0	99.0	90.0
75	–	–	–	255.0	123.0	111.0
100	–	–	–	341.0	164.0	148.0
125	–	–	–	425.0	205.0	185.0
150	–	–	–	506.0	246.0	222.0
200	–	–	–	675.0	330.0	294.0

[a] The full-load current for a 1/4-horsepower, 32-volt d-c motor is 8.6 amperes.

43 Solid State Motor Overload Protection Test

43.1 General requirements

43.1.1 Drive series that incorporate solid state motor overload protection circuitry shall have one sample of the representative model used for testing.

43.1.2 When the representative model from a drive series provides overload protection for a range of motor horsepower ratings, then the test shall be conducted at the lowest specified current rating, or at a current rating which is either the lowermost horsepower rating or a horsepower rating low enough to achieve the 600 percent overload condition.

43.1.3 The solid state overload protection circuitry in the representative model shall operate as follows:

a) Ultimately, when subjected to 100 percent of the maximum rated tripping current appropriate for the horsepower rating under test;

b) Within 8 minutes when subjected to 200 percent of the maximum rated tripping current appropriate for the horsepower rating under test; and

Exception: When the overload protection operates prior to reaching the 200 percent overload condition, then this test complies with the requirements in 43.1.3.

c) Within 20 seconds when subjected to 600 percent of the maximum rated tripping current appropriate for the horsepower rating under test.

Exception: When the overload protection operates prior to reaching the 600 percent overload condition, then this test complies with the requirements in 43.1.3.

43.1.4 The overloading of each drive shall be accomplished by one of the following methods:

a) The connection of an actual motor to the motor output terminals that provides the required overload condition; or

b) The connection of a resistive or resistive-inductive load to the motor output terminals that provides the required overload condition.

43.1.5 Once the protection circuitry has operated under the overload conditions noted in 43.1.3, the drive shall still be electrically and mechanically operational.

43.1.6 Marking or instructions in accordance with 56.1 are required to indicate the overload ratings.

43.2 Test set-up

43.2.1 The test sample shall be mounted, connected, and operated as described in 39.1 – 39.8 and 40.5 of the Temperature Test and then subjected to the overload condition.

44 Dielectric Voltage-Withstand Test

44.1 General

44.1.1 Power conversion equipment shall withstand for 1 minute without breakdown the application of a 60 hertz sinusoidal potential or a direct-current potential:

a) Between any uninsulated live parts and the walls of a metal enclosure including fittings for conduit or armored cable;

b) Between isolated secondary circuit uninsulated live parts, involving potential in excess of 30 V ac or 42.4 V peak, and any uninsulated live parts and the walls of a metal enclosure including fittings for conduit or armored cable; and

c) Between primary circuit uninsulated live parts and isolated secondary circuit uninsulated live parts.

44.1.2 With respect to 44.1.1, the test potential shall be the following values for alternating-current, or 1.414 times the following values for direct-current:

a) For power conversion equipment rated not more than 250 volts and intended for use in a pollution degree 2 location, 1000 volts; and

b) For all other power conversion equipment, 1000 volts plus twice the rated voltage of the equipment.

44.1.3 To determine whether power conversion equipment complies with the requirements in 44.1.1, it is to be tested by means of a 500 volt-ampere or larger capacity transformer, the output voltage of which is sinusoidal and is able to be varied. The applied potential is to be increased from zero to the required value at a substantially uniform rate and as rapidly as is consistent with its value being correctly indicated by a voltmeter.

Exception: A 500 volt-ampere or larger capacity transformer is not required to be used when the transformer is provided with a voltmeter that directly measures the applied output potential.

44.1.3 revised November 5, 2004

44.2 Clamped joints

44.2.1 With respect to 36.12.1, a clamped joint between two insulators is to be tested using two samples.

a) The first sample is to have the clamped joint opened up to produce a space 1/8 inch (3.2 mm) wide. This is accomplished by loosening the clamping means or by drilling a 1/8 inch diameter hole at the joint between the insulators at a point of minimum spacing between the metal parts on the opposite sides of the joint. The drilled hole shall not decrease spacings between the opposite polarity parts as measured through the crack between the insulators. The 60 hertz dielectric breakdown voltage through this hole is then determined by applying a gradually increasing voltage (500 volts per second) until breakdown occurs.

b) The second sample with the clamped joint intact is to be subjected to a gradually increasing 60 hertz voltage until 110 percent of the breakdown voltage of (a) has been reached. When the breakdown voltage of (a) is less than 4600 volts rms, the voltage applied to the second sample is to be further increased to 5000 volts rms and held for 1 second. The clamped joint meets the intent of the requirement when there is no dielectric breakdown of the second sample.

45 Short Circuit Test – Standard Fault Currents

45.1 General

45.1.1 One sample of the representative model from each drive series is to be used for testing. Only drive models rated more than 1 hp (745.7 W) are to be used for testing and each representative model shall be subjected to only one short circuit test.

45.1.2 A drive series shall comply with the Short Circuit Test – High Fault Currents, Section 47, and the Short Circuit Test – Standard Fault Currents, Section 45, when it is intended to be rated with:

a) A standard fault current value in accordance with Table 45.1; and

b) A high fault current value in excess of the standard fault current value.

Exception: A drive series is in compliance with the Short Circuit Test – High Fault Currents, Section 47, without additional testing when:

a) The drive series uses solid state short circuit protection circuitry for compliance with the standard fault current short circuit test; and

b) The solid state short circuit protection circuitry is used in accordance with 45.1.3.

Table 45.1
Short circuit test current values for devices rated 600 volts or less

Ratings		Test current
Horsepower	(kW)	Amperes
1.5 – 50	(1.1 – 37.3)	5,000
51 – 200	(39 – 149)	10,000
201 – 400	(150 – 298)	18,000
401 – 600	(299 – 447)	30,000
601 – 900	(448 – 671)	42,000
901 – 1600	(672 – 1193)	85,000
1601 or more	(1194 or more)	100,000, 125,000, 150,000, or 200,000

45.1.3 Any model is able to serve as the representative model from a series that uses solid state short circuit protection circuitry for compliance with this test. As an example, for a drive series with models rated from 25 hp to 700 hp (18.64 – 521.99 kW), the testing of the 25 hp model at 5000 A represents the testing of any models at 10,000 A, 18,000 A, 30,000 A, or 42,000 A. In addition, short circuit testing may be conducted at 5,000 A to represent higher short circuit test values when all of the following requirements are met:

a) The same solid state protection circuitry is used throughout the series;

b) Any revisions to the protection circuitry requires re-evaluation;

c) The protection circuitry turns off the output devices (Insulated Gate Bi-polar Transistor (IGBT), bi-polar, and similar devices prior to the time in which the devices are damaged by any increase in current. This is based on the manufacturer's rating of the output devices (typically 10 micro-seconds for IGBTs, and 50 micro-seconds for bi-polars);

d) Any increase in current experienced by the output devices is the result of the DC bus capacitor bank discharging;

e) The output devices are turned off by the protection circuitry prior to any significant increase in the input current;

f) In response to a higher standard fault current (for example 42,000 A vs. 5000 A), the protection circuitry shall react to the higher standard fault current (42,000 A) in the same or shorter time as the lower standard fault current (5000 A). This may be verified through testing at the higher fault current value or through inspection of the solid state short circuit protection hardware and software circuitry; and

g) When relying on current sensing (as opposed to output device collector voltage sensing) to actuate the protection circuitry, either the DC bus or all main motor output lines shall be monitored.

45.1.3 revised July 16, 2003

45.1.4 The criteria for samples to test for a drive series that uses fuses or circuit breakers for compliance with this test is based on comparing the fuse or circuit breaker ratings to the Silicon Controlled Rectifier (SCR) or transistor output device ratings for each model within the series (specific ratings to evaluate are the I^2t and I_p values).

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45.1.5 The representative model from each drive series shall be connected to a test circuit as noted in 45.2.1 – 45.7.1 and then loaded such that the output devices are actuated when each drive is energized.

45.1.6 Actuation of the output devices is attainable by any one of the following methods of loading:

a) The connection of an actual motor to the motor output terminals such that enough loading is provided to actuate the output devices;

b) The connection of a resistive or resistive-inductive load to the motor output terminals such that enough loading is provided to actuate the output devices; or

c) The connection of a remote circuit to each drive such that the output devices are actuated independent of any loading.

45.1.7 Upon actuation of the output devices, a short is to be introduced across the main motor output power terminals (the motor field output terminals are not required to be shorted) and the drive is to be operated until one or more of the following ultimate results are obtained:

a) The operation of a solid state short circuit protection circuitry that is subjected to the requirements in 64.1 – 64.3;

b) The opening of a branch circuit short circuit protection fuse (either a semiconductor or non-semiconductor type) that complies with the UL 248 series of standards for fuses;

c) The opening of a branch circuit short circuit protection circuit breaker (either an inverse-time or instantaneous trip type) that complies with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489; or

d) The opening of a self-protected combination motor controller that complies with the Standard for Industrial Control Equipment, UL 508; or

e) The opening of a semiconductor device.

45.1.7 revised November 5, 2004

45.1.8 The test is to be conducted with the unevaluated protection circuitry defeated when the output solid state short circuit protection circuitry, that is not subjected to the requirements in 64.1 – 64.3, trips prior to obtaining ultimate results.

45.1.8 revised November 5, 2004

45.1.9 When none of the ultimate results in 45.1.7 (a) – (e) occur, the drive shall not be in compliance with this section.

45.1.9 revised November 5, 2004

45.1.10 When one or more of the ultimate results in 45.1.7 (a) – (e) occur, the drive shall be in accordance with this section, only when the drive complies with each of the following:

a) The drive is not required to be operational after testing;

b) The cotton indicator shall not have ignited;

c) The ground fuse shall not have opened;

d) The door or cover shall not have blown open;

e) The door or cover shall be able to be opened; and

f) The enclosure is not prohibited from deforming, however, live parts shall not be accessible as determined by 6.8.1.

45.1.10 revised November 5, 2004

45.2 Test circuit current/voltage

45.2.1 Drives rated for direct current are to be tested using a direct current source.

45.2.2 Drives rated for alternating current are to be tested using a 60 ±12 hertz sinusoidal current source.

45.2.3 Under short circuit conditions, the test circuit shall be capable of delivering the current specified in Table 45.1 based on the horsepower rating of the drive. This circuit capability shall be verified in accordance with the Calibration of Short Circuit Test Circuit, Section 46.

Exception: For a drive rated only in current and not in horsepower, the equivalent horsepower rating shall be as specified in Tables 42.1 and 42.2.

45.2.4 The open-circuit voltage of the test circuit is to be 100 – 105 percent of the rated input voltage.

Exception: The open-circuit voltage is not prohibited from exceeding 105 percent of the rated input voltage at the request of the manufacturer.

45.3 Input/output wiring connection

45.3.1 Each drive is to be tested with 4 feet (1.2 m) of wire, or less, attached to each input and output terminal. The input and output wiring is then to be routed through 10 – 12 inch (250 – 305 mm) lengths of conduit installed on the enclosure with the ends of the conduit plugged with surgical cotton.

Exception No. 1: The cotton is not required to be provided when circuit breakers (either inverse-time or instantaneous trip types), in accordance with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489, are being relied upon to provide the branch circuit short circuit protection.

Exception No. 2: Both the cotton and the conduit are not required to be provided when inverse-time circuit breakers, in accordance with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489, are being relied upon to provide branch circuit short circuit protection.

Exception No. 3: The input/output test wiring is not prohibited from exceeding 4 feet (1.2 m) in length when they are in the test circuit during its calibration.

Exception No. 4: For drives rated more than 200 hp (150 kW), the main input/output power connections are not prohibitied from being made with bus bars equivalent in cross-sectional area to the required wiring.

45.3.2 The wire size of the input and output wiring shall be in accordance with Table 40.3 with the required ampacity of the wiring being based on the marked wire temperature rating [either 60°C (140°F) or 75°C (167°F)] and each of the following:

a) The main input power wiring shall be sized for 125 percent of the rated full-load output motor current;

b) All other input wiring shall be sized for 100 percent of the maximum intended full-load current;

c) The main output power wiring shall be sized for 125 percent of the rated full-load current or shall be sized for 125 percent of the full-load output motor current specified in Table 42.1 or 42.2, based on the rated horsepower rating; and

d) All other output wiring shall be sized for 100 percent of the maximum intended full-load current.

45.3.3 The type of wire insulation shall be T or TW for 60°C (140°F) wiring and shall be THW or THWN for 75°C (167°F) wiring.

45.4 Ground fuse

45.4.1 A 30 ampere nontime delay ground fuse shall be connected, by means of a 4 – 6 foot (1.22 m – 1.83 m) long 10 AWG (2.59 mm) copper wire, in accordance with one of the following:

a) The ground fuse shall be connected between the enclosure and earth ground, with the main input ground connection removed; or

b) The ground fuse shall be connected between the enclosure and the main input power terminal judged least at risk of arcing to earth ground, with the main input ground connection removed. For 3-phase drives, the main input power terminal judged least at risk of arcing to earth ground is the L2 terminal.

Exception: The ground fuse connection is able to be made with 12 or 14 AWG (2.05 or 1.63 mm) copper wire when the main input power wiring is either 12 or 14 AWG (2.05 or 1.63 mm) respectively.

45.4.1 revised November 5, 2004

45.4.2 The ground fuse shall have an Amperes Interrupting Current (A.I.C.) rating equal to or greater than the short circuit test current required by Table 45.1.

45.5 Enclosures

45.5.1 Enclosed type drives shall be tested within the intended enclosure.

45.5.2 Open type drives shall be tested within one of the following:

a) An unventilated solid outer enclosure 1-1/2 times the size of the drive;

b) A wire mesh outer enclosure 1-1/2 times the size of the drive; or

c) An outer enclosure of such size and with such ventilation as described in the installation instructions provided with the drive.

45.6 Mounting

45.6.1 Each drive shall be mounted as described in the manufacturer's installation instructions.

45.7 Openings

45.7.1 Surgical cotton is to be placed at all openings, handles, flanges, joints, and similar locations on the outside of the enclosure.

Exception: The cotton is not required to be provided when circuit breakers (either inverse-time or instantaneous trip types), in compliance with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489, are being relied upon to provide the branch circuit short circuit protection.

45.8 Branch circuit short circuit protection

45.8.1 Drives shall always be tested with fuses (either semiconductor or non-semiconductor types) in accordance with the UL 248 series of standards and circuit breakers (either inverse time or instantaneous trip types) in accordance with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489.

Exception: When the drive is marked to identify that branch circuit short circuit protection shall be provided by fuses only (either semiconductor or non-semiconductor types), then testing with circuit breakers is not required.

45.8.2 Testing with fuses (either semiconductor or non-semiconductor types) shall not be used in lieu of testing with circuit breakers (either inverse-time or instantaneous trip types).

Exception: Testing with non-semiconductor type fuses covers testing with inverse-time circuit breakers, when it is shown that the let-through energy (i^2t) and peak let-through current (I_p) of the inverse-time current-limiting circuit breaker will be less than that of the non-semiconductor type fuses with which the drive has been tested.

45.8.3 Even though the operation of solid state short circuit protection circuitry that is subjected to the requirements in 64.1 – 64.3 serves as the ultimate result to discontinue the short circuit test (see 45.1.7), the presence of this circuitry shall not replace the requirement for the fuses or the breakers.

45.8.4 Non-semiconductor fuse types are able to be rated any Class that is evaluated for branch circuit protection and shall have a voltage rating at least equal to the input voltage rating of the drive. These fuses shall have a current rating that is one of the following standard values – 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000 or 6000 amperes – and that complies with one of the following:

a) For drives with rated full-load output motor currents of 600 amperes or less, the current rating of the fuses shall be four times the maximum full-load motor output current rating; or

b) For drives with rated full-load motor output currents of more than 600 amperes, the current rating of the fuses shall be three times the maximum full-load motor output current rating.

When the calculated value of the fuse is between two standard ratings, the nearest standard rating less than the calculated value shall apply.

Exception: For a drive of any full-load motor output current rating, the current rating of the fuse is able to be less than that specified in (a) or (b) above and still shall comply with all other requirements, and shall be marked in accordance with 45.8.9.

45.8.5 Semiconductor fuse types shall have a voltage rating at least equal to the input voltage rating of the drive and are able to have any current rating. Semiconductor fuse types shall be marked in accordance with 45.8.9.

45.8.6 Inverse-time circuit breakers shall have a voltage rating at least equal to the voltage rating of the drive. These breakers shall have a current rating that is one of the following standard values – 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000 or 6000 amperes – and that complies with one of the following:

a) For drives with rated full-load motor output currents of 100 amperes or less, the current rating of the breaker shall be four times the maximum full-load motor output current rating; or

b) For drives with rated full-load motor output currents of more than 100 amperes, the current rating of the breaker shall be three times the maximum full-load motor output current rating.

When the calculated value of the circuit breaker is between two standard ratings, the nearest standard rating less than the calculated value shall apply. When the calculated value of the breaker is less than 15 amperes, a breaker rated 15 amperes shall be used.

Exception: For drives of any full-load motor output current rating, the current rating of the breaker are not prohibited from being less than that specified in (a) or (b) above and still shall comply with all other requirements, and shall be marked in accordance with 45.8.9.

45.8.7 Instantaneous trip circuit breaker types shall have a voltage rating at least equal to the input voltage rating of the drive, they shall be marked in accordance with 45.8.9, and they are able to have any current rating.

45.8.8 A drive utilizing non-semiconductor type fuses or inverse-time type circuit breakers sized, in accordance with 45.8.4(a), 45.8.4(b), 45.8.6(a), or 45.8.6(b) require no marking to indicate the manufacturer, model number or rating of the fuse or breaker.

45.8.9 A drive utilizing fuses (either semiconductor or non-semiconductor types), or circuit breakers (either inverse-time or instantaneous trip types) sized in accordance with 45.8.5, 45.8.7 or the exceptions to 45.8.4 and 45.8.6 shall be marked as noted below:

a) For non-semiconductor fuse types, the marking shall include the Class – when other than Class H or K5 – and the voltage and current or voltage and percent of the full-load motor output current rating;

b) For semiconductor fuse types, the marking shall include the fuse manufacturer and fuse model number (no fuse rating is required);

c) For inverse-time circuit breaker types, the marking shall include voltage and current or voltage and percent of the full-load motor output current rating; or

d) For instantaneous trip circuit breaker types, the marking shall include the breaker manufacturer and breaker model number (no breaker rating is required).

46 Calibration of Short Circuit Test Circuits.

46.1 10,000 amperes or less

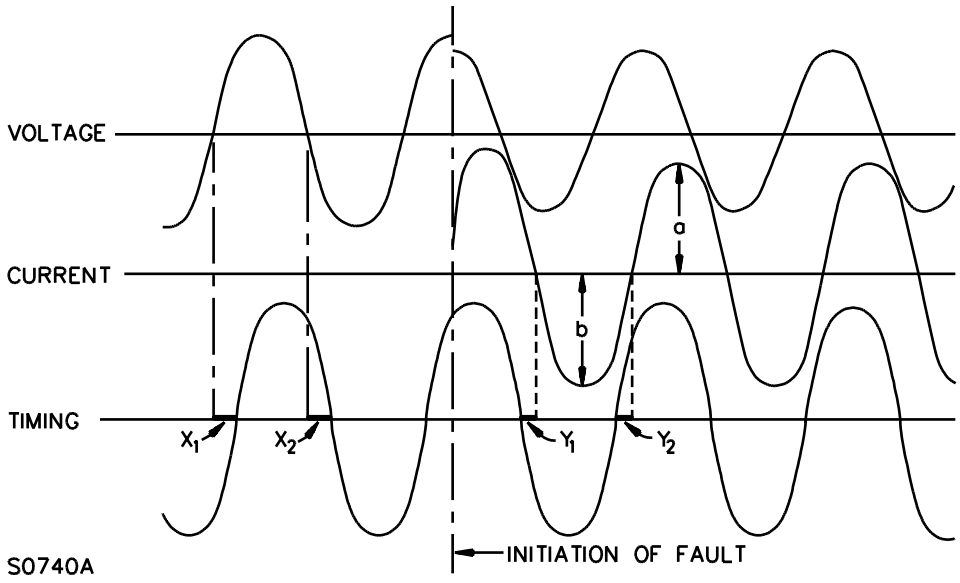
46.1.1 For an AC circuit intended to deliver 10,000 amperes or less, the current is to be determined in accordance with one of the following:

a) For a 3-phase test circuit, the current is to be determined by averaging the rms values of the first complete cycle of current in each of the three phases;

b) For a single phase test circuit, the current is to be the rms value of the first complete cycle (see Figure 46.1) when the circuit is closed to produce symmetrical current waveform. The direct current component is not to be added to the value obtained when measured as illustrated. In order to obtain the required symmetrical waveform of a single phase circuit, controlled closing is most often used although random closing methods are not prohibited from being used; or

c) For a single or 3 phase test circuit, an analytical evaluation that suitably demonstrates the available current is able to be used.

Figure 46.1
Determination of current for circuits of 10,000 amperes and less



Current = [(a + b) /2] (rms calibration of instrument element)

46.2 More than 10,000 amperes

46.2.1 For an AC circuit intended to deliver more than 10,000 amperes, the current is to be determined in accordance with one of the following:

a) In accordance with the requirements in 46.2.2 – 46.2.6. Instrumentation used to measure these test circuits of more than 10,000 amperes is to comply with the requirements in 46.2.7 – 46.2.17; or

b) For a single or 3 phase test circuit, an analytical evaluation that suitably demonstrates the available current is able to be used.

46.2.2 The rms symmetrical current is to be determined, with the supply terminals short-circuited by measuring the alternating-current component of the wave at an instant 1/2 cycle – on the basis of the test frequency timing wave – after the initiation of the short circuit. The current is to be calculated in accordance with Figure 7 in the Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis, ANSI/IEEE C37.09-1989.

46.2.3 For a 3-phase test circuit, the rms symmetrical current is to be the average of the currents in the three phases. The rms symmetrical current in any one phase is not to be less than 90 percent of the required test current.

46.2.4 The test circuit and its transients are to be such that:

a) 3 cycles after initiation of the short circuit, the symmetrical alternating component of current is not less than 90 percent of the symmetrical alternating component of current at the end of the first 1/2 cycle; or

b) The symmetrical alternating component of current at the time at which the overcurrent-protective device interrupts the test circuit is at least 100 percent of the rating for which the controller is being tested. In 3-phase circuits, the symmetrical alternating component of current of all three phases is to be averaged.

46.2.5 The recovery voltage is to be at least equal to the rated voltage of the controller. The peak value of the recovery voltage within the first complete half cycle after clearing and for the next five successive peaks is to be at least equal to 1.414 times the rms value of the rated voltage of the controller. Each of the peaks is not to be displaced by more than ±10 electrical degrees from the peak values of the open-circuit recovery voltage – that is, the displacement of the peak from its normal position on a sinusoidal wave. The average of the instantaneous values of recovery voltage each of the first six, half cycles measured at the 45 degree and 135 degree points on the wave is to be not less than 85 percent of the rms value of the rated voltage of the controller. The instantaneous value of recovery voltage measured at the 45 degree and 135 degree points of each of the first six, half cycles is in no case to be less than 75 percent of the rms value of the rated voltage of the controller.

46.2.6 When there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave when compared with the open-circuit secondary voltage wave before current flow in a circuit that employs secondary closing, the detailed measurement of recovery voltage characteristics as indicated in 46.2.5 is not required.

46.2.7 The galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration and while testing are to be of a type having a flat (±5 percent) frequency response from 50 – 1200 hertz. For fast acting fuses, current limiters, or motor-short-circuit protectors, a galvanometer is often required to have a flat frequency response from 50 – 9000 hertz or an oscilloscope is required to be used to obtain accurate values of peak current, (I_p), and energy let-through, (I^2t).

46.2.8 Galvanometers are to be calibrated as described in 46.2.9 – 46.2.12.

46.2.9 When a shunt is used to determine the circuit characteristics, a direct-current calibrating voltage is normally used. The voltage applied to the oscillograph galvanometer circuit is to result in a deflection of the galvanometer equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the nominal short-circuit current is flowing. The voltage is to be applied so as to result in the galvanometer deflecting in both directions. Additional calibrations are to be made using 50 percent and 150 percent of the voltage used to obtain the deflection indicated above, except that when the anticipated maximum deflection is less than 150 percent, such as a symmetrically closed single-phase circuit, any other usable calibration point is to be chosen. The sensitivity of the galvanometer circuit in volts per inch (or millimeter) is to be determined from the deflection measured in each case, and the results of the six trials averaged. The peak amperes per inch (or millimeter) is obtained by dividing the sensitivity by the resistance of the shunt. This multiplying factor is to be used for the determination of the rms current as described in 46.2.2.

46.2.10 A 60 hertz sine-wave potential is able to be used for calibrating the galvanometer circuit, using the same general method described in 46.2.9. The resulting factor is to be multiplied by 1.414.

46.2.11 When a current transformer is used to determine the circuit characteristics, an alternating current is to be used to calibrate the galvanometer circuit. The value of current applied to the galvanometer circuit is to result in a deflection of the galvanometer equivalent to that which is expected when the same galvanometer is connected to the secondary of the current transformer and nominal short circuit current is flowing in the primary. Additional calibrations are to be made at 50 percent and 150 percent of the current used to obtain the deflection indicated above except that when the anticipated maximum deflection is less than 150 percent, such as in a symmetrically closed single-phase circuit, any other usable calibration point is to be chosen. The sensitivity of the galvanometer circuit in rms amperes per inch (or millimeter) is to be determined in each case and the results averaged. The average sensitivity is to be multiplied by the current-transformer ratio and by 1.414 to obtain peak amperes per inch. This constant is to be used for the determination of the rms current as described in 46.2.2.

46.2.12 All the galvanometer elements employed are to line-up properly in the oscillograph, or the displacement differences are to be noted and used as required.

46.2.13 The sensitivity of the galvanometers and the recording speed are to be such that the values of voltage, current, and power factor are accurately determined. The recording speed is to be at least 60 inches (1.5 m) per second.

46.2.14 With the test circuit adjusted to provide the specified values of voltage and current and with a noninductive (coaxial) shunt that has been found to provide the intended function for use as a reference connected into the circuit, the tests described in 46.2.15 and 46.2.16 are to be conducted to verify the accuracy of the manufacturer's instrumentation.

46.2.15 With the secondary open-circuited, the transformer is to be energized and the voltage at the test terminals observed to see when rectification is occurring making the circuit unusable for test purposes because the voltage and current are not sinusoidal. Six random closings are to be made to demonstrate that residual flux in the transformer core does not result in rectification. When testing is done by closing the secondary circuit, this check is able to be omitted when testing is not commenced before the transformer has been energized for 2 seconds, or longer and when an investigation of the test equipment shows that a longer time is required.

46.2.16 With the test terminals connected together by means of a copper bar, a single-phase circuit is to be closed as nearly as possible at the moment that produces a current wave with maximum offset. The short circuit current and voltage are to be recorded. The primary voltage is to be recorded when primary closing is used. The current measured by the reference shunt is to be within 5 percent of that measured using the manufacturer's instrumentation and there is to be no measurable variation in phase relationship between the traces of the same current. Controlled closing is not required for polyphase circuits.

46.2.17 When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt is to be removed from the circuit. The reference coaxial shunt is not to be used during the final calibration of the test circuit nor during the testing of controllers.

47 Short Circuit Test – High Fault Currents

47.1 When any models within a drive series are intended to be rated with high fault current values in excess of the standard current values required by Table 45.1, then one representative model from those intended to be rated with high fault current values shall be used for testing. This representative model shall be subjected to only one high fault current short circuit test.

Exception: A drive series complies with the High Fault Current Short Circuit Test in this section without additional testing when:

a) The drive series uses solid state short circuit protection circuitry for compliance with the Short Circuit Test, Section 45; and

b) The solid state short circuit protection circuitry is used in accordance with 45.1.3.

47.2 The criteria for samples to test for a drive series that uses fuses for compliance with this test is based on comparing the fuse ratings to the Silicon Controlled Rectifier (SCR) or transistor output device ratings for each model within the series (specific ratings to evaluate are the I^2t and I_p values).

47.3 The high fault current values for which a drive is able to be tested are not required to be one of the same values detailed in Table 45.1.

47.4 The requirements for conducting the high fault current short circuit test shall be in accordance with 45.1.5 except for the following differences:

a) For drives rated over 10,000 amperes, the branch circuit short circuit protection fuses shall be limited to high-interrupting capacity, current limiting types such as Class CC, G, J, L, R, T, etc.

b) For drives rated 50 hp (37 kW) or less and tested at 10,000 amperes, the branch circuit short circuit protection fuses are able to be Class H or K.

c) A drive that is intended to be used with Class RK1 or RK5 fuses shall be tested with fuses having I^2t and I_p characteristics for Class RK5 fuses. All references to Class R fuses are intended to mean fuses with energy let-through (I^2t) characteristics of Class RK5 fuses.

d) Instead of the 30 ampere nontime delay ground fuse, the enclosure of the drive shall be connected through a solid conductor without a fuse to one of the main input power terminals by a 10 AWG (2.59 mm) copper wire 4 – 6 feet (1.22 – 1.83 m) long.

e) For noncombination controllers, the circuit breaker to be used is to be from commercially available units of the molded-case type having the same characteristics with respect to opening time and without current-limiting features.

f) For circuit breakers with current limiters provided as part of the controller, the current limiter shall be capable of handling a peak let-through current and a clearing I^2t not less than the maximum value established for the current limiter intended to be used with the controller being tested, when tested on a single-phase circuit.

g) A Class CC, G, J, L, R, or T fuse, or motor short-circuit protector shall be capable of handling a peak let-through current and clearing I^2t not less than the maximum value established for the fuse (see the UL 248 series of standards for fuses), or motor short-circuit protector rating that is intended to be used with the controller being tested, when tested on a

single-phase circuit. For a fuse with I_p and I^2t limits established for several different short-circuit current levels, the test fuse is to be capable of handling at least the maximum values of the current corresponding to the marked short-circuit-withstand current of the controller.

Exception: A test limiter is not prohibited from being used in place of the fuses.

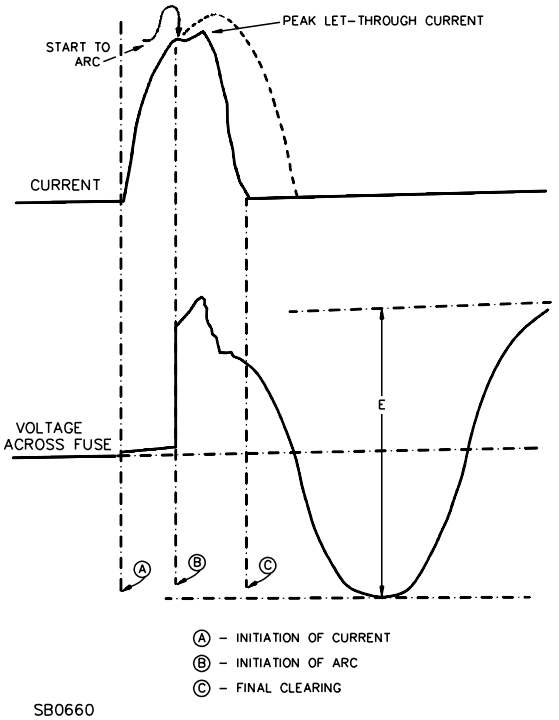
47.4 revised November 5, 2004

47.5 To obtain the required values specified in 47.4 (f) and (g), a fuse, current limiter, or motor short-circuit protector larger than that specified for use with the device being tested is able to be used; or a commercially available test fuse designed and calibrated to exhibit I^2t and I_p characteristics at least equal to the maximum limits for the fuse, current limiter, or motor short-circuit protector rating. The let-through characteristics are to be determined in accordance with 46.2.9 – 46.2.12.

47.6 Fuses, current limiters, or motor short-circuit protectors used for tests are to be from a batch from which two samples have been tested. The value of the I_p and I^2t determined for the two samples is to be equal to or greater than the required values. These determinations are to be made in accordance with 47.7 – 47.8.

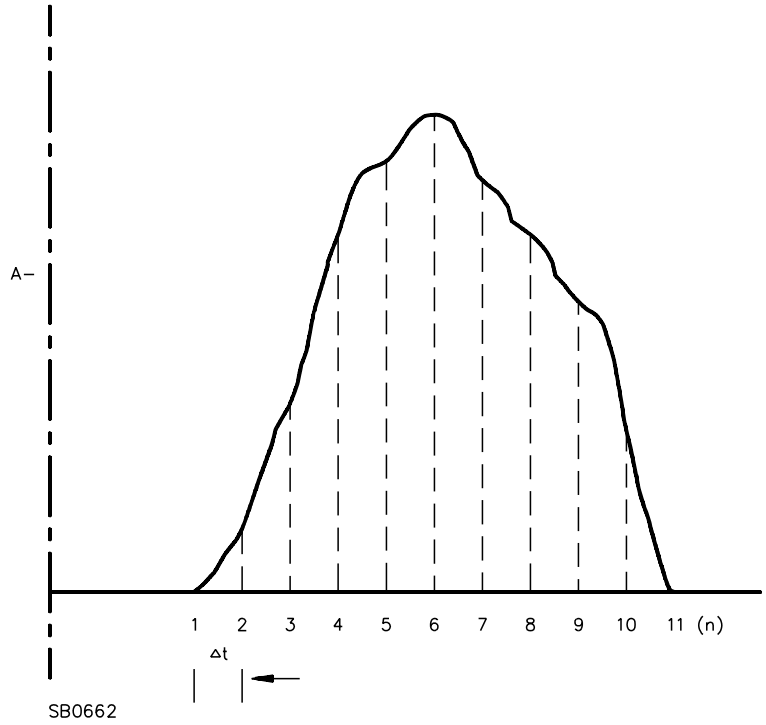
47.7 Figure 47.1 is typical of oscillograms obtained during the test of a fuse, current limiter, or motor short-circuit protectors on an alternating-current circuit; and represents a circuit that opened before the current reached its first major peak. The peak let-through current I_p is to be determined as illustrated.

Figure 47.1
Peak let-through current



47.8 The let-through energy (I^2t) is to be determined from an oscillogram showing a current trace during the interruption of the circuit by the fuse, current limiter, or motor short-circuit protectors. The determination is to be made by the application of Simpson's rule illustrated in Figure 47.2 or the use of an integrating planimeter.

Figure 47.2
Application of Simpson's Rule to fuse current oscillogram to obtain let-through I^2t



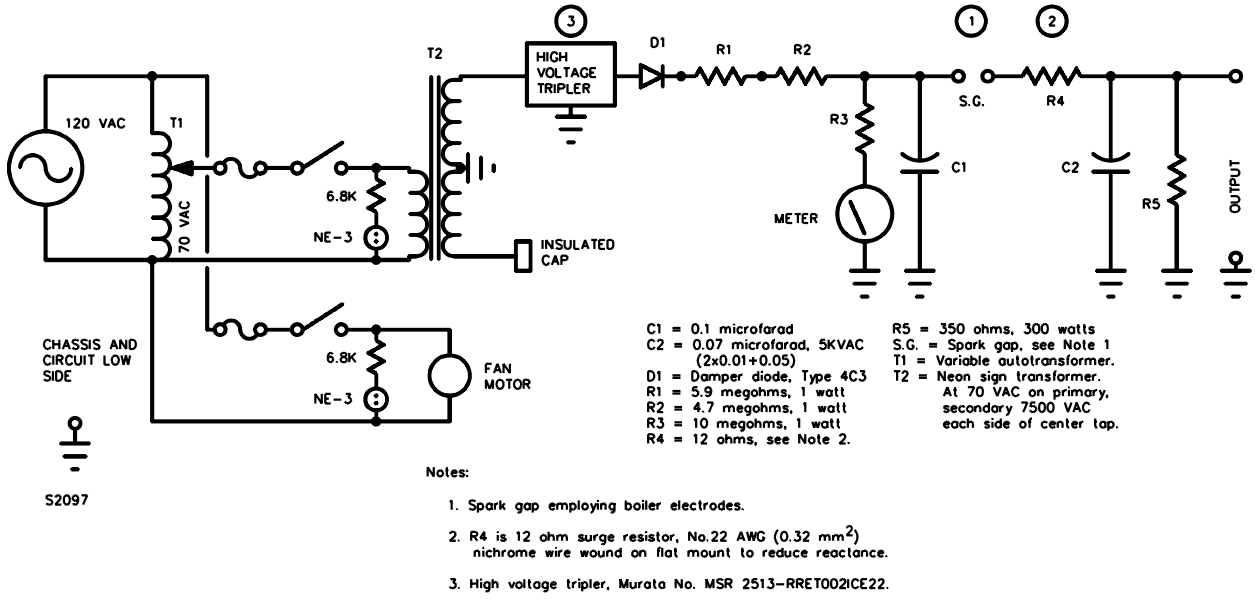
47.9 The time base in degrees-per-inch (degrees/cm) is to be determined by averaging the distance, between zero-line crossover points of the voltage wave or a timing wave, in which the fuse-current trace is most nearly centered.

48 Transient-Voltage-Surge Suppression Test

48.1 A surge-controlled circuit as specified in 36.7.1 and 36.7.3 shall withstand without breakdown a single 1.2 by 50 microseconds full-wave impulse with a crest value of 5.0 kilovolts. See Standard Techniques for Dielectric Tests, ANSI C68.1-1968. The transient voltage surge shall not exceed 300 percent of the peak working voltage, or 300 volts, whichever is greater and the equipment shall be operative after conclusion of the test.

48.2 The wave form specified in 48.1 is provided by an impulse generator illustrated in Figure 48.1 when operated under open-circuit conditions. Caution is required to prevent back surges on the line.

Figure 48.1
Typical impulse generator



48.3 The equipment is to be connected to a single-phase source of supply operating at rated voltage with the impulse generator connected across the equipment.

49 Accelerated Aging Test

49.1 When tested as described in 49.2, a sealing compound shall not melt, become brittle, or otherwise deteriorate to a degree that affects its sealing properties as determined by comparing the conditioned sample to an unconditioned sample.

49.2 A sealing compound is to be applied to the surface it is intended to seal. For a temperature rise not exceeding 35°C (63°F), a representative sample of the surface with the sealing compound applied is to be conditioned for 7 days in an air oven at 87°C (189°F).

50 Breakdown of Components Test

50.1 There shall be no emission of flame or molten metal nor ignition of cotton, when cotton is loosely placed over all openings of ventilated equipment or totally around open type drives while capacitors, diodes, or other solid state components are short- or open-circuited.

Exception: The test is not required:

a) When circuit analysis indicates that no other component or portion of the circuit is overloaded as a result of the assumed open circuiting or short circuiting of another component.

b) For components in Class 2 circuits as defined in 32.2.

c) For components in limited voltage/current secondary circuits as defined in 32.3 or limiting impedance circuits as defined in 32.7.

d) On power semiconductor devices when equivalent testing is accomplished during short circuit tests.

e) For components complying with requirements applicable to the component.

50.2 The breakdown of the component shall be simulated after the drive is fully energized and in operation.

50.3 Components shall be evaluated one at a time.

50.4 For an open type drive controller, a wire mesh cage that is 1.5 times the size of the controller is usable to simulate the intended enclosure.

50.5 The outer enclosure or wire mesh cage (when provided) and any grounded or exposed dead metal parts are to be connected through a four foot maximum length of solid wire, sized per 37.2 to the supply circuit pole least at risk of arcing to ground. The wire shall not open.

50.5 revised July 16, 2003

51 Terminal Torque Test

51.1 Deleted November 5, 2004

51.2 Deleted November 5, 2004

51.3 Deleted November 4, 2004

52 Printed Wiring Board Abnormal Operation Test

52.1 Spacings on printed wiring boards that are less than those specified in Tables 36.1 – 36.4 and that comply with 36.10.1 to provide operational insulation are to be tested as described in 52.2 – 52.5. As a result of this test:

a) Overcurrent protection integral to the drive or required to be used with the drive is not prohibited from opening.

b) Flame shall not be emitted from the overall enclosure of the equipment.

c) The cotton shall not ignite.

d) The 30-ampere fuse shall not open (see 45.4.1).

52.2 A sample of the equipment employing the printed wiring board is to be wired as intended to an electrical supply circuit sized and protected to simulate end-use conditions. When the live parts on the printed wiring board have spacings between them that are less than those specified in Tables 36.1 – 36.4, they are to be short-circuited one at a time.

52.3 During the test, cotton shall be placed at all openings, handles, flanges, joints, and similar locations on the outside of the drive enclosure. For open equipment, an enclosure judged representative of that encountered in service is able to be used. When agreeable to those concerned, tests are able to be conducted using a wire mesh cage 150 percent the size of the drive as representative of tests conducted using an enclosure.

52.4 The test is to be continued for 1 hour or until one of the conditions described in 52.1 occurs. However, when at the end of 1 hour no condition described in 52.1 occurs, and indications are that such a condition is able to eventually occur, the test is to be continued until ultimate results are obtained (usually 7 hours).

52.5 When the circuit is interrupted by the opening of a component, or of a Printed-Wiring Board (PWB) trace, the test is to be repeated until consistent results are observed.

Exception: When a component opens, the test is not required to be repeated when it is determined that the opening of the component is a repeatable result for that test. For example, when a component opens that is upstream of the short, then this component's opening reoccurs each time the same short is introduced. Therefore, in this example, the test is not required to be repeated due to the opening of this component.

53 Secondary Circuits Test

53.1 General

53.1.1 Unless otherwise specified, the test measurements are to be made as follows:

a) The primary voltage supplied to the isolating source shall be not less than specified in 39.3 for the Temperature Test. For an isolating source with multiple primary voltage ratings, the highest voltage rating shall be used for this test. Overcurrent protective devices in the branch circuit shall not open as a result of this test.

b) The maximum open circuit voltage potential available to the secondary circuit under consideration is to be measured directly across the output terminals of the isolating source; and

c) For an isolating source with multiple secondary circuits, only one secondary circuit is to be tested at a time. All other secondaries not under test are not required to be connected to a load.

d) The applicable voltage, current, and volt-ampere capacity measurements shall be made directly across the secondary output terminals of the isolating source. When a tapped transformer winding is used to supply a full-wave rectifier, the measurements are to be made from either end of the winding to the tap. When the transformer is used as part of a switching-type power supply, the measurements are to be made after the transformer secondary winding rectification means.

53.2 Limited voltage/current secondary test

53.2.1 With the isolating source connected as described in 53.1.1, the open circuit voltage of each secondary shall not exceed 30 Vrms or 42.4 V peak, and the available current in the secondary shall not exceed 8 amperes after the 1 minute test interval as described in 53.2.2.

53.2.2 The current available to the secondary circuit under evaluation is to be measured by connecting a variable resistive load across the source of that secondary and then constantly adjusting the load to maintain a secondary current that is slightly more than 8 amperes during the 1 minute test interval. When an available current of more than 8 amperes is not able to be obtained under any condition of loading, up to and including a short circuit, then the test is to be discontinued for that circuit.

53.3 Limited energy secondary test

53.3.1 With the isolating source connected as in 53.1.1, the open circuit voltage of the secondary shall not exceed 100 V, and the calculated volt-ampere capacity described in 53.3.2 shall not exceed 200 volt-amperes.

53.3.2 The maximum volt-ampere capacity available to the secondary circuit under consideration is to be measured by connecting a variable resistive load across the source of that secondary and then measuring the voltage and current while varying the resistive load from open-circuit to short circuit in 1-1/2 to 2-1/2 minutes. The maximum available volt-ampere capacity is then calculated by multiplying the simultaneously measured values of secondary voltage and secondary current.

53.4 Isolated power supply capacity test

53.4.1 With the isolating source connected as in 53.1.1, the open circuit voltage of the secondary shall not exceed 150 V and the calculated short circuit power described in 53.4.2 shall not exceed 10,000 volt-amperes.

53.4.2 The maximum short circuit power available to the secondary circuit under consideration is the product of the measured open circuit voltage and the measured maximum short circuit current of the isolating source with any protective devices bypassed.

53.5 Limited voltage secondary test

53.5.1 With the isolating source connected as in 53.1.1, an isolating source that is not provided with secondary overcurrent protection shall be subjected to the test described in 53.5.2. As a result of the test, there shall be no softening or discoloration of conductor insulation.

53.5.2 Each secondary circuit of the isolating source is operated with the secondary short circuited until ultimate conditions occur. The opening of an integral protective device or constant temperatures are indications of ultimate conditions.

53.6 Limiting impedance test

53.6.1 Limiting Impedance Abnormal Test

53.6.1.1 With the isolating source connected as described in 53.1.1, a circuit supplied by a limiting impedance shall not emit molten metal or flames or ignite cotton loosely placed over all openings of ventilated equipment or totally around open type equipment when the circuit connected to the load side of the limiting impedance is short circuited. Additional trials of this test shall be performed under single component fault conditions described in 53.6.1.3.

53.6.1.1 revised November 5, 2004

53.6.1.2 With the isolating source connected as described in 53.1.1, a circuit supplied by a limiting impedance relied upon to reduce the risk of an electric shock shall be connected to a 1500-ohm resistor between the load side of the limiting impedance and ground. The current measured through the 1500-ohm resistor shall not exceed 5 mA. Additional trials of this test shall be performed under single component fault conditions described in 53.6.1.3.

53.6.1.3 A single malfunction (short or open) of any circuit component, such as a resistor, capacitor, or solid-state device shall not result in a risk of electric shock and the available voltage and current shall not exceed the limits specified in Section 29, Risk of Electric Shock. For a discrete, multiple (more than two) terminal device, such as a transistor, SCR, triac, or similar device, any combination of terminals taken two at a time shall be open- or short-circuited. For an integrated circuit device, the following combinations of terminals shall be tested:

a) Each pair of adjacent terminals shorted;

b) Each input terminal shorted to (referenced) ground terminal;

c) Each output terminal shorted to (referenced) ground terminal;

d) Each input terminal shorted to each power supply;

e) Each output terminal shorted to each power supply; and

f) Each terminal open-circuited.

53.6.2 Limiting impedance 15 W determination, alternate method

53.6.2.1 As an alternate method of determining limiting impedance components, a circuit may be evaluated as described in 53.6.2.2. As a result of this evaluation, each component of the limiting impedance circuit identified as a primary circuit component shall be subjected to the Limiting Impedance Abnormal test in 53.6.1.

53.6.2.2 Starting at the input to the circuit, the maximum wattage available to the secondary circuit under consideration is to be measured by connecting a variable resistive load between the load side point of each component in line with the source and the supply return. The variable resistance is to be adjusted to a value which maintains a level of 15 watts as measured by a wattmeter. Each component capable of maintaining 15 watts or more for a period of 5 seconds is to be identified as a primary circuit component.

53A Strain Relief Test

53A.1 The device provided with a strain relief as in 27.6.2 shall withstand without damage to the cord or conductors and without displacement, a direct pull of 35 pounds (156 N) applied to the cord for 1 minute. Supply connections within the equipment are to be disconnected from terminals or splices during the test when applicable.

27.6.2 revised and separated into 27.6.2 and 53A.1 effective July 16, 2005

53A.2 A field wiring lead shall withstand without damage or displacement a direct pull of:

a) 20 pounds (90 N) for 1 minute applied to a lead extending from the enclosure such as through a hub or nipple; and

b) 10 pounds (44.5 N) for 1 minute applied to a lead within a wiring compartment or an outlet box.

Added 53A.2 effective July 16, 2005

53B Push-Back Relief Test

53B.1 To determine compliance with 27.6.5, a product shall be tested in accordance with 53B.2 without occurrence of any of the conditions specified in 27.6.5 (a) – (d).

Added 53B.1 effective July 16, 2005

53B.2 The supply cord or lead is to be held 1 inch (25.4 mm) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing which extends further than 1 inch is present it is to be removed prior to the test. When the bushing is an integral part of the cord, then the test is to be carried out by holding the bushing. The cord or lead is to be pushed back into the product in 1-inch (25.4-mm) increments until the cord buckles or the force to push the cord into the product exceed 6 pounds-force (26.7 N). The supply cord or lead within the product is to be manipulated to determine compliance with 27.6.5.

Added 53B.2 effective July 16, 2005

53C Leakage Current Test

53C.1 The leakage current of cord-and-plug-connected equipment rated for a nominal 120-, 208-, or 240-V supply when tested in accordance with 53C.3 – 53C.8 shall not be more than 3.5 mA for grounded, 3-wire, portable and stationary equipment employing a standard attachment plug rated 20 A, or less.

Added 53C.1 effective July 16, 2005

53C.2 Leakage current refers to all currents, including capacitively coupled currents, that may be conveyed between exposed conductive surfaces of the equipment and ground or other exposed surfaces of the equipment.

Added 53C.2 effective July 16, 2005

53C.3 All exposed conductive surfaces are to be tested for leakage currents. Leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one surface to another if simultaneously accessible. Parts are considered to be exposed surfaces unless they are guarded by an enclosure considered acceptable for protection against the risk of electric shock. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages that are not considered to involve a risk of electric shock. If all accessible surfaces are bonded together and connected to the grounding conductor of the power-supply cord, the leakage current can be measured between the grounding conductor and the grounded supply conductor. If exposed dead metal parts of the equipment are connected to the neutral supply conductor, this connection is to be open during the test.

Added 53C.3 effective July 16, 2005

53C.4 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 by 20 cm (4 by 8 inches) in contact with the surface. If the surface is less than 10 by 20 cm (4 by 8 inches), the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the equipment.

Added 53C.4 effective July 16, 2005

53C.5 The measurement circuit for leakage current for single phase equipment is to be as illustrated in Figure 53C.1. For 3-phase equipment, the leakage current shall be the sum of measurements from each phase to neutral. The measurement instrument is defined in (a) – (c). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument; it need not have all the attributes of the defined instrument.

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

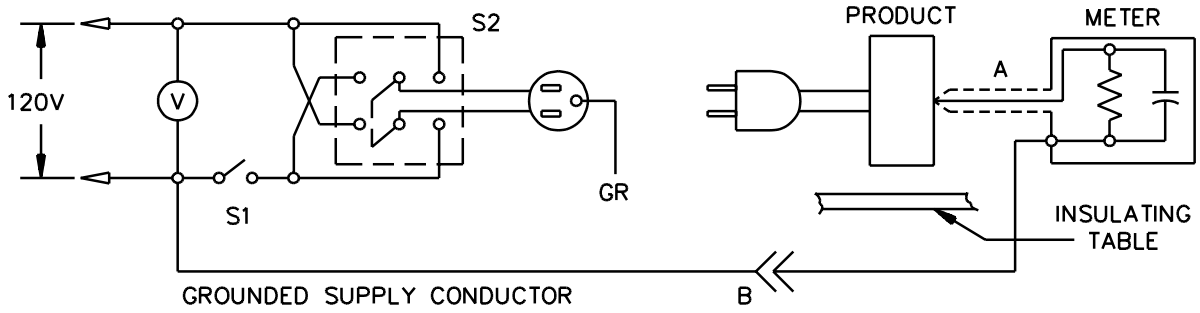
b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

c) Over a frequency range of 0 – 100 kHz, the measurement circuitry is to have a frequency response – ratio of indicated to actual value of current – that is equal to the ratio of the impedance of a 1500-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 3.5 mA, the measurement is to have an error of not more than 5 percent at 60 Hz.

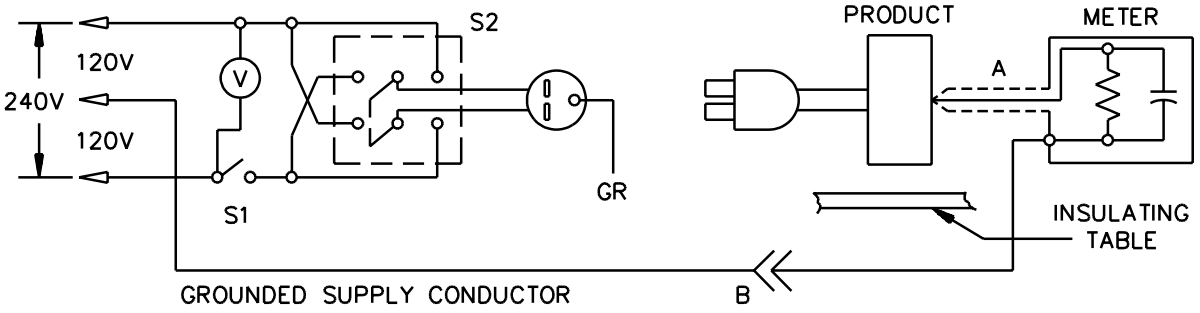
Added 53C.5 effective July 16, 2005

Figure 53C.1
Leakage-current measurement circuits

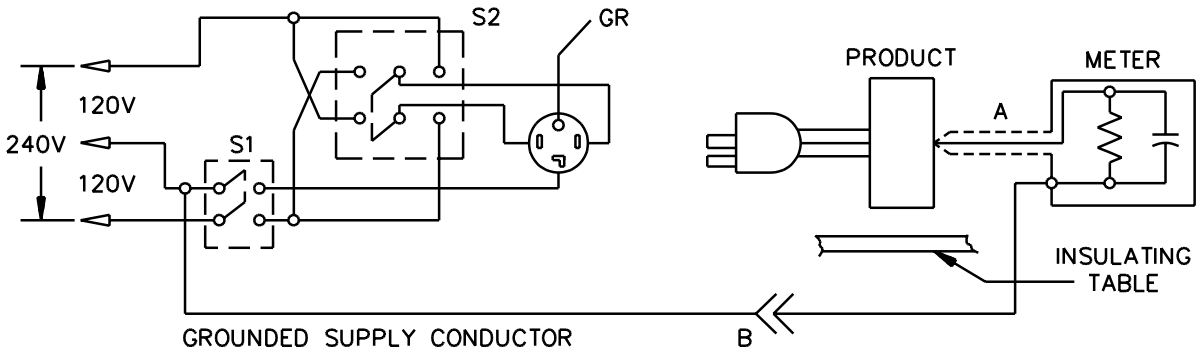
Added Figure 53C.1 effective July 16, 2005



Equipment intended for connection to a 120 V power supply, as illustrated above.



Equipment intended for connection to a 3–wire, grounded neutral power supply, as illustrated above.



Equipment intended for connection to a 3–wire, grounded neutral power supply, as in the 240 V example illustrated above.

A – Probe with shielded lead.

B – Separated and used as clip when measuring currents from one part of equipment to another.

LC100K

53C.6 Unless the meter is being used to measure leakage from one part of the equipment to another, the meter is to be connected between the accessible parts and the grounded supply conductor.

Added 53C.6 effective July 16, 2005

53C.7 A sample of the equipment is to be tested for leakage current starting with the as-received condition – as-received being without prior energization except as may occur as part of the production-line testing. The grounding conductor, if any, is to be open at the attachment plug. The supply voltage is to be in accordance with Table 39.2. The test sequence, with reference to the measuring circuit, Figure 53C.1, is to be as follows:

a) With switch S1 open, the equipment is to be connected to the measuring circuit. Leakage current is to be measured using both positions of switch S2, and with the equipment switching devices in all their normal operating positions.

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

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

Added 53C.7 effective July 16, 2005

53C.8 Normally a sample will be carried through the complete leakage-current-test programs described in 53C.7, without interruption for other tests. With the concurrence of those concerned, the Leakage Current Tests may be interrupted for the purpose of conducting other nondestructive tests.

Added 53C.8 effective July 16, 2005

54 Rating

54.1 Power conversion equipment shall be rated according to:

a) Input.

1) Voltage.

2) Full load current.

3) Number of phases.

4) Frequency.

b) Output.

1) Voltage.

2) Full load current or maximum horsepower.

3) Number of phases.

4) Base frequency and frequency range (applies only to alternating current outputs).

54.2 Equipment incorporating circuitry for motor field supply shall be rated in field voltage and maximum current capability of the supply.

54.3 When the equipment is intended for control of a range of motors, the input current rating is not prohibited from being expressed as a percentage of motor current rating.

54.4 Equipment which operates intermittently shall include a duty cycle rating.

54.5 Equipment shall be rated for service in an ambient temperature of 40°C (104°F) or at a higher or lower ambient temperature at an interval from 40°C (104°F) in a whole number multiple of ±5°C (9°F), such as 45, 50, 55, 60.

DEVICE MARKING

55 General

55.1 Power conversion equipment shall be plainly marked with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is identifiable – hereinafter referred to as the manufacturer's name;

b) The electrical rating per Section 54, Rating;

c) The catalog number or equivalent;

d) The type of refrigerant for operation if the equipment is intended to employ refrigerant;

e) The design pressure if intended for use with a liquid or gas medium; and

f) The enclosure type rating for enclosed equipment.

55.1 effective March 21, 2004

55.2 When the manufacturer produces or assembles power conversion equipment at more than one factory, each finished item of equipment shall have a distinctive marking, by which it is identifiable as the product of a particular factory.

55.3 For equipment intended for use in various applications that require different wiring arrangements with corresponding different capabilities, the information in 55.1 is not prohibited from being provided in literature supplied with the equipment when the equipment is marked: ″Multiple rated equipment. See instruction manual. ″ or with an equivalent statement.

55.4 The optional marking, ″Suitable for Installation in a Compartment Handling Conditioned Air″ shall only be marked on power conversion equipment that has been evaluated in accordance with requirements for plenum rated drives.

55.5 Power conversion equipment intended for use in an ambient other than 40°C shall be marked to indicate the end use ambient. See 40.2. Equipment shall be rated for service in an ambient temperature of 40°C (104°F), or at a higher or lower ambient temperature at an interval from 40°C (104°F) in a whole number multiple of ±5°C (9°F), such as 45, 50, 55, 60.

55.6 Power conversion equipment evaluated in accordance with 39.6 shall be marked ″Maximum Surrounding Air Temperature __°C″.

55.7 When required by 27.6.1.3, cord-connected equipment shall be marked with the voltage and ampere rating of the required overcurrent protection.

Added 55.7 effective July 16, 2005

55.8 Where marking or information is provided in accordance with location designation ″H″ as noted in the footnote section of Table 63.1, the following marking or equivalent is provided on the device or on an information sheet provided with the equipment, ″WARNING – Operation of this equipment requires detailed installation and operation instructions provided in the Installation/Operation manual intended for use with this product. This information is provided on the CD ROM, floppy diskette(s), or other storage device included in the container this device was packaged in. It should be retained with this device at all times. A hard copy of this information may be ordered at ___-___-____", where the manufacturer's phone number is provided.

55.8 added November 5, 2004

56 Overload, Over-Current, and Over-Speed Protection

56.1 Equipment incorporating internal overload protection for the motor load and not required to be used with external or remote overload protection shall be marked to indicate the degree of protection provided. The marking shall indicate protection level in percent of full-load current. When the protection level is adjustable, the marking shall be provided with instructions for adjustment, or make reference to the manual for adjustment instructions. Equipment not incorporating internal overload protection for the motor load and intended to be used with external or remote overload protection shall be marked to indicate that such protection must be provided.

56.2 Equipment intended to be used with motors that have thermal protectors in or on the motors shall be marked to indicate that the motors must have integral thermal protection and identify the proper connection and the rating of the load imposed by the equipment on the protector contacts. The rating shall be in volts and amperes except it shall be in volts and volt-amperes when the load is electromagnetic. The marking shall also indicate alternating or direct current.

56.3 Equipment employing ventilation in accordance with 6.10.1, 6.10.3, 6.10.4, and 6.10.5 shall be marked to indicate the specific size, catalog number, and manufacturer for replacement fuses. The equipment shall be marked to indicate at least one type fuse intended for the application.

56.4 Equipment required to be connected to a supply source with a specific overcurrent protective device as referenced in 41.6.1 shall be marked to indicate the required protective device.

56.5 Deleted July 16, 2003

57 Branch Circuit Short Circuit Protection

57.1 Power conversion equipment rated more than 1 horsepower (746 W output), shall be marked ″Suitable For Use On A Circuit Capable Of Delivering Not More Than _____ rms Symmetrical Amperes, _____ Volts Maximum. ″ The ampere rating is not to be more than the value for which the controller was tested in accordance with 45.1.8 or Table 45.1. When tested in accordance with 47.1, the marking shall also include the following or the equivalent:

a) ″When Protected by _____ Class Fuses,″ or

b) ″When Protected By A Circuit Breaker Having An Interrupting Rating Not Less Than _____ rms Symmetrical Amperes, _____ Volts Maximum.″

57.2 Power conversion equipment provided with solid state short circuit protection in accordance with 45.1.3 shall be marked “Integral solid state short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electrical Code and any additional local codes”, or the equivalent.

57.2 added November 5, 2004

58 Control Circuit Protection

58.1 In accordance with Exception No. 4 of 20.2.1, when the additional wiring protection is not required due to the rating or trip setting of an instantaneous trip circuit breaker used as the branch circuit short circuit protection, then the drive shall be provided with a marking or instructions indicating the maximum wiring protective device size required by Table 20.1.

58.2 Regarding the requirement in 20.2.2(f), when a supplementary fuse is being relied upon for compliance with this requirement, then a replacement marking or instructions shall be provided that includes the voltage and current rating of the fuse.

58.3 In accordance with Exception No. 1 of 20.2.2, when a field installed accessory kit is being relied upon to provide the additional wiring protection, then the drive shall be provided with a marking or instructions to identify this kit.

58.4 Regarding the requirement in 20.2.3, when a fuse (other than supplementary) is being relied upon to provide the additional wiring protection and when the fuse-holder accepts a fuse having a higher current rating than required by 20.2.3, then the drive shall be provided with a marking or instructions identifying the maximum fuse size.

59 Class 2 Circuit Markings

59.1 A Class 2 power source shall be durably marked where visible after installation to indicate the class of supply and its electrical rating.

59.2 A Class 2 power source not evaluated for use in wet locations shall be marked ″Not for use in wet locations ″ or the equivalent.

59.3 A secondary circuit intended to be supplied from a Class 2 transformer or power source in the field shall be marked ″Class 2″ next to the voltage rating of the device (for example, 30Vac, Class 2), or the equivalent.

59.4 A secondary circuit evaluated to the requirements in Exception No. 1 of 32.3.3 or 32.4.1 shall be provided with installation instructions that specify the use of the isolating source and ratings of the overcurrent protective devices required to be installed in the field.

60 Wiring Terminal Markings

60.1 Wiring terminals shall be marked to indicate the proper connections for the power supply, load, control circuit, and similar devices, or a wiring diagram coded to the terminal marking shall be securely attached to the equipment.

Exception No. 1: The terminals are not required to be marked when the wire connections are plainly evident, as for a 2-terminal switching device.

Exception No. 2: A wiring diagram with multiple circuit arrangements is able to be provided loose or in an envelope when the nameplate or similar permanent attachment visible after installation references the wiring diagram, for example, by number. For open-type equipment, the wiring diagram is not prohibited from being furnished loose with the equipment.

60.2 A terminal for the connection of a grounded supply circuit conductor shall be identified by means of a metallic plated coating substantially white in color and shall be readily distinguishable from the other terminals, or proper identification of the terminal for the connection of the grounded supply circuit conductor shall be clearly shown in some other manner, such as on an attached wiring diagram. When wire leads are provided, the lead intended to be connected to a grounded supply circuit shall have a white or gray color and shall be readily distinguishable from other leads.

60.2 revised November 5, 2004

60.3 A single white terminal – in other than a single-pole device – for the connection of an ungrounded conductor shall not be provided, however, two or more white terminals may be provided when:

a) It does not make any difference how line connections are made;

b) It is obvious which terminal is intended for the connection of the grounded conductor; or

c) The line connections are plainly indicated on a wiring diagram.

60.4 When low-voltage equipment or a part of low-voltage equipment is intended to be wired in the field to become only part of:

a) A Class 1 circuit; or

b) A Class 2 circuit wired with Class 1 wire;

The terminals of the equipment or part of the equipment shall be marked accordingly. Low-voltage switching or power-consuming equipment or a part of equipment that is intended to be wired in the field to become part of a Class 2 circuit only shall be marked accordingly.

Exception No. 1: A low-voltage power-supply device that includes a transformer is not required to be marked to indicate that it is acceptable for use in a Class 2 circuit only.

Exception No. 2: Low-voltage equipment or a part of equipment that is intended for connection to either a Class 1 or a Class 2 circuit is not required to be so marked.

60.5 Equipment incorporating two or more separate circuits that are capable of being connected to separate power supplies and that are intended to be connected to a common power supply shall be marked ″All circuits must have a common disconnect and be connected to the same pole of the disconnect,″ or with an equivalent wording. The wiring diagram of the equipment shall illustrate a typical connection of the various circuits connected to the common power supply.

60.6 Equipment employing a special fitting for the connection to a specific wiring system shall be marked to indicate that it must be installed with such a wiring system.

60.7 Equipment that is intended for installation with a nonmetal-enclosed wiring system only shall be marked to indicate that it must be installed with such a wiring system.

60.8 Equipment having field-wiring terminals shall be marked:

a) ″Use Copper Conductors Only ″ when the terminal is intended only for connection to copper wire.

b) ″Use Aluminum Conductors Only ″ when the terminal is intended only for connection to aluminum wire.

c) ″Use Copper or Aluminum Conductors ″ or ″Use Copper, Copper-Clad Aluminum, or Aluminum Conductors ″ when the terminal is intended for connection to either copper or aluminum wire.

d) ″USE COPPER-CLAD ALUMINUM OR COPPER CONDUCTORS ″ when the terminal is intended for connection to either copper or copper-clad aluminum wire.

Exception: A field-wiring terminal is not required to be marked with a wire type when it is intended for the connection of a copper control circuit conductor only.

60.9 A wiring terminal that is not intended to receive a conductor one size larger than that specified in 27.5.1 shall be marked to restrict its use to the smaller size conductor.

60.10 When leads, wire binding screws, or pressure wire connectors are not provided on the equipment as shipped, the equipment shall be marked stating which pressure wire connector or component terminal kits are intended for use with the equipment. A wire connector of the type specified in the marking is able to be installed in the equipment at the factory with instructions, when required to effect proper connection of the conductor. A terminal kit shall carry an identifying marking, wire size, and manufacturer's name or trademark.

60.11 With reference to 27.5.8, equipment shall be marked to show a range of values or a nominal value of tightening torque in pound-inches to be applied to the clamping screws of all terminal connectors for field wiring. The marking is able to be located adjacent to the terminal or on the wiring diagram.

60.12 Power conversion equipment shall be marked to indicate the temperature rating (60°C only, 60/75 or 75°C only) of the field installed conductors for which the equipment has been investigated.

Exception: A field-wiring terminal is not required to be marked to indicate the temperature rating when it is intended for the connection of a control circuit conductor only.

61 Cautionary Markings

61.1 Cautionary markings shall be located on a part that is not removable without impairing the operation or appearance of the equipment.

61.2 A cautionary marking shall be prefixed with the word ″CAUTION ″ or ″WARNING,″ as applicable, in letters not less than 1/8 inch (3.2 mm) high. The remaining letters of such marking, unless specified otherwise in individual marking requirements, shall not be less than 1/16 inch (1.6 mm) high.

61.3 A cautionary marking intended to instruct the operator shall be legible and visible to the operator during normal operation of the equipment. A marking that provides servicing instructions shall be legible and visible when such servicing is being performed.

61.4 When more than one disconnect switch is required to disconnect all power within a control assembly or compartment, the assembly or compartment shall be marked with the word ″CAUTION″ and the following or the equivalent, ″Risk of Electric Shock – More than one disconnect switch is required to de-energize the equipment before servicing.″

61.5 The marking required by 61.4 shall be in a permanent location on the outside of the equipment or on a stationary fixed, nonremovable part inside the equipment. The warning marking shall not be placed inside the cover or on the connection diagram attached to the inside of a cover.

61.6 A live heat sink or other part mistaken as dead metal and exposed to persons shall be marked with the word ″CAUTION″ and the following or equivalent, ″Risk of Electric Shock – Plates (or other word describing the type of part) are live – Disconnect Power Supply Before Servicing.″ The marking shall be located on the live part.

61.7 The marking required for enclosures that are intended for field assembly of the bonding means in accordance with 6.6.1 shall:

a) Be located where visible during installation, such as inside the cover; and

b) Consist of the word ″CAUTION″ and the following or the equivalent, ″Bonding between conduit connections is not automatic and must be provided as a part of the installation″; or the word ″CAUTION″ and the following or equivalent, ″Nonmetallic enclosure does not provide grounding between conduit connection. Use grounding bushings and jumper wires.″

61.8 Power conversion equipment intended for use on circuits having high available fault currents as indicated in 47.1 shall be marked with the word ″WARNING″ and the following or equivalent, ″The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. To reduce the risk of fire or electric shock, current-carrying parts and other components of the controller should be examined and replaced if damaged. If burnout of the current element of an overload relay occurs, the complete overload relay must be replaced.″

61.9 A control with direct-current motor ratings that does not comply with the requirements in 27.5.1 shall be marked with the word ″WARNING″ and the following or the equivalent, ″Do not connect to a circuit supplied by a single-phase, half-wave rectifier″; and a control that does not comply with the requirements in 27.5.1 shall be marked with the word ″WARNING″ and the following or the equivalent, ″Do not connect to a circuit supplied by a single-phase rectifier of the half-wave or full-wave type.″

61.10 All enclosure surfaces subject to casual contact and in excess of the maximum temperatures specified in Table 40.2 shall be marked ″WARNING″ and the following or equivalent: ″Hot Surface – Risk of Burn″.

62 Instructions and Markings Pertaining to Accessories

62.1 The equipment markings shall include identification of an accessory to be attached in the field, or a reference to a separate publication that identifies all such accessories. For equipment such as an open device for which the required marking is on a separate sheet, the accessory information is also capable of being on the separate sheet.

Exception: When a new accessory has been designed for an existing product, the accessory shall be marked with the identification of the equipment on which it is intended to be used.

62.2 An accessory that is not shipped from the factory in the same carton as the equipment with which it is intended to be used shall be plainly marked with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is identifiable;

b) The electrical rating; and

c) The catalog number or equivalent.

Exception: The electrical rating of the accessory is not required to be on the accessory when the accessory electrical rating is marked on the equipment for which it is intended.

62.3 An accessory shall be provided with installation and wiring instructions.

62.4 When an overload-protective device is provided within an enclosure that does not have a hinged cover, and a kit is available for resetting the device from outside the enclosure, in accordance with 6.4.2(c), the kit number shall be marked on the enclosure or in the installation instructions.

63 Marking Location

63.1 The required markings and the location for enclosed Power Conversion Equipment and open Power Conversion Equipment shall be in accordance with Table 63.1. The markings noted in Table 63.1 are a brief summary of the marking requirements given elsewhere in this Standard. For complete details on the required marking, see the marking reference specified in Table 63.1.

Table 63.1
Marking location for power conversion equipment

Table 63.1 revised November 5, 2004

Marking reference	Required marking[a]	Location[b]	
		Enclosed	Open
	General		
55.1	Manufacturers name, trademark, or identifier, electrical rating, catalog number or equivalent	B	D
55.2	Marking for more than one factory	E	E
55.3	Markings in accordance with 55.1	B	F
		H	H
	Exception: Use in various applications		
55.4	Marking indicating a compartment handling conditioned air	H	–
55.5	Ambient temperature	H	H
55.6	Surrounding air temperature	H	H
55.8	Installation/instruction manual and additional markings required in this table designated as ″H″, when provided in electronic format.	G	G
	Overload, Over-current, and over-speed protection		
56.1	Degree of protection level	B or H	F or H
56.2	Equipment used with motors having thermal protectors	B or H	F or H
56.3	Equipment employing ventilation in accordance with 6.10.1, 6.10.3, 6.10.4 and 6.10.5	B or H	F or H
56.4	Equipment connected to supply source with specific overcurrent protective device as referred in 41.6.1	B or H	F or H
	Branch circuit short circuit protection		
57.1	Short circuit rating and fuse type/circuit breaker and size	B or H	F or H
57.2	Power conversion equipment provided with solid state short circuit protection in accordance with 45.1.3	B or H	F or H
	Control circuit protection		
58.1	By instantaneous trip circuit breaker in accordance with Exception No. 4 of 20.2.1	B or H	F or H
58.2	By supplementary fuse in accordance with 20.2.2(f)	B or H	F or H
58.3	By field installed accessory kit in accordance with Exception No. 1 of 20.2.2	B or H	F or H
58.4	By non-supplementary fuse in accordance with 20.1.4	B or H	F or H
	Wiring terminal markings		
60.1	Marking for proper connections	H	H
		–	–
	Exception No. 1: Marking not required for wire connections plainly evident		
		B	H
	Exception No. 2: Wiring diagram with multiple circuit arrangements		
60.2, 60.3	Terminal connection of ground supply conductor	H	H
60.4	Marking for low voltage wiring	H	H

Table 63.1 Continued on Next Page

Table 63.1 Continued

Marking reference	Required marking[a]	Location[b]	
		Enclosed	Open
60.5	Circuits capable of being connected to separate supplies and intended to be connected to common supply	H	H
60.6	Equipment with special fitting for connection	H	H
60.7	Equipment that is intended for nonmetal-enclosed wiring system	H	H
60.8	Field wiring terminal marking for wire type (Al, Cu)	H	H
		–	–
	Exception: Marking not required when intended for connection to copper control circuit conductors		
60.9	Field wiring terminal not intended to receive conductor one size larger per 27.5.1	H	H
60.10	Marking for providing terminals separately in terminal kit	H	H
60.11	Torque values marking for field terminals per 27.5.8	H	H
		–	–
	Exception: Marking not required when field terminal connected to control circuit conductor when investigated for 7 lb-in.		
37.4	Field ground terminal identification	B	–
	Enclosure markings		
13.1	Environmental type rating	B	–
13.2	Type 4x indoor use only	B	–
	Cautionary markings		
61.1	Placement of cautionary markings	B	B or F
61.3	Instructing operator or servicing instructions	B	B or F
61.4, 61.5	Provided with more than one disconnect means	A	–
61.6	Marking for live heat sink or other live parts which appears to be grounded dead metal	C	C
61.7	For enclosures that are intended for field assembly of the bonding means in accordance with 6.6.1	H	H
61.8	Marking for motor controllers having indication that high available fault current interrupted	B	B or F
61.9	Control with direct-current motor ratings that does not comply with 27.5.1	H	H
61.10	Marking for accessible parts of enclosure subject to casual contact	A	B
21.3	Capacitor terminals in accordance with Exception to 21.3	B	B or F
	Instructions and markings pertaining to accessories		
62.1	Accessories	I	I
		I	I
	Exception: New accessory on existing product		
62.2	Accessories	J	J
		B	D
	Exception: Rating of accessory		
62.3	Accessories provided with instructions	H	H
62.4	Kit available for overload protection device in accordance with 6.4.2(c)	H	H

Table 63.1 Continued on Next Page

Table 63.1 Continued

Marking reference	Required marking[a]	Location[b]	
		Enclosed	Open

[a] These are a brief summary of marking requirements. For complete details see the specific Marking Reference.

[b] For marking locations identified below, ″A″ is the highest order of location, and ″J″ is the lowest order of location. At the option of the manufacturer, a higher order of location category is able to be used.

A. Marking shall be visible when the enclosure cover is on and the door is closed.

B. Marking shall be visible:

1. When the enclosure cover is removed or the door is open;

2. When other devices are mounted nearby as intended; and

3. When devices are installed side by side with intended clearances.

The marking shall not be obscured by attachments such as a disconnect switch operating handle.

C. Marking is on live parts which appear to be grounded.

D. Marking is visible when the device is mounted singularly. The marking is able to be on the side of the device, and is not required to be visible when the device is mounted next to other devices.

E. Marking is able to be anywhere on the device and is not required to be visible after installation.

F. Marking is on a separable, self-adhesive permanent label that is shipped with the device. For a device that is installed in an enclosure, the marking shall be on the inside of the enclosure.

G. Marking is on device or separate sheet provided with device.

H. Marking is on wiring diagram or instructional manual shipped with the device or provided in electronic read-only digital media format, such as a CD ROM, diskette, or other media, provided with the device.

I. Marking is provided on a separate sheet which is available from the manufacturer, and not necessarily shipped with the product.

J. Marking is shipped separately with kit.

MANUFACTURING AND PRODUCTION LINE TEST

64 Circuit Functionality Evaluation

64.1 Prior to being shipped from the manufacturing facility, all solid state short circuit and motor overload protection circuitry shall be subjected to a procedure involving:

a) Identification of early production faults; and

b) Verification of functionality.

Exception: Solid state short circuit or motor overload protection circuitry that is not required for compliance with 20.1.1 or 20.1.3 is not required to be subjected to this procedure.

64.2 This identification and verification procedure is able to involve:

a) In-coming component screening;

b) A burn-in method that varies in conditions (such as duration, temperature, and similar conditions) throughout the design stages of the circuitry; or

c) Diagnostic test.

64.3 The specific identification and verification procedure used is able to necessitate that some aspects of this procedure be conducted on 100 percent of the applicable solid state short circuit or motor overload protection circuitry.

64A Production-Line Dielectric Voltage-Withstand Test

64A.1 Equipment provided with a power-supply cord with an attachment plug for connection to a nominal 120 V or higher voltage circuit shall withstand without electrical breakdown, as a routine production-line test, the application of an alternating-current potential at a frequency within the range of 40 – 70 Hz or a direct-current potential between the primary wiring, including connected components, and accessible dead metal parts that are likely to become energized.

Added 64A.1 effective July 16, 2005

64A.2 The production-line test shall be in accordance with either Condition A or B of Table 64A.1.

Added 64A.2 effective July 16, 2005

Table 64A.1
Production-line test conditions

Added Table 64A.1 effective July 16, 2005

Equipment rating, volts	Condition A			Condition B		
	Potential, volts ac	Potential, volts dc	Time, seconds	Potential, volts ac	Potential, volts dc	Time, seconds
250 or less	1000+2V [a]	1400	60	1200+2V [a]	1700	1
More than 250	1000+2V [a]	1400+2.8V [a]	60	1200+2.4V [a]	1700+3.4V [a]	1

[a] Maximum marked voltage.

64A.3 The test potential is able to be gradually increased to the required value but the full value is to be applied for 1 second or 1 minute as required.

Added 64A.3 effective July 16, 2005

64A.4 The equipment is able to be at normal operating temperature, at room temperature, or at any intermediate temperature for the test.

Added 64A.4 effective July 16, 2005

64A.5 The test shall be conducted when the equipment is fully assembled. It is not intended that the equipment be unwired, modified, or disassembled for the test.

a) A part, such as a snap cover or friction-fit knob, that would interfere with performance of the test need not be in place.

b) The test is able to be performed before final assembly if the test represents that for the completed equipment. Any component not included shall not affect the results with respect to determination of possible risk of electric shock resulting from miswiring, defective component, insufficient spacings, and the like.

Added 64A.5 effective July 16, 2005

64A.6 Solid-state and similar components that might be damaged by a secondary effect of the test are able to be short-circuited by means of a temporary electrical jumper or the test is able to be conducted without the component electrically connected, providing the wiring and terminal spacings are maintained.

Added 64A.6 effective July 16, 2005

64A.7 The test equipment shall have a means of indicating the test potential, an audible or visual indicator of electrical breakdown, and, for automated or station-type operations, either a manually reset device to restore the equipment after electrical breakdown or an automatic-reject feature for any unacceptable unit. When an alternating-current test potential is applied, the test equipment shall include a transformer having an essentially sinusoidal output.

Added 64A.7 effective July 16, 2005

64A.8 When the test equipment is adjusted to produce the specified voltage, and a resistance of 120,000 ohms is connected across the output, the test equipment is to indicate an unacceptable performance within 0.5 second. A resistance of more than 120,000 ohms is able to be used to produce an indication of unacceptable performance when the manufacturer elects to use a tester having higher sensitivity.

Added 64A.8 effective July 16, 2005

64A.9 When the rated output of the test equipment is less than 500 VA, the equipment shall include a voltmeter in the output circuit to directly indicate the applied test potential.

Added 64A.9 effective July 16, 2005

64A.10 When the rated output of the test equipment is 500 VA or more, the test potential is able to be indicated by:

a) A voltmeter in the primary circuit or in a tertiary winding circuit;

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

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

If an indicating voltmeter is not used, the test equipment shall include a visual means, such as an indicator lamp, to indicate that the test voltage is present at the test-equipment output.

Added 64A.10 effective July 16, 2005

64A.11 Test equipment other than that described by 64A.7 – 64A.10 is able to be used if found to accomplish the intended factory control.

Added 64A.11 effective July 16, 2005

64A.12 For the test, either a sufficient number of control devices are to be closed or separate applications of the test potential made so that all parts of the primary circuit are tested.

Added 64A.12 effective July 16, 2005

64B Production-Line Grounding-Continuity Test

64B.1 Equipment that has a power-supply cord with an attachment plug shall be tested, as a routine production-line test, to determine that grounding continuity is provided between the grounding blade or pin of the attachment plug and the accessible dead metal parts that are likely to become energized.

Added 64B.1 effective July 16, 2005

64B.2 Only a single test need be conducted if the accessible metal selected is conductively connected to all other accessible metal.

Added 64B.2 effective July 16, 2005

64B.3 Any indicating device (an ohmmeter, a battery and buzzer combination, or the like) is able to be used to determine compliance with the grounding continuity requirement.

Added 64B.3 effective July 16, 2005

64C Production-Line Polarization-Continuity Test – Cord and Plug Connected Equipment

64C.1 Equipment provided with an attachment plug shall maintain electrical continuity between the grounding blade of the attachment plug and all accessible parts and shall be verified as a routine production-line test. The continuity shall be determined either visually or through the use of an electrical test.

Added 64C.1 effective July 16, 2005

COOLING SYSTEMS

65 General

65.1 These requirements cover cooling systems other than convection or forced air, for power conversion equipment. These requirements supplement the requirements in Sections 6 – 63.

65.1 effective March 21, 2004

66 Construction

66.1 The cooling medium used in a cooling system shall be water, glycol, a mixture of water and glycol, oil, or other refrigerants investigated for the purpose. The temperature of the cooling medium shall not exceed the limits in Table 40.1 during normal operation.

66.2 All tubing, tanks, and other cooling system components intergral to or included with the drive shall be constructed of corrosion resistant material and shall be suitable for use with the cooling medium.

66.2 effective March 21, 2004

66.3 Tubing used to connect refrigerant-containing components shall comply with the minimum wall thickness requirements of Table 66.1 and with the Hydrostatic Pressure Test requirements of 67.2.

66.3 effective March 21, 2004

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Table 66.1
Tubing wall thickness

Table 66.1 effective March 21, 2004

Outside diameter		Minimum wall thickness,[a] mm (inch)					
		Copper				Steel	
		Protected		Unprotected			
mm	(inch)						
6.35	(1/4)	0.62	(0.0245)	0.67	(0.0265)	0.64	(0.025)
7.94	(5/16)	0.62	(0.0245)	0.72	(0.0285)	0.64	(0.025)
9.53	(3/8)	0.62	(0.0245)	0.72	(0.0285)	0.64	(0.025)
12.70	(1/2)	0.62	(0.0245)	0.72	(0.0285)	0.64	(0.025)
15.88	(5/8)	0.80	(0.0315)	0.80	(0.0315)	0.81	(0.025)
19.05	(3/4)	0.80	(0.0315)	0.98	(0.0385)	0.81	(0.032)
22.23	(7/8)	1.04	(0.0410)	1.04	(0.0410)	1.17	(0.032)
25.40	(1)	1.17	(0.0460)	1.17	(0.0460)	1.17	(0.046)
28.58	(1-1/8)	1.17	(0.0460)	1.17	(0.0460)	1.17	(0.046)
31.75	(1-1/4)	1.28	(0.0505)	1.28	(0.0505)	1.17	(0.046)
34.93	(1-3/8)	1.28	(0.0505)	1.28	(0.0505)	1.58	(0.046)
38.10	(1-1/2)	1.41	(0.0555)	1.41	(0.0555)	1.58	(0.062)
41.3	(1-5/8)	1.410	(0.0555)	1.410	(0.0555)	–	(0.062)
54.0	(2-1/8)	1.626	(0.0640)	1.626	(0.0640)	–	–
66.7	(2-5/8)	1.880	(0.0740)	1.880	(0.0740)	–	–

[a] Nominal wall thickness of tubing will have to be greater than the thickness indicated to maintain the minimum wall thickness.

Note: *"Protected" implies that the tubing is shielded by the cabinet or assembly, to the extent that unintended damage caused by objects such as tools falling on or otherwise striking the tubing during handling and after installation of the unit, is prevented. This protection may be provided in the form of baffles, channels, flanges, perforated metal, or equivalent means. If a cabinet is employed for the intended installation of a unit, the tubing is considered shielded. Tubing not so shielded is considered to be unprotected.*

66.4 If a means for relieving pressure from the cooling system is provided as part of the power conversion equipment, it shall be investigated for the purpose in accordance with 67.2.

66.4 effective March 21, 2004

66.5 When normal operation of the cooling system results in expected condensation inside the power conversion equipment, the spacings of the equipment shall be evaluated for a Pollution Degree 3 environment (see 2.8). The possibility of accumulation of water due to condensation and a means for its exit from the enclosure shall be determined.

66.5 effective March 21, 2004

66.6 There shall be no leakage of the cooling medium onto live parts as a result of:

a) Normal operation, including expected condensation;

b) Servicing of the equipment; or

c) Loosening or detachment of hoses or other cooling system parts over time.

66.6 effective March 21, 2004

67 Performance

67.1 Loss of cooling medium circulation test

67.1.1 Following the Temperature Test of Section 40, one sample of the power conversion equipment is to be connected to its rated source of supply and operated as intended. The cooling medium flow is to be suspended by either blocking the coolant flow or disabling the coolant pump motor, if provided.

67.1.1 effective March 21, 2004

67.1.2 Completion of this test is achieved when the following occurs:

a) Thermal stabilization occurs;

b) A protective device opens; or

c) An internal component opens or shorts.

In all cases, there shall be no evidence of a risk of fire or electric shock. The fuse specified in 67.1.3 shall not open and the surgical cotton specified in 45.7.1 shall not glow or flame.

67.1.2 effective March 21, 2004

67.1.3 To assess the risk of electric shock, the outer enclosure (when provided) and grounded or exposed dead metal parts are to be connected through a 30-ampere fuse to the supply circuit pole least at risk of arcing to ground. For grounded control circuits, the enclosure and grounded or exposed dead metal parts are to be connected through the 30-ampere fuse to ground. To assess the risk of fire, the procedures specified in 45.5.1 – 45.7.1 are to be followed.

67.1.3 effective March 21, 2004

67.1.4 The Dielectric Voltage-Withstand Test of Section 44 shall be performed after completion of the test.

67.1.4 effective March 21, 2004

67.2 Hydrostatic pressure test

67.2.1 One sample of the power conversion equipment is to have water or other required liquid injected into the coolant loop. The pressure is to be increased at a steady rate until the pressure relief means, if provided, opens or a pressure of five times the rated maximum pressure rating marked on the equipment is attained. For equipment not provided with an integral pressure relief means, the pressure attained during this test shall be maintained for one minute.

67.2.1 effective March 21, 2004

67.2.2 There shall be no risk of fire, electric shock, or injury to persons indicated as a result of the test. For equipment provided with integral pressure relief means, there shall be no leakage of the coolant into the electrical compartment. For equipment not provided with integral pressure relief means there shall be no leakage of the coolant.

67.2.2 effective March 21, 2004

67.2.3 After the test, the Dielectric Voltage-Withstand Test of Section 44 shall be performed.

68 Plenum Rated Drives

68.1 Drives intended for use in air handling ducts and plenums shall be of the enclosed type and shall comply with the requirements in Sections 4 – 68.

68.2 Enclosure surfaces which are exposed in a compartment handling conditioned air for circulation through a duct system shall have a flame spread rating of not more than 25, and a smoke developed rating of not more than 50, when tested as specified in Surface Burning Characteristics of Building Materials and Assemblies, CAN/ULC-S102, and in the Standard for Test for Surface Burning Characteristics of Building Materials, UL 723. This requirement does not apply to the following:

a) Air filters, drive belts, wire insulation, paint applied for corrosion protection, or tubing of material equivalent to one of the types of wire insulation permitted by this Standard;

b) Gaskets forming air or water seals between metal parts;

c) Miscellaneous small parts such as refrigerant line bushings or insulating bushings, resilient or vibration mounts, wire ties, clamps, labels, or drain line fittings having a total exposed surface area not exceeding 25 square inches (161.29 cm^2);

d) An adhesive that, when tested in combination with the specific insulating material, complies with the requirement;

e) Moulded or formed components (not liners) of polymeric materials in such quantities that their total exposed surface area within the compartment does not exceed 10 square feet (0.93 m^2); or

Exception: Polymeric materials shall have a flame spread rating of not more than 25, or shall comply with the requirements of the vertical burning test for classifying materials 5V in accordance with Tests for Flammability of Plastic Materials in Devices and Appliances, UL 94, and Test 5V (500 W) of Evaluation of Properties of Polymeric Materials, CAN/CSA-C22.2 No. 0.17 with a flammability rating of 5VA.

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APPENDIX A

Standards for Components

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

Title of Standard − UL Standard Designation

Batteries, Lithium – UL 1642
Capacitors – UL 810
Electrical Analog Instruments – Panel Board Types – UL 1437
Electrical Equipment, Organic Coatings for Steel Enclosures for Outdoor Use – UL 1332
Electrical Wires, Cables, and Flexible Cords, Reference Standard for – UL 1581
Enclosure for Electrical Equipment – UL 50
Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors – UL 486E
Fittings for Cable and Conduit – UL 514B
Fuseholders – UL 512
Fuses, Class R – UL 248-12
Fuses, Low-Voltage – UL 248-1
Fuses, Plug – UL 248-11
Fuses, Supplemental – UL 248-14
Industrial Control Equipment – UL 508
Industrial Control Equipment for Use in Hazardous (Classified) Locations – UL 698
Information Technology Equipment, Safety of – UL 1950
Insulation Coordination Including Clearances and Creepage Distance for Electrical Equipment – UL 840
Marking and Labeling Systems – UL 969
Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures – UL 489
Optical Isolators – 1577
Plastic Materials for Parts in Devices and Appliances, Tests for Flammability of – UL 94
Power Units, Class 2 – UL 1310
Polymeric Materials – Long Term Property Evaluations – UL 746B
Polymeric Materials – Short Term Property Evaluations – UL 746A
Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C
Power Units Other Than Class 2 – UL 1012
Printed-Wiring Boards – UL 796
Protectors, Supplementary, for Use in Electrical Equipment – UL 1077
Semiconductor Devices, Electrically Isolated – UL 1557
Service Equipment – UL 869A
Speed Controls, Solid-State Fans – UL 1917
Switches, Clock-Operated – UL 917
Switches, Enclosed and Dead-Front – UL 98
Switches, Molded Case – UL 1087
Systems of Insulating Materials – General – UL 1446
Temperature-Indicating and -Regulating Equipment – UL 873
Terminal Blocks, Electrical – UL 1059
Terminals, Electrical Quick-Connect – UL 310
Transformers, Class 2 and Class 3 – UL 1585
Transformers, Specialty – UL 506
Wire Connectors and Soldering Lugs for Use With Copper Conductors – UL 486A
Wire Connectors for Use With Aluminum Conductors – UL 486B

Wires and Cables, Machine Tool – UL 1063
Wires and Cables, Thermoplastic-Insulated – UL 83
Wire, Flexible Cord and Fixture – UL 62

Superseded requirements for
the Standard for
Power Conversion Equipment

UL 508C, Third Edition

The requirements shown are the current requirements that have been superseded by requirements in this edition. The numbers in parentheses refer to the new requirements with future effective dates that have superseded these requirements. To retain the current requirements, do not discard the following requirements until the future effective dates are reached.

27.6.2 Strain relief shall be provided on power supply or signal multicable cords. The device shall withstand without damage to the cord or conductors and without displacement, a direct pull of 35 pounds (156 N) applied to the cord for 1 minute. Supply connections within the equipment are to be disconnected from terminals or splices during the test when applicable.

27.6.5 Means shall be provided to prevent the flexible cord from being pushed into the enclosure of the equipment through the cord entry hole when such displacement subjects the cord to mechanical damage or exposes the cord to a temperature higher than that for which it is rated or when it reduces spacings, such as to a metal strain-relief clamp, below the minimum required values.

39.3 Tests are to be conducted at rated frequency and a test potential not less than 120, 208, 240, 277, 480, or 600 volts as appropriate for the voltage ratings. The Temperature Test shall be conducted at a potential between 90 – 110 percent of the potential specified when the load current is adjusted to produce the maximum normal heating.

53.1 (55.1) Power conversion equipment shall be plainly marked with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is identifiable – hereinafter referred to as the manufacturer's name;

b) The electrical rating per Section 52, Rating; and

c) The catalog number or equivalent.

67.1 (65.1) These requirements cover cooling systems for power conversion equipment. These requirements supplement the requirements in Sections 5 – 60.

68.2 (66.2) All tubing, tanks, and other cooling system components shall be investigated and shall meet the requirements for use with the cooling medium.

68.3 (66.4) A means shall be provided for relieving pressure from the cooling system. The pressure relief means shall be investigated for the purpose.

68.4 (66.5) When normal operation of the cooling system results in expected condensation inside the power conversion equipment, the spacings of the equipment shall be evaluated for a Pollution Degree 3 environment (see 2.7).

68.5 (66.6) There shall be no leakage of the cooling medium onto live parts as a result of:

a) Normal operation;

b) Servicing of the equipment; or

c) Loosening or detachment of hoses or other cooling system parts over time.

69.1.1 (67.1.1) Following the Temperature Test of Section 39, one sample of the cooled power conversion equipment is to be connected to its rated source of supply and operated as intended. The cooling medium is to be allowed to leak out of any possible connections and/or emptied from the cooling system by means of a puncture. The unit is to be operated until ultimate conditions occur.

69.1.2 (67.1.4) The cooling medium shall not fall onto uninsulated live parts or insulated live parts that present a risk of tracking, and there shall be no accumulation of liquid in the electrical compartment. The Dielectric Voltage-Withstand Test of Section 43 shall be performed after completion of the test.

69.2.1 (67.2.1) One sample of the cooled power conversion equipment is to have water injected into the coolant cavity, with the circulating pump de-energized. The pressure is to be increased at a steady rate until the pressure relief means opens.

69.2.2 (67.2.2) There shall be no risk of fire, electric shock, or injury to persons indicated as a result of the test. Additionally, there shall be no leakage of the coolant into the electrical compartment.