UL 551

STANDARD FOR SAFETY

Transformer-Type Arc-Welding Machines

UL Standard for Safety for Transformer-Type Arc-Welding Machines, UL 551

Eighth Edition, Dated April 24, 2009

Summary of Topics

This revision to UL 551 is being issued to reaffirm the Eighth Edition of the Standard for Safety for Transformer-Type Arc-Welding Machines, UL 551, as an American National Standard and to incorporate an editorial correction to the Table of Contents.

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

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

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APPENDIX A

Standards for Components A1

INTRODUCTION

1 Scope

1.1 These requirements cover limited duty welding and cutting power sources, wire feeders, torches, and electrode holders that are intended for use by a layperson in a nonindustrial setting in accordance with the National Electrical Code, NFPA 70. Products covered by these requirements include only those welding products rated 600 volts or less, and are commonly known as hobby welders.

1.1 effective July 15, 2009

1.2 These requirements do not cover motor-generator sets or rectifier- or resistance-type welding machines. These requirements do not cover industrial or professional use welders.

1.2 effective July 15, 2009

2 Components

2.1 Except as indicated in this clause, a component of a product covered by this standard shall comply with the requirements for that component. See the Standards for Components appendix for a list of standards covering components generally used in the products covered by this standard.

2.2 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b) Is superseded by a requirement in this standard.

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

2.4 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.

3 Units of Measurement

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

4 References

4.1 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.

5 Terminology

5.1 In the following text, a requirement that applies only to a particular type of product is so identified by a specific reference in that requirement to the type or types of products involved. Absence of such specific reference or use of the term product indicates that the requirement applies to all types of products unless the context indicates otherwise.

CONSTRUCTION

6 General

6.1 An enclosure, an opening, a frame, a guard, a knob, a handle, or the like shall not be sufficiently sharp to cause a risk of injury to persons during normal maintenance or use.

Exception: A sharp edge that must be exposed to enable the product to perform its intended function.

6.2 A welding lead or electrode holder that is attached to a product shall be acceptable for the purpose.

7 Frame and Enclosure

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

7.2 A product shall be provided with a case or cabinet that encloses all live parts.

Exception No. 1: A flexible supply cord or cable and welding leads need not be enclosed.

Exception No. 2: Ungrounded secondary output terminals for the connection of welding leads, tap jacks, or similar parts connected to the secondary circuit need not be enclosed if they are:

a) Limited in voltage as specified in 27.1.1; and

b) Protected so as to reduce the risk of unintentional contact.

7.3 The protection referred to in Exception No. 2 to 7.2 will usually be afforded if:

a) Jacks are of the dead-front type,

b) An uninsulated live part is recessed for a distance not less than half the minimum dimension of the opening behind which the live part is located,

c) A hinged cover is provided over the terminals with smooth-edged slots or openings for the cable, or

d) In a product with a marked duty cycle more than 20 percent, an uninsulated live part, including the secondary terminals in the case of stud connections, is recessed beyond the plane of the opening.

7.4 An enclosure shall be made of cast metal, iron, steel, aluminum, copper, or brass.

Exception: Other material that has been investigated and found to be acceptable for the purpose may be used.

7.5 Among the factors to consider in determining the acceptability of an enclosure are its:

a) Mechanical strength,

b) Resistance to impact,

c) Moisture-absorptive properties,

d) Combustibility,

e) Resistance to corrosion,

f) Resistance to distortion at temperatures to which the enclosure may be subjected under conditions of normal or abnormal use, and

g) Resistance to ignition from electrical sources.

For a nonmetallic enclosure, all of these factors are considered with respect to thermal aging.

7.6 The thickness of a cast-metal enclosure shall be as specified in Table 7.1.

Table 7.1
Thickness of cast–metal for enclosures

Dimensions of location of area involved	Minimum thickness, Inch (mm)			
	Cast metal other than die-cast		Die-cast metal	
Area of 24 square inches (154.8 cm^2) or less and having no dimension greater than 6 inches (152.4 mm)	1/8	(3.2)	1/16[a]	(1.6)
Area greater than 24 square inches (154.8 cm^2) or having any dimension greater than 6 inches (152.4 mm)	1/8	(3.2)	3/32	(2.4)
At a threaded conduit hole	1/4	(6.4)	1/4	(6.4)
At an unthreaded conduit hole	1/8	(3.2)	1/8	(3.2)

[a] The area limitation for metal 1/16 inch (1.6 mm) thick may be obtained by the provision of acceptable reinforcing ribs subdividing a larger area.

7.7 Sheet metal to which a wiring system is to be connected in the field shall have a thickness not less than 0.053 inch (1.35 mm) if uncoated steel, not less than 0.056 inch (1.42 mm) if galvanized steel, and not less than 0.075 inch (1.91 mm) if nonferrous.

7.8 Other than as specified in 7.7, a sheet-metal enclosure shall not be thinner than specified in Table 7.2 or 7.3, as applicable.

Exception: The minimum thickness of a reinforced enclosure without supporting frame may be less than specified in Tables 7.2 and 7.3 but not less than 0.020 inch (0.51 mm) for uncoated steel, 0.023 inch (0.58 mm) for coated steel, brass, aluminum, or copper if when subjected to compression and torsion forces, its strength and rigidity are shown to be not less than the corresponding properties of an enclosure of the same maximum length and width having the required thickness of metal. See Compression and Torsion Tests, Section 38.

7.9 With reference to Tables 7.2 and 7.3, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface. The frame also has the necessary torsional rigidity to resist the bending moments that may be applied to the surface of the enclosure when it is deflected. A structure that is as rigid as one built with a frame of angles or channels is considered to have equivalent reinforcing.

7.10 Construction considered to be without supporting frame includes:

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, or

d) An enclosure surface having an unsupported edge.

Table 7.2
Thickness of sheet metal for electrical enclosures, carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[b]				Minimum thickness Inch (mm)			
Maximum width,[c] Inches	(cm)	Maximum length,[d] Inches	(cm)	Maximum width,[c] Inches	(cm)	Maximum length,[d] Inches	(cm)	Uncoated		Metal coated	
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020[e]	(0.51)	0.023[e]	(0.58)
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[e]	(0.66)	0.029[e]	(0.74)
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)	0.034	(0.86)
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)	0.045	(1.14)
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)	0.056	(1.42)
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)	0.063	(1.60)
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)	0.070	(1.78)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)				

Table 7.2 Continued on Next Page

Table 7.2 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[b]				Minimum thickness Inch (mm)			
Maximum width,[c] Inches	(cm)	Maximum length,[d] Inches	(cm)	Maximum width,[c] Inches	(cm)	Maximum length,[d] Inches	(cm)	Uncoated		Metal coated	
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited		0.080	(2.03)	0.084	(2.13)
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)	0.097	(2.46)
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)	0.111	(2.82)
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)	0.126	(3.20)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)				

[a] See 7.10.

[b] See 7.9.

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

[d] Not limited applies only if 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.

[e] Sheet steel for an enclosure intended for outdoor use – rainproof – shall not be less than 0.034 inch (0.86 mm) thick if zinc coated and not less 0.032 inch (0.81 mm) thick if uncoated.

Table 7.3
Thickness of sheet metal for electrical enclosures, aluminum, copper, or brass

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

[a] See 7.10.

[b] See 7.9.

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

Table 7.3 Continued on Next Page

Table 7.3 Continued

Without supporting frame[a]		With supporting frame or equivalent reinforcing[b]		
Maximum width[c] Inches (cm)	Maximum length[d] Inches (cm)	Maximum width[c] Inches (cm)	Maximum length[d] Inches (cm)	Minimum thickness Inches (mm)
[d] Not limited applies only if 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. [e] Sheet copper, brass, or aluminum for an enclosure intended for outdoor use – rainproof – shall not be less than 0.029 inch thick.				

7.11 The bottom of a product shall be solid or shall be provided with screening or wire mesh.

7.12 The wires of a screen shall not be less than 16 AWG (1.3 mm^2) for a screen having openings that are 1/2 square inch (3.2 cm^2) or less in area, and shall not be less than 12 AWG (3.3 mm^2) for a screen having larger openings.

7.12 revised June 23, 2011

7.13 Sheet steel employed for expanded-metal mesh and perforated sheet steel having mesh openings or perforations:

a) One-half square inch (3.2 cm^2) or less in area shall not be less than 0.043 inch (1.1 mm) thick – 0.046 inch (1.2 mm) if zinc-coated; and

b) More than 1/2 square inch in area shall not be less than 0.081 inch (2.06 mm) thick – 0.084 inch (2.13 mm) if zinc-coated.

8 Accessibility of Live Parts

8.1 An opening in an enclosure through which an uninsulated live part of the primary circuit is accessible shall be of such size or shape that it will not permit passage of a rod having the diameter specified in Table 8.1.

Table 8.1
Test rods for openings

Distance from current-carrying part to opening, inches (mm)	Diameter of test rod that will not pass through opening
1.5 or less (38.1)	1/3 of distance from current-carrying part to opening
1.6 – 4 (40.6 – 101.6)	33/64 inch (13.1 mm)
4.1 – 6 (104.1 – 152.4)	49/64 inch (19.5 mm)
Over 6 (152.4)	49/64[a] inch (19.5 mm)
[a] No limit is specified for openings in the bottom wall of an enclosure that are not directly below a transformer or a reactor.	

9 Protection Against Corrosion

9.1 Iron and steel parts shall be protected against corrosion by painting, enameling, galvanizing, plating, or other equivalent means such as a plastic coating that has been investigated and found to be acceptable for the purpose.

Exception: Bearings and other parts where protection is impracticable.

10 Supply Connections

10.1 General

10.1.1 A product with a duty cycle rating:

a) Of more than 20 percent shall be equipped with a power supply cord or provision for connection to a wiring system; and

b) Of 20 percent shall be equipped with a power supply cord.

Exception: A product that does not have wheels, casters, or other means for mobility may have provision for connection to a wiring system in lieu of a power supply cord.

10.1.2 A product rated 125 volts, or 125/250 volts, 3 wire or less and employing:

a) A lamp- or element-holder of the Edison-screw-shell type, or

b) A single-pole circuit breaker or switch

shall have one terminal or lead identified for the connection of the grounded conductor of the supply circuit. The terminal or lead intended to be connected to a grounded conductor of the supply circuit shall be the one that is connected to the screw shells of lamp- or element-holders and to which are connected no single-pole switches other than an automatic control without a marked off position.

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

10.1.4 A lead intended to be connected to a grounded power-supply conductor shall be finished to show a white or gray color, and shall be readily distinguishable from the other leads.

10.1.4 revised June 23, 2011

10.2 Cords and plugs

10.2.1 A product that is intended for connection to the supply circuit by means of a flexible cord in accordance with 10.1.1 shall be provided with a flexible cord as specified in 10.2.2 or 10.2.3 that is not less than 6 feet (1.8 m) long and that is terminated in an attachment plug. The attachment plug shall be an armored plug, a solid molded-rubber plug, or the equivalent, that is acceptable for hard service.

Exception No. 1: For a product having ratings above 250 volts only, the flexible cord need not be terminated in an attachment plug if the markings described in 43.24, 44.2, and 44.3 are provided.

Exception No. 2: For a product having ratings above and below 250 volts, the flexible cord need not be terminated in an attachment plug if the product is wired for voltages above 250 volts when shipped, and the markings described in 43.24, 44.2, and 44.3 are provided.

10.2.2 A product having a primary input rating of 12 kVA or less shall be provided with Type S, SO, ST, STO, SJ, SJO, SJT, SJTO, or SPT-3 cord.

10.2.3 A product having a primary input rating of more than 12 kVA shall be provided with Type S, SO, ST, or STO cord.

10.2.4 The flexible cord shall be of a size and ampacity as specified in Table 10.1, with the ampacity determined by the following formula:

$$I_r \geq \sqrt{I_a^2\, d + I_b^2\, (1 - d)}$$

in which:

I_r is the ampacity of the cord;

I_a is the rated input current corresponding to the rated load output;

I_b is the input current with product idling – energized but with no output load; and

d is the rated duty cycle expressed as a fraction of total time.

Table 10.1
Ampacities of cords

Conductor size, AWG (mm^2)		Ampacity[a]
18	(0.82)	10
16	(1.3)	13
14	(2.1)	18
12	(3.3)	25
10	(5.3)	30
8	(8.4)	40
6	(13.3)	55
4	(21.2)	70
2	(33.6)	95

[a] The ampacities are applicable only when 2 conductors are current carrying. A conductor used for equipment grounding and a neutral conductor are not considered to be current-carrying conductors.

10.2.5 The rating of an attachment plug terminating the supply cord shall not be less than the primary rating of the product.

Exception: For a product that is provided with a switch or circuit breaker that complies with the requirement in 22.2, the current rating of the plug may not be less than 75 percent of the primary current rating of the product. See 43.5.

10.3 Strain relief, bushings, and entrance holes

10.3.1 A hole, a knockout, or a fitting shall be provided in a product intended for connection to a permanent wiring system.

10.3.2 The diameter of a knockout and the width of the flat surface surrounding the knockout shall be as specified in Table 10.2.

Table 10.2
Diameter of knockout and width of surrounding flat surface

Size of supply conductor, AWG (mm^2)	Trade size of conduit, inches	Knockout diameter, inches (mm)[a]		Minimum width of flat surface surrounding knockout, inch (mm)	
14 – 8 (2.1 – 8.4)	1/2	0.875	(22.22)	0.133	(3.38)
6 (13.3)	3/4	1.109	(28.17)	0.156	(3.96)
4 – 2 (21.2 – 33.6)	1	1.375	(34.93)	0.198	(5.03)
1 – 0 (42.4)	1-1/4	1.734	(44.04)	0.274	(6.96)

[a] A plus tolerance of 0.031 inch (0.79 mm) and a minus tolerance of 0.015 inch (0.38 mm) apply to the knockout diameter. The diameter is not to be measured at points where a tab may remain after removal of the knockout.

10.3.3 A product having a power-supply cord shall be provided with strain relief and bushings as described in 10.3.4 – 10.3.7.

10.3.4 Means shall be provided so that the flexible cord cannot be pushed into the enclosure through the cord-entry hole if such displacement is likely to:

a) Subject the cord to mechanical damage,

b) Expose the cord to a temperature higher than that for which it is rated, or

c) Reduce spacings, such as to a metal strain relief clamp, below the minimum acceptable values.

10.3.5 If a knot in a flexible cord serves as a strain relief, the surface against which the knot may bear or which it may contact shall be free from projections, sharp edges, burrs, fins, or the like that may cause abrasion of the cord insulation.

10.3.6 At a point where a flexible cord passes or is intended to pass through an opening in a wall, barrier, or enclosing case, there shall be a bushing or the equivalent that is substantial, secured in place, and smoothly rounded on the surface against which the cord may bear.

10.3.7 Ceramic materials, some molded compositions, smooth metal grommets, or the equivalent are acceptable for bushings, but a separate bushing of wood, rubber, or hot-molded shellac-and-tar composition is not acceptable.

10.4 Wiring terminals and leads

10.4.1 Other than as noted in 10.4.10, a product that is not provided with an attached flexible cord shall have wiring terminals or supply leads for the connection of supply conductors sized in accordance with Table 10.3 with the ampacity based on the value determined from the formula in 10.2.4.

Table 10.3
Terminal current and conductor size

Copper conductor			Aluminum or copper-clad aluminum conductor		
	Size			Size	
Terminal current, amperes	AWG or kcmil (mm^2)		Paralleled	AWG or kcmil (mm^2)	
15 or less	14 AWG	(2.1)	–	12 AWG	(3.3)
20	12	(3.3)	–	10	(5.3)
25	10	(5.3)	–	10	(5.3)
30	10	(5.3)	–	8	(8.4)
40	8	(8.4)	–	6	(13.3)
50	6	(13.3)	–	4	(21.2)
60	4	(21.2)	–	3	(26.7)
70	4	(21.2)	–	2	(33.6)
80	3	(26.7)	–	1	(42.4)
90	2	(33.6)	–	1/0[a]	(53.5)
100	1	(42.4)	–	1/0[a]	(53.5)
110	1	(42.4)	–	1/0[a]	(53.5)
125	1	(42.4)	–	2/0	(67.4)
150	1/0	(53.5)	–	3/0	(85.0)
175	2/0	(67.4)	–	4/0	(107.2)

Table 10.3 Continued on Next Page

Table 10.3 Continued

Copper conductor			Aluminum or copper-clad aluminum conductor		
Terminal current, amperes	Size AWG or kcmil (mm^2)		Paralleled	Size AWG or kcmil (mm^2)	
200	3/0	(85.0)	–	250 kcmil	(127)
225	4/0	(107.2)	–	300	(152)
250	250 kcmil	(127)	–	350	(177)
275	300	(152)	–	500	(253)
300	350	(177)	–	500	(253)
325	400	(203)	two	1/0 AWG	(53.5)
350	500	(253)	two	4/0	(107.2)

[a] 1 AWG, 75°C aluminum conductor may be used if the product is so marked. See 43.21.

10.4.2 A fixed wire terminal shall be prevented from turning.

10.4.3 Other than as indicated in 10.4.4, a wiring terminal shall be provided with an acceptable pressure wire connector.

Exception: A wire-binding screw may be employed at a wiring terminal intended for the connection of a 10 AWG (5.3 mm^2) or smaller conductor if an upturned lug or the equivalent is provided to retain the conductor under the head of the screw when the screw is loosened sufficiently to permit shifting of the conductor.

10.4.4 Pressure terminal connectors for line or load field connection need not be provided if the following conditions, where appropriate, are met.

a) A component terminal kit shall be available from the equipment manufacturer, or one or more acceptable pressure terminal connectors shall be specified for field installation on the product, or the equivalent.

b) Fastening devices such as studs, nuts, bolts, spring and flat washers, and the like required for an effective installation shall either be provided as part of the component terminal kit or be mounted on or separately packaged with the product.

c) The installation of a terminal kit shall not involve the loosening or disassembly of parts other than a cover or another part giving access to the terminal location. The means for securing the terminal connector shall be readily accessible for tightening before and after installation of conductors.

d) If the pressure terminal connector provided in a component terminal kit requires the use of a specific tool for securing the conductor, any necessary instructions shall be included in the component terminal kit package or with the product.

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

f) The product shall be marked in accordance with 43.12.

10.4.5 If a screw-and-washer construction is employed at a wiring terminal, the binding screw shall not be smaller than No. 10, with not more than 32 threads per inch.

Exception: A No. 8 machine screw having not more than 32 threads per inch may be used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) or smaller conductor.

10.4.6 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 inch (1.27 mm) thick and shall not have less than two full threads in the metal.

Exception: An alloy plate not less than 0.030 inch (0.76 mm) thick may be used if the tapped threads have acceptable mechanical strength.

10.4.7 A terminal plate may be extruded at the tapped hole to give the thickness necessary for at least two full threads, provided that the thickness of the unextruded metal is not less than the pitch of the thread.

10.4.8 The point of attachment of a pressure wire connector or a wire-binding-screw terminal shall not overhang the base unless the construction is such that the required spacings will not be reduced.

10.4.9 A wire-binding screw shall not thread into material other than metal.

10.4.10 All wiring terminals and supply leads shall be located entirely within the enclosure.

11 Wire-Bending Space

11.1 Wire-bending space shall be provided for each conductor that enters or leaves the enclosure. The minimum wire-bending space shall be as specified in:

a) Table 11.1 for a conductor that enters or leaves the enclosure in the wall opposite the terminal to which the conductor is intended to be connected,

b) Table 11.2 for a conductor that does not enter or leave the enclosure in the wall opposite the terminal to which the conductor is intended to be connected, and

c) Table 11.2 between a barrier or other obstruction in the wiring area and a connector or a hole, a knockout, or other provision provided for the connection of a wiring system.

11.2 With respect to 11.1, if a hole, knockout, or other provision for connection of a wiring system for the main conductors is provided in the wall opposite the main terminals, it will be considered that the main conductors will enter or exit the enclosure through that wall, and the wire-bending space for those conductors shall be as specified in Table 11.1.

Table 11.1
Minimum wire–bending space at terminals for a conductor that enters or leaves the enclosure wall opposite its terminal

Wire size AWG or kcmil	Wires per terminal (pole)[a]			
	1 wire		2 wires	
14 – 10	Not Specified		–	
8	1-1/2		–	
6	2		–	
4	3		–	
3	3		–	
2	3-1/2		–	
1	4-1/2		–	
0	5-1/2		5-1/2	
2/0	6		6	
3/0	6-1/2	(1/2)	6-1/2	(1/2)
4/0	7	(1)	7-1/2	(1-1/2)
250	8-1/2	(2)	8-1/2	(2)
300	10	(3)	10	(2)
350	12	(3)	12	(3)
400	13	(3)	13	(3)
500	14	(3)	14	(3)

NOTES –

1) For arc-welding machines rated 110 amperes or less and marked to indicate use of both 60 and 75°C wire, the wire bending space is based on the use of 60°C (140°F) insulated wire.

2) For SI units 1 inch = (25.4 mm)

[a] Wire-bending space shall be permitted to be reduced by the number of inches shown in parentheses under the following conditions:

1) Only removable wire connectors receiving one wire each are used (there may be more than one removable wire connector per terminal), and

2) The removable wire connectors can be removed from their intended location without disturbing structural or electrical parts other than a cover, and can be reinstalled with the conductor in place.

Table 11.2
Minimum wire–bending space at terminals for a conductor that does not enter or leave the enclosure wall opposite its terminal

Size of wire AWG or kcmil (mm^2)		Minimum bending space, terminal to wall			
		Wires per terminal			
		1 wire		2 wires	
		Inch	(mm)	Inch	(mm)
14 – 10	(2.1 – 5.3)	Not specified		–	
8 – 6	(8.4 – 13.3)	1.5	(38.1)	–	
4 – 3	(21.1 – 26.7)	2	(50.8)	–	
2	(33.6)	2.5	(63.5)	–	
1	(42.2)	3	(76.2)		
1/0 – 2/0	(53.5 – 67.4)	3.5	(88.9)	5	(127)
3/0 – 4/0	(85.0 – 107.2)	4	(102)	6	(152)
250	(127)	4.5	(114)	6	(152)
300 – 350	(152 – 177)	5	(127)	8	(203)
400 – 500	(203 – 253)	6	(152)	8	(203)
600 – 700	(304 – 355)	8	(203)	10	(254)

NOTE – For welding machines rated 110 amperes or less and marked to indicate use of both 60 and 75°C wire, the wire bending space is based on the use of 60°C (140°F) insulated wire.

11.3 If a wire is restricted by a barrier, or other means, from being bent in a 90-degree or an S bend from the terminal to any usable location in a wall of the enclosure, the distance is to be measured from the end of the barrier or other obstruction.

11.4 The wire-bending space for a conductor that enters or leaves the enclosure in the wall opposite the terminal is to be measured in a straight line from the edge of the wire terminal closest to the wall or barrier in a direction perpendicular to the wall or barrier. The wire terminal is to be turned in all positions that it can assume without defeating any reliable means provided to prevent its turning, such as a boss, a shoulder, a wall of a recess, multiple bolts securing the connector, or the like. A barrier, shoulder, or the like is to be disregarded when the measurement is being made if it does not reduce the radius to which the wire must be bent. The main connection for a neutral is considered to be a pole.

11.5 Side bending space is to be measured in a straight line from the center of the wire opening in the direction the wire leaves the terminal. However, it is assumed that the connector is not so oriented that the wire will be directed into a corner to such extent that the transverse wall would necessitate additional bending of the wire. If a terminal is provided with one or more lugs or connectors for the connection of conductors in multiple, the distance is to be measured from the wire opening closest to the wall of the enclosure. If the connectors for a circuit are fixed in position (for example, by the walls of a recess) so that they are turned toward each other, the distance is to be measured at the wire opening nearest to the wall, in a direction perpendicular to the wall.

12 Grounding

12.1 A product shall be provided with a means that does not depend upon the use of solder for grounding parts that are required to be grounded. The core of a transformer, the core of a reactor coil, the case of a capacitor, and all exposed dead metal parts other than small isolated parts shall be in reliable electrical connection with the point of attachment of a single grounding conductor.

12.2 A product is considered to have acceptable means for grounding if all the parts that are required to be grounded are in reliable electrical connection with the point of attachment of the wiring system.

12.3 A power-supply cord attached to a product shall contain a grounding conductor in addition to the supply-circuit conductors. The surface of an insulated grounding conductor shall be green with or without one or more yellow stripes. The grounding conductor shall terminate at a blade of the attachment plug.

12.4 product intended to be connected to a wiring system shall be provided with a means for attachment of the grounding conductor.

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

12.6 A pressure wire connector intended solely for the connection of an equipment-grounding conductor shall be plainly marked, such as “G,” “GR,” “GND,” “Ground,” “Grounding,” or the like, or by a wiring diagram provided on the product. The wire-binding screw or pressure wire connector shall be located so that it is unlikely to be removed during normal servicing of the product.

12.7 The means provided for the connection of the grounding conductor shall be accessible without disturbing the assembly of the product, other than opening a door, cover, or the like.

12.8 The size of the grounding means for a product shall be as specified in Table 12.1.

Exception: A copper grounding conductor need not be larger than the size required for the supply conductors.

Table 12.1
Size of grounding means

Primary current rating, amperes	Minimum size of copper grounding wire[a] AWG (mm^2)	
15	10	(5.3)
20	10	(5.3)
30	10	(5.3)
50	8	(8.4)
100	6	(13.3)
200	3	(26.7)
300	1	(42.4)
400	1/0	(53.5)

[a] These conductor sizes are based on a setting of the overcurrent device at 200 percent of the nameplate rating of the product.

12.9 The surface of an insulated lead intended for the connection of an equipment-grounding conductor shall be green with or without one or more yellow stripes, and no other lead shall be so identified.

13 Spacings

13.1 Spacings in a product shall not be less than those specified in Table 13.1.

Exception: The spacings specified in Table 13.1 do not apply to wiring devices – snap switches, lampholders, or the like – motors, or other accessories for which there are established spacing requirements.

Table 13.1
Spacings in a product

Voltage between parts involved	Minimum spacings in inches (mm) between any uninsulated live part and an uninsulated live part of opposite polarity, a metal part that may be grounded – including fittings for the connection of a wiring system – or an exposed dead metal part that is isolated											
	At wiring terminals[a]				At other than wiring terminals[a,b]							
	A				B[c]				C[d]			
	Through air		Over surface		Through air		Over surface		Through air		Over surface	
125 or less	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)	1/8	(3.2)	1/4	(6.4)
126 – 250	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)	1/4	(6.4)	3/8	(9.5)
251 – 600	1	(25.4)	1	(25.4)	1	(25.4)	1	(25.4)	3/8	(9.5)	1/2	(12.7)
601 – 1000	–		–		1	(25.4)	1	(25.4)	3/4	(19.1)	1	(25.4)

[a] Wiring terminals are considered to be terminals to which supply connections are made in the field.

[b] Values do not apply to a turn of wire on a coil or to spacings between:

1) Two conductors of a coil,

2) A coil and the transformer core, and

3) A coil and any other part of opposite polarity including the crossover lead.

[c] If indentation or deformation of the ultimate enclosure may reduce spacings to less than those in Column C.

[d] If indentation or deformation of the ultimate enclosure will not affect spacings.

13.2 Other than as indicated in 13.7, a barrier or liner that comprises the sole separation shall:

a) Be of material acceptable for supporting an uninsulated live part, and

Exception: A barrier between the enclosure and an uninsulated part electrically connected to a grounded circuit conductor may be of fiber;

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

13.3 Other than as indicated in 13.6 and 13.7, a barrier or liner used in conjunction with an air space shall be at least 0.028 inch (0.71 mm) thick.

13.4 If the barrier mentioned in 13.3 is of fiber, the air space shall be at least 1/32 inch (0.8 mm).

13.5 If the barrier mentioned in 13.3 is of material other than fiber that is not acceptable for the support of uninsulated live parts, the air space shall be acceptable for the application.

13.6 A barrier or liner used in conjunction with an air space of at least one-half the required through-air spacing may have a thickness of not less than 0.013 inch (0.33 mm) – see also 13.7 – if it is:

a) Of material acceptable for supporting uninsulated live parts,

b) Of acceptable strength if exposed or otherwise likely to be subjected to mechanical damage,

c) Reliably held in place, and

d) Located so that it will not be adversely affected by operation of the equipment in service.

13.7 Insulating material having a thickness less than that specified in 13.2 (b) and 13.3 and 13.6 may be used if it has been found to be acceptable for the application.

13.8 A wrap of thermoplastic tape, acceptable for use as sole insulation, may be employed at a point where the spacing prior to the application of the tape is less than the required through-air spacing, if:

a) The wrap is not less than 0.028 inch (0.71 mm) thick,

b) The tape is not subject to compression, and

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

Exception: At a point where the spacing prior to the application of the tape is not less than half the required through-air spacing, the wrap may be not less than 0.013 inch (0.33 mm) thick if it is applied in two or more layers.

13.9 Where a spacing is less than the required value, acceptable thermoplastic tubing may be employed if:

a) The tubing is not subjected to compression, repeated flexure, or sharp bends;

b) All edges of the conductor covered with the tubing are well rounded and free from sharp edges;

c) For chemically dilated tubing, a solvent recommended by the tubing manufacturer is used;

d) For heat-shrinkable tubing, hot air as recommended by the tubing manufacturer is used; and

e) The wall thickness of the tubing, after assembly, is not less than 0.022 inch (0.56 mm) for tubing 1/2 inch (12.7 mm) or less in diameter and not less than 0.028 inch (0.71 mm) for larger diameter tubing.

14 Mechanical Assembly

14.1 A pressure wire connector shall be prevented from turning if spacings would be reduced to less than those required by 13.1 and Table 13.1. If the required minimum or greater spacings are maintained when lugs are turned 30 degrees toward each other or toward other uninsulated live or grounded-metal parts, no means to prevent turning need be provided.

14.2 A bus bar or uninsulated live part, other than a pressure wire connector as mentioned in 14.1, shall be reliably secured so that ordinary vibration will not loosen the securing means, and shall be prevented from turning or shifting in position if any spacings less than those specified in Table 13.1 would result from such turning or shifting.

14.3 Friction between surfaces is not acceptable as a means to prevent turning or shifting of an uninsulated live part. Turning or shifting may be prevented by the use of two screws or rivets, by noncircular shoulders, or mortises, by a dowel pin, lug, or offset, by a connecting strap or clip fitted into an adjacent part, or by an equivalent method.

14.4 In determining the adequacy of means to prevent turning or shifting with regard to the requirement in 14.2, any screw or nut is to be loosened and retightened finger-tight without a tool. The bus bar is then to be pushed to the extent limited by the screws or other means and the resulting spacings measured.

15 Internal Wiring

15.1 The wiring and connections between parts of a product shall be protected or enclosed.

15.2 Wiring shall be protected from sharp edges, including screw threads, burrs, fins, moving parts, and the like that may abrade the insulation on conductors or otherwise damage the wiring.

15.3 A hole in a sheet-metal wall through which insulated wires pass or are intended to pass shall be provided with a smooth, rounded bushing or shall have a smooth, rounded surface upon which the wires may bear to reduce the likelihood of abrasion of the insulation.

15.4 Insulated wires that are entirely enclosed within metal walls may be bunched and passed through a single opening.

15.5 An uninsulated conductor shall be supported so that the minimum required spacings will be maintained.

15.6 Each splice and connection shall be mechanically secure and shall provide electrical contact without stress on any connection or terminal.

15.7 A splice shall be provided with insulation that has a rating equivalent to the rating of the wire insulation for the following conditions:

a) Permanent spacing is not maintained between a splice and uninsulated live parts of opposite polarity; or

b) Permanent spacing is not maintained between a splice and a grounded dead metal part.

Exception: When spacings are maintained using mechanical means and comply with Section 13, Spacings, the splice insulation is not required

15.8 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for interconnection between current-carrying parts, shall be terminated at each end by a method that is acceptable for the combination of metals involved at the connection point.

Exception: Aluminum conductors for a transformer or motor winding need not comply.

15.9 With reference to 15.8, a wire-binding screw or a pressure terminal connector used as a termination device shall be acceptable for use with aluminum under the conditions involved – for example, temperature, heat cycling, and the like.

15.10 A nominal 0.110, 0.125, 0.187, 0.205, or 0.250-inch-wide quick-connect terminal shall comply with the requirements in the Standard for Electrical Quick-Connect Terminals, UL 310. Other sizes of quick-connect terminals shall be investigated with respect to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rises. All tests are to be conducted as specified in the requirements in UL 310.

16 Current-Carrying Parts

16.1 Iron or steel, plain or plated, shall not be used for a part that is depended upon to carry current.

Exception: A work clamp used with a welding lead may be made of plated steel.

16.2 Joints or connections of bolted aluminum contacts are to be plated with silver, tin, cadmium, or other metal that has been found acceptable by investigation. They also are to be provided with spring washers or the equivalent.

17 Electrical Insulating Materials

17.1 Insulating washers, bushings, and the like used, and bases or supports for mounting of uninsulated live parts shall be of moisture-resistant material that will not be damaged by the temperature that they will be subjected to under conditions of actual use.

17.2 Insulating material employed in a product is judged with respect to its acceptability for the application. Materials such as mica, some molded compounds, and certain refractory materials are usually acceptable as the sole support of uninsulated live parts, but ordinary fiber is not acceptable. To determine whether a material is acceptable, consideration is to be given to its mechanical strength, dielectric properties, insulation-resistance, heat-resistant qualities, the degree to which it is enclosed or protected, and any other features that have a bearing on the risk of fire, electric shock, and injury to persons, in conjunction with the conditions of actual service.

18 Capacitors

18.1 A capacitor connected across the line or across a winding of the main transformer, such as a capacitor for power-factor correction, shall be housed within an enclosure.

Exception No. 1: A capacitor housed by the outer enclosure of the product, reducing the likelihood of mechanical damage need not be separately enclosed.

Exception No. 2: A capacitor with a metal shell that complies with Table 7.2 or 7.3 need not be separately enclosed if terminals are acceptably enclosed.

18.2 The container of a capacitor containing a liquid shall be liquid-tight. The size of the container shall be such that the quantity of liquid does not exceed 1 quart (0.95 L) unless the liquid is nonflammable.

18.3 A capacitor shall be provided with automatic means for draining the stored charge so that the voltage across the capacitor will be 50 volts or less within the time necessary to gain access to any live part not in the output circuit, after disconnecting the product.

18.4 If a capacitor is connected so that its residual potential may exist at the blades of a disconnected attachment plug, the time necessary to gain access to a live part is considered to be 2 seconds. A capacitor connected directly across a winding of the main transformer, without any interposed switching device, is considered to have acceptable discharge means.

18.5 If a capacitor employs a liquid dielectric medium more flammable than askarel, the dielectric medium shall not be expelled under normal or abnormal conditions of use.

18.6 A capacitor that is connected so that it operates normally at a potential of more than 600 volts shall be investigated to determine whether it is acceptable for the purpose.

19 Fans

19.1 A fan shall be acceptable for its application. Among the factors to be considered in determining acceptability are the following:

a) Reliability of operation; and

b) Risk of fire, electric shock, or injury to persons that may result due to malfunction or breakdown of the fan during operation of the product if the fan is depended upon to maintain temperatures within the limits specified in Table 30.1. See 37.1.

20 Overload Protection

20.1 A fuseholder or circuit breaker shall be rated for the application and shall not be accessible from the outside of the product without opening a door or a cover.

Exception No. 1: The operating handle of a circuit breaker that projects outside of the enclosure complies with the requirement.

Exception No. 2: A panel-mounted fuseholder that projects outside of the enclosure complies with the requirement.

20.2 A fuseholder for a plug fuse that protects a receptacle as mentioned in 21.1 shall be Type S or shall be the Edison-base type with a factory-installed, nonremovable Type S adapter.

20.3 A cartridge fuse that protects a receptacle as mentioned in 21.1 shall be acceptable as branch-circuit protection and shall be provided with a switch on the supply side unless the fuseholder location is marked as specified in 43.7.

20.4 The motor of a fan shall be provided with at least one of the following types of overload protection:

a) Thermal protection complying with the requirements in the Standard for Overheating Protection for Motors, UL 2111, or the Standard for Thermally Protected Motors, UL 1004-3;

Exception: A motor that directly drives the fan is considered to have acceptable overload protection if it is protected against locked-rotor conditions only.

b) Impedance protection complying with such requirements in the Standard for Impedance Protected Motors, UL 1004-2; or

c) Other protection that is shown by test to be equivalent to (a).

Exception: A motor that is protected by circuitry designed to automatically stop all operation of the product if the fan does not operate is considered to have acceptable overload protection.

20.4 revised November 19, 2013. UL 1004-3 will replace Part III of UL 2111 effective September 15, 2014

20.5 The functioning of a protective device provided for a motor shall not result in a risk of fire, electric shock, or injury to persons.

21 Receptacles

21.1 A 15- or 20-ampere attachment-plug receptacle intended for general use shall be of the grounding type, and the grounding contact of the receptacle shall be electrically connected to the enclosure of the product.

22 Switches and Control Devices

22.1 A switch, controller, or circuit breaker shall be acceptable for the application, and shall be of a type that will plainly indicate whether the circuit is open or closed.

22.2 The opening of a manual switch, controller, or circuit breaker shall disconnect the product from all ungrounded conductors of the supply circuit.

Exception No. 1: A single-pole device is acceptable only on a product having a primary rating of 125 volts or less.

Exception No. 2: A tap-changing switch.

22.3 An automatic device provided to reduce the open-circuit voltage at the secondary output terminals or electrodes shall be substantial and reliable, and shall be investigated with respect to its acceptability for the purpose.

22.4 A voltage-regulating tap and a current-regulating tap shall have means for maintaining definite contact positions for the movable member with respect to the stationary contacts. The movable member of a voltage-regulating tap shall not bridge any two of the stationary contacts.

Exception: Brush or sliding contacts are acceptable if tests show that shorting of turns of the winding will not cause temperatures to exceed the rating of the insulating materials.

22.5 Flexible cable attached to a voltage-regulating or a current-regulating tap that involves the use of plugs external to the enclosure shall be acceptable for hard service. The open-circuit voltage at the plugs shall not be more than that specified in 27.1.1 for secondary terminals. The construction of a plug shall be such that no live part will be exposed when the plug is fully inserted. See 7.3.

23 Transformers

23.1 A transformer shall have the secondary insulated from the primary and shall not be of the oil-filled type. A coil shall be provided with insulation between the windings, leads, core, and enclosure. A coil shall be treated with an insulating varnish and baked, or otherwise impregnated, to exclude moisture.

23.2 A voltage-regulating tap or a current-regulating tap in the primary circuit shall not be on the side of the transformer winding to which a grounded supply conductor is connected.

PERFORMANCE

24 General

24.1 A product shall be subjected to the tests described in Sections 25 – 38 while connected to a supply circuit of rated frequency and maximum rated primary voltage, except that if the marked primary voltage is within the range of 110 – 115, 220 – 230, 440– 460, or 550 – 575 volts, the supply-circuit potential shall be 115, 230, 460, or 575 volts, respectively, for the leakage current, temperature, overload, endurance, and abnormal-operation tests.

24.2 The output voltage is to be measured at the output terminals of the product, or at the point of attachment for permanently attached welding cables.

24.3 The sequence of the performance tests shall be as follows:

a) Leakage Current Test – Section 25.

b) Leakage Current Test Following Humidity Conditioning – Section 26.

c) Output Test – Section 27.

d) Input Test – Section 28.

e) Short-Circuit Current Test – Section 29.

f) Temperature Test – Section 30.

g) Dielectric Voltage-Withstand Test – Section 31.

h) Overload Test on Switches and Controls – Section 32.

i) Endurance Test on Switches and Controls – Section 33.

j) Dielectric Voltage-Withstand Test on Switches and Controls – Section 34.

k) Short Circuit Test on Capacitors – Section 35.

l) Abnormal Operation Test – Section 36.

m) Stalled Fan Abnormal Operation Test – Section 37.

n) Compression and Torsion Tests – Section 38.

24.4 The tests mentioned in 24.3 are to be conducted on the same sample.

Exception: Tests mentioned in:

a) (a) – (e) may be conducted on one sample,

b) (f) – (h) may be conducted on a new sample, and

c) Each of items (i) – (k) may be conducted on a new sample.

24.5 For the purpose of this standard, duty cycle is defined as the ratio of arc time to total time, that is, the time the secondary is to be loaded in a 10-minute cycle.

25 Leakage Current Test

25.1 When tested as described in 25.2 – 25.11, the leakage current of a cord-connected product with a 20-percent duty-cycle rating and rated for a nominal 250-volt or less supply shall not be more than 0.75 milliamperes.

25.2 Leakage current refers to all currents, including capacitively coupled currents, that may be conveyed between exposed conductive surfaces of a product and ground or other exposed conductive surfaces of the product.

25.3 All exposed conductive surfaces are to be tested for leakage currents. The leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively where simultaneously accessible, and from one surface to another where simultaneously accessible. Parts are considered to be exposed surfaces unless guarded by an enclosure that has been investigated and found to be acceptable to reduce the risk of electric shock – see Frame and Enclosure, Section 7. 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.

25.4 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 metal foil with an area of 10 by 20 centimeters in contact with the surface. Where the surface is less than 10 by 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the product.

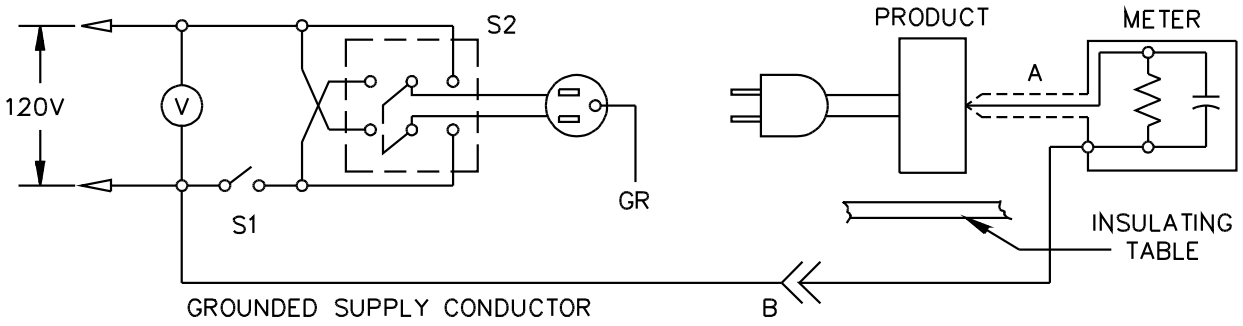
25.5 The measurement circuit for leakage current shall be as illustrated in Figure 25.1. The measurement instrument is defined in (a) – (c). The meter that is used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument. The meter used need not have all of the attributes of the defined instrument.

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

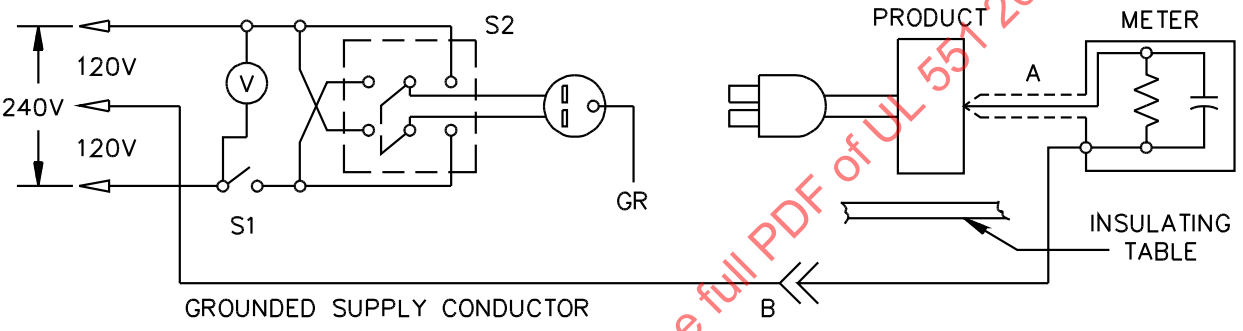
b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

c) Over a frequency range of 0 – 100 kilohertz, the measurement 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 0.75 milliamperes, the measurement is not to have an error of more than 5 percent at 60 hertz.

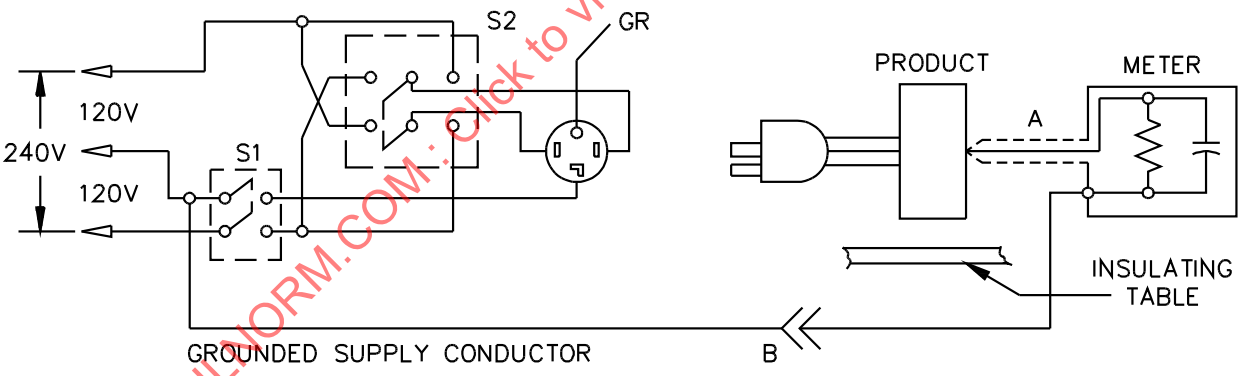
Figure 25.1
Leakage-current measurement circuits



Product intended for connection to a 120–volt power supply, as illustrated above.



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



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

LC300J

A: Probe with shielded lead.

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

25.6 Unless the meter is being used to measure leakage from one part of a product to another, the meter is to be connected between the accessible parts and the grounded supply conductor.

25.7 The sample product tested for leakage current is to be representative of the wiring methods, routing, components, component location and installation, and the like of a production product.

25.8 The grounding conductor of the test sample is to be open at the attachment plug and the test unit is to be isolated from ground.

25.9 The supply voltage is to be adjusted to the voltage specified in 24.1.

25.10 The test sequence with reference to the measuring circuit, Figure 25.1, is to be as follows:

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

b) Switch S1 is then to be closed, energizing the product; and within 5 seconds the leakage current is to be measured using both positions of switch S2 with the product 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 to be obtained by operation as in the Temperature Test, Section 30.

25.11 Normally the complete leakage current test program, as described in 25.10, is to be conducted 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.

26 Leakage Current Test Following Humidity Conditioning

26.1 A product shall comply with the requirements for leakage current in 25.1 following exposure for 48 hours to air having a relative humidity of 88±2 percent at a temperature of 32±2°C (90±4°F).

26.2 To determine whether a product complies with the requirement in 26.1, a sample of the product is to be heated to a temperature just above 34°C (93°F) to reduce the likelihood of condensation of moisture during conditioning. The heated sample is to be placed in the humidity chamber and conditioned for 48 hours under the conditions specified in 26.1. Following the conditioning, the sample is to be tested unenergized as described in 25.10 (a). The sample is then to be energized and tested as described in 25.10 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

27 Output Test

27.1 Open-circuit voltage

27.1.1 The open-circuit rms output voltage of a product, when connected to a supply circuit of maximum rated voltage, shall not be more than 5 percent greater than the marked secondary open-circuit voltage, and shall not be more than 80 volts for a manual product, nor more than 100 volts for an automatic product.

27.1.2 If a voltage-regulating or a current-regulating tap involves the use of plugs external to the enclosure, the open-circuit voltage at the plugs shall not be greater than that specified in 27.1.1 for secondary terminals.

27.2 Rated current

27.2.1 A product, when connected to a supply circuit of maximum rated voltage, shall deliver not less than its rated output current and maximum output current, if applicable, at rated output voltage.

Exception: A product with a 20-percent duty-cycle rating shall deliver not less than 95 percent of its rated output current and maximum output current, if applicable.

27.2.2 The test is to be conducted with the product at room temperature, and with the secondary connected to a variable resistance load having a power factor of not less than 0.99 at a frequency of 60 hertz.

27.2.3 The highest current tap of a product that is provided with more than a single secondary tap intended to deliver a greater output current than the rated output shall be used when measuring the maximum output specified in 27.2.1.

27.3 Secondary current

27.3.1 When a product that is marked with a 20-percent duty-cycle is connected to a supply circuit of maximum rated voltage, the maximum secondary current obtainable at rated secondary voltage with any setting of the product shall not exceed 130 percent of the rated output current, nor 105 percent of any value of maximum output current included in the marked rating of the product.

28 Input Test

28.1 The current input when the product is at room temperature and is connected and loaded so as to deliver its rated output shall not exceed the marked input ampere rating by more than 10 percent for a product having a duty cycle rating of more than 20 percent, and 25 percent for a product having a duty cycle rating of 20 percent.

28.2 A product having voltage-regulating or current-regulating taps is to be operated under the conditions that result in the maximum primary input current when the load on the secondary is the rated full-load current at rated output voltage.

28.3 The measured power factor of the primary input at rated load of a product that has the power factor marked on the nameplate shall be within 5 percent of the marked power-factor value.

28.4 If the power input in kilowatts is included in the marked nameplate rating, the measured power factor of the primary input to a product at rated load shall be within 5 percent of the power-factor value computed on the basis of the marked values of power, voltage, and current.

29 Short-Circuit Current Test

29.1 The secondary current obtained within 2 minutes at any setting of a product with the output terminals short-circuited and with the primary connected to a supply circuit of maximum rated voltage shall not be greater than 160 percent of the secondary current obtained at rated output voltage with the product set at the maximum tap or setting.

Exception: The secondary short-circuit current obtained within 2 minutes may be greater than 160 percent of the secondary current obtainable, provided the product is equipped with a protective device that shuts the product off under short-circuit conditions. See 29.4.

29.2 If the measured short-circuit current is less than the 160 percent value prior to the 2 minutes specified, the test may be terminated.

29.3 For the test, a 4-foot (1.22-m) length of copper conductor of the size specified in Table 29.1 is to be used for the connection between the output terminals.

Exception: Four feet of secondary welding leads that are supplied with the product may be used for the short-circuit connection between the output terminals.

Table 29.1
Short–circuit connections

Rated-secondary current, amperes	Size of connecting cable, AWG	(mm^2)
100	4	(21.2)
200	2	(33.6)
300	0	(53.5)
500	00	(67.4)

29.4 A product provided with a protective device as mentioned in the Exception to 29.1 shall not become a risk of fire, electric shock, or injury to persons with the secondary terminals of the machine short-circuited as noted in 29.3 and with a ground fuse connected as required in 32.2. The test is to be continued until an automatic protective device has cycled five times or a manual protective device has been reset five times.

30 Temperature Test

30.1 A product, when tested under the conditions described in 30.2 – 30.14, shall not attain a temperature at any point sufficiently high to constitute a risk of fire, to damage any materials employed in the device, or to exceed the temperature rises specified in Table 30.1. A metal part in contact with or adjacent to any insulating material shall not attain a temperature higher than that for which the insulation is acceptable.

Table 30.1
Maximum temperature rises

Material and Components	°C	°F
A. COMPONENTS		
1. Capacitors[a]		
2. Contacts:		
a. Bolted aluminum	55	99
b. Bolted copper	60	108
c. Laminated[b]	60	108
d. Solid[b]	75	135
e. Switch blades and contact jaws	40	72
3. Fuses[f]	60	108
4. Resistors and resistor material		
a. Bare resistor	385	693
b. Embedding resistor material	260	468
5. Sealing compound	c	c
6. Transformers:		
a. Class 105 insulation system:		
Thermocouple method	80	144
Resistance method	70	126
b. Class 130 insulation system:		
Thermocouple method	100	180
Resistance method	90	162
c. Class 155 insulation system:		
Thermocouple method	125	225
Resistance method	115	207

Table 30.1 Continued on Next Page

Table 30.1 Continued

	Material and Components	°C	°F
	d. Class 180 insulation system:		
	Thermocouple method	150	270
	Resistance method	135	243
B.	CONDUCTORS		
	1. Types S, SO, ST, STO, SJ, SJO, SJT, SJTO, and SPT-3 flexible cords[d]	30	54
C.	ELECTRICAL INSULATION– GENERAL		
	1. Fiber employed as electrical insulation	60	108
	2. Phenolic composition employed as electrical insulation[e]	120	216
D.	SURFACES		
	1. Any point on or within a terminal box or compartment on a stationary product	60	108
	2. Supporting surface on which a portable product may be placed	120	216
	3. Surfaces adjacent to or upon which a stationary product may be mounted in service	60	108
	4. Wood and other combustible material	60	108
E.	MISCELLANEOUS		
	1. Issuing air 1 inch (25.4 mm) above the enclosure	170	306

[a] The maximum acceptable temperature rise is the marked temperature limit of the capacitor minus an assumed ambient temperature of 30°C (86°F).

[b] This limitation does not apply to a contact mounted directly on a resistor element.

[c] Except for a thermosetting material, the maximum acceptable temperature of a sealing compound when corrected to a 30°C (86°F) ambient temperature is 20°C (36°F) less than the softening point of the compound as determined in accordance with the Standard Test Method for Softening Point by Ring-and-Ball Apparatus, ASTM E28-1992.

[d] A short length of rubber or thermoplastic insulated flexible cord exposed to a temperature in excess of that normally considered as the maximum allowable temperature for the compound involved, such as at the terminals, may be acceptable if supplementary heat-resistant insulation of acceptable dielectric strength is employed on the individual conductors of the cord to prevent deterioration of the compound. In any case, the insulation shall be of a type normally available that has a temperature limit as close as possible to the temperature involved. Reference should be made to the National Electrical Code, ANSI/NFPA 70-1993 for the temperature limits applicable to insulated conductors not included in this table.

[e] This limitation does not apply to a compound that has been investigated and found to be acceptable for a higher temperature.

[f] A fuse that has been investigated and found acceptable for use at a higher temperature may be used at that temperature.

30.2 At the conclusion of the temperature test and while still in a heated condition, a product shall be capable of delivering 125 percent of the secondary rated output current for one half of the load duty cycle portion of a 10-minute time period without causing the protective device mentioned in the Exception to 29.1 to trip. For example, a product shall be capable of delivering 125 percent of the secondary output current without tripping the protective device for:

a) 3 minutes for a machine marked with a 60 percent duty cycle,

b) 4 minutes for a machine marked with an 80 percent duty cycle, and

c) 5 minutes for a machine marked with a 100 percent duty cycle.

30.3 The product is to be connected to a supply circuit as specified in 24.1 and operated as described in 30.4 – 30.14 with the output terminals or leads connected to a resistance load as specified in 27.2.2. Operation is to be continued at the rated duty cycle of the product until temperatures become stabilized. See 30.9.

30.4 The primary is to be energized continuously throughout the test. The total time of each complete on-off cycle of a product for manual welding is to be 10 minutes, and the duty cycle is not to be exceeded.

30.5 A product for manual welding that has taps or adjustments for regulating the output current or voltage is to be tested under conditions of rated output and also under conditions of maximum rated output. The tests are also to be conducted at lower tap settings to determine whether the current capacity of a stepped winding that is in doubt is acceptable for the marked output current of any tap.

30.6 An automatic product that has taps or adjustments for regulating the output current or voltage is to be tested under conditions of rated output.

30.7 The test at rated or maximum rated output is to be conducted with the secondary of the product loaded so that it will deliver its rated or maximum output current at the corresponding duty cycle and at not less than the rated-load voltage. The primary-input voltage is to be maintained at the value specified on the nameplate. See 24.1.

Exception: If the product will not maintain both rated current and voltage, the secondary is to be loaded to rated output current regardless of the resulting load voltage.

30.8 As far as practicable, temperature measurements are to be taken during the test as well as immediately after shutdown. If sufficient time elapses between the instant of shutdown and the time of temperature measurement to permit the temperature to all, corrections are to be applied to obtain as nearly as practicable the temperature at the instant of shutdown. The recorded temperatures are to be the highest values observed during operation or after shutdown if subsequent measurements show increased temperatures.

30.9 A temperature is considered to be stable when three successive readings taken at 10-minute intervals indicate no change. Temperature measurements are to be timed so that the highest temperature during each cycle is observed.

30.10 A product having more than one rating is to be tested at the rating that will produce the greatest temperature rise. If this cannot be predetermined, the product is to be tested separately at each rating.

30.11 All values for temperature rise in Table 30.1 are based on an assumed ambient temperature of 30°C (86°F); however, tests may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F). It is to be assumed that a temperature rise is the same for any ambient temperature within this range.

30.12 Temperatures are to be measured by means of thermocouples, or, for a coil, by the resistance method.

30.13 For the thermocouple method of determining temperature, thermocouples or other temperature-measuring instruments of comparable size are to be applied to the hottest parts that are normally inaccessible to liquid-in-glass thermometers. Depending upon the thickness of the insulation separating them from current-carrying conductors, thermocouple readings may be considerably lower than those obtained by the resistance method. Accordingly, the thermocouples used to determine the temperatures of windings are to be applied directly to the conductors or separated from the metallic circuit only by the integrally-applied insulation of the conductor itself.

30.14 To calculate the temperature rise of a coil by the resistance method, the following formula is to be used:

$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$

in which:

Δt is the temperature rise 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 when the coil is at room temperature;

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

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

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

31 Dielectric Voltage-Withstand Test

31.1 A product, while heated from the temperature test, shall withstand for 1 minute without breakdown the application of a 60-hertz essentially sinusoidal potential of 1000 volts plus twice the maximum operating voltage of any circuit involved between any two circuits, and between any circuit and dead metal parts of the product that may be grounded.

31.2 A switch or other part having an established dielectric voltage-withstand requirement need not be subjected to a test potential higher than that specified in such a requirement, but all other electrical parts are to remain connected during the test. One terminal of any circuit that is connected to the enclosure is to be opened before the test potential is applied between that circuit and dead metal parts.

31.3 The dielectric voltage-withstand test is to be conducted using a 500-volt-ampere or larger capacity transformer, the output voltage of which is essentially sinusoidal and can be varied. The applied potential is to be increased from zero until the required test level is reached, and is to be held at that level for 1 minute. The applied potential is to be increased at a substantially uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter.

Exception: A 500-volt-ampere or larger transformer need not be used if the transformer is provided with a voltmeter to measure directly the applied output potential.

32 Overload Test on Switches and Controls

32.1 A switch, a contactor, a circuit breaker, or other type of control device shall perform acceptably, without electrical or mechanical breakdown or undue burning, pitting, or welding of the contacts, for 100 cycles of operation with the secondary output terminals of the product short-circuited.

Exception: An overload test is not required for a primary-circuit control device consisting of a circuit breaker having voltage and current ratings not less than the primary rating of the product, or a two-pole switch having, at the voltage involved, a horsepower rating at least equal to the numerical value obtained by multiplying the rated primary current of the product in amperes, by 0.1, 0.2, or 0.25, respectively, for a 220 – 250, 440– 480, or 550 – 600-volt product.

32.2 During the test, the frame of a product for use on a grounded-neutral system is to be connected through a 15-ampere cartridge fuse to the grounded conductor. The frame of a product intended for use on any other type of system is to be connected through a 15-ampere fuse to the live pole least likely to arc to ground.

32.3 The test is to be conducted with the product connected to a supply circuit as specified in 24.1, and the rate of operation of the control device is to be 6 cycles per minute. The product is to be operated with any voltage-regulating tap or current-regulating tap, or any other control that may affect the operating current adjusted to cause the highest primary input.

32.4 The connections involved in the operation of a voltage-regulating tap and a current-regulating tap shall be subjected to the overload test specified in 32.1 and 32.2, if the tap is constructed or located so that it may be operated under load conditions.

Exception: If more than one such control is provided on the product, the test need not be conducted on a set of taps, a tap switch, or a primary switch that has no off position, and that is plainly marked to indicate that it is not to be operated under load, provided that at least one other control device on the product is known to perform acceptably under the overload conditions. See 43.13.

33 Endurance Test on Switches and Controls

33.1 A switch, a circuit breaker, or other type of control device that is not known to be acceptable for the purpose shall make and break the full rated current of the product for 6000 cycles of operation. There shall be no electrical or mechanical breakdown of the device nor undue burning, pitting, or welding of the contacts.

33.2 The test is to be conducted with the product operating under the conditions of current and voltage described in 24.1 and 30.7 and with the frame of the product grounded as specified in 32.2. The rate of operation of the control device is to be 6 cycles per minute. The load on the secondary circuit is to be a variable resistor as described in 27.2.2.

33.3 A tap switch for voltage or current regulation shall perform acceptably for 6000 cycles of operation. A switch connected in a circuit other than the secondary – output – circuit shall be tested with the primary energized, but with no load on the secondary. A switch in the secondary circuit shall be subjected to mechanical operation only.

34 Dielectric Voltage-Withstand Test on Switches and Controls

34.1 A switch, a circuit breaker, or other control device that has been subjected to the overload and endurance tests shall withstand for 1 minute without breakdown, the application of a 60-hertz essentially sinusoidal potential of 1000 volts plus twice the maximum operating voltage between:

a) Line and load with the control in the open position,

b) Live parts of opposite polarity with the control in both the open and closed position, and

c) Between live parts and dead metal parts of the product that may be grounded with the control in the closed position.

34.2 The transformer used for the test specified in 34.1 is to be as specified in 31.3.

35 Short Circuit Test on Capacitors

35.1 When operated with no load on the secondary and with any or all capacitors short-circuited, a product shall not:

a) Become a risk of fire,

b) Emit flame or molten metal,

c) Breakdown mechanically, or

d) Become a risk of electric shock because of electrical breakdown.

35.2 The test is to be conducted with the product connected to a supply circuit of the frequency and voltage specified in 24.1, with the primary connections fused at 200 percent of rated input current, but not less than 20 amperes, and with the frame of the product grounded as described in 32.2.

35.3 If fuses are the overcurrent protection provided on the product, the highest rated fuses that the fuseholder will accommodate are to be in place during the test.

35.4 An adjustable circuit breaker used for overcurrent protection is to be set for its maximum current during the test.

35.5 The product is to be operated until:

a) Constant temperatures are reached,

b) Burnout occurs, or

c) The primary overcurrent-protective means in the supply circuit or on the product opens the circuit.

36 Abnormal Operation Test

36.1 A product for manual welding shall not become a risk of fire or electric shock when operated for 8 hours at rated output current and at either 150 percent of its rated duty cycle or continuously, whichever is the lesser value.

36.2 The product is to be connected to a supply circuit as specified in 24.1, and the frame of the product is to be grounded as specified in 32.2.

36.3 The product is to be operated without regard to temperatures attained on any part of the product; and a primary circuit breaker, if provided as part of the product, is to be reset as many times as necessary to provide for the required operation throughout the entire 8-hour period.

36.4 A product having a voltage-regulating or a current-regulating tap is to be operated on the setting of the tap that will give the greatest primary input. An automatic temperature-regulating or -limiting control or other protective device provided as part of the product is to be shunted out of the circuit during the test, unless the control has been shown by investigation to be acceptable for the intended use.

36.5 The product is considered to present a risk of fire if flames, molten metal, or other materials are emitted that ignite a cotton indicator placed under the product. The cotton indicator is to extend 6 inches (152 mm) beyond the sides of the product. The cotton may be secured in place with 1/2-inch (12.7 mm) hardware cloth. The cotton indicator is to be dry, absorbent surgical cotton such as is commonly used for medical purposes.

37 Stalled Fan Abnormal Operation Test

37.1 A product that depends upon a motor-driven fan to comply with the temperature requirements specified in Table 30.1 shall not:

a) Become a risk of fire,

b) Emit flame or molten metal, or

c) Break down electrically or mechanically when operated for 8 hours under the conditions specified in 30.7 with the fan disconnected.

37.2 A product provided with thermal or overcurrent protection is to be reset to continue the test within the 8-hour period if such resetting is accomplished without bypassing the protective circuitry. Temperatures attained on any part of the product are not specified.

38 Compression and Torsion Tests

38.1 General

38.1.1 When subjected to the compression and torsion tests described in 38.2.1 and 38.3.1, an enclosure that is thinner than that specified in Tables 7.2 and 7.3 – see 7.8 – shall be reinforced so that its strength and rigidity are shown to be not less than those of an enclosure of the same maximum length and width having the thickness of sheet steel that would otherwise be required.

38.2 Compression test

38.2.1 Force is to be applied to the end, side, and rear walls of each enclosure. The value of force and limit of deflection are not specified, but the force on each wall of both the test and reference enclosures is to be sufficient to result in a measurable deflection of the test enclosure. For the test, the enclosure is to rest on a smooth, solid, horizontal surface. A vertical force is to be applied, at any point, through a rod having a 1/2-inch-square (12.7 mm) flat, steel face.

38.3 Torsion test

38.3.1 With each enclosure in a vertical position, one end wall is to be secured to a rigid surface. The opposite end wall is then to be twisted around the vertical axis of the enclosure. The force on both the test and the reference enclosures shall be sufficient to result in a measurable angle of rotation of the test enclosure.

39 Strain Relief Test

39.1 When tested as specified in 39.2, the strain-relief means provided on the flexible supply cord and on the output leads or cord shall withstand for 1 minute, without displacement, a direct pull applied to the cord with the internal connections disconnected. The means of strain relief is not acceptable if, at the point of disconnection of the conductors, there is such movement of the cord to indicate that stress on the connections would have resulted.

39.2 A 35-pound (15.8 kg) weight is to be suspended on a cord incorporating 16 AWG (1.3 mm^2) or 18 AWG (0.82 mm^2) conductors, a 50-pound (22.7 kg) weight for a cord having 12 AWG (3.3 mm^2) or 14 AWG (2.1 mm^2) conductors, and a 100-pound (45.4 kg) weight for a cord having conductors 10 AWG (5.3 mm^2) or larger. The weight is to be supported by the product so that the strain-relief means will be stressed from any angle that the construction of the product permits.

Exception: The weight used for conducting the test on the output leads or cord need not be more than that required to be applied to the supply cord.