UL 1650

STANDARD FOR SAFETY

Portable Power Cable

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UL Standard for Safety for Portable Power Cable, UL 1650

First Edition, Dated January 28, 2015

Summary of Topics

This revision of ANSI/UL 1650 dated September 7, 2023 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

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

The requirements are substantially in accordance with Proposal(s) on this subject dated July 24, 2023.

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JANUARY 28, 2015
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UL 1650

Standard for Portable Power Cable

Prior to the first edition, the requirements for the products covered by this standard were included in the Outline of Investigation for Portable Power Cable, UL 1650.

First Edition

January 28, 2015

This ANSI/UL Standard for Safety consists of the First Edition including revisions through September 7, 2023.

The most recent designation of ANSI/UL 1650 as a Reaffirmed American National Standard (ANS) occurred on September 7, 2023 ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 General

1.1.1 This Standard specifies the requirements for Portable Power Cables for use in accordance with the National Electrical Code, NFPA 70.

1.1.2 Any references to UL 2556, refer to the Standard for Wire and Cable Test Methods, UL 2556.

2 Units of Measurement

2.1 The values stated without parentheses are the requirements. Values in parentheses are explanatory or approximate information.

3 Undated References

3.1 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.

4 Glossary

4.1 For the purpose of this standard the following definitions apply:

4.2 GROUND-CHECK CONDUCTOR – A conductor used in cables to monitor the continuity of the grounding circuit, so that a discontinuity or "open" in the grounding circuit causes the power conductors to be de-energized.

4.3 PORTABLE POWER CABLE – Cable used to supply power to mobile equipment and machinery.

4.4 XL– A thermoset compound whose characteristic constituent is cross-linked polyethylene (XLPE), cross-linked polyvinyl chloride (XLPVC), cross-linked ethylene vinyl acetate (XLEVA), or blends thereof.

CONSTRUCTION

5 General

5.1 Portable power cables consist of either a single insulated conductor or two or more insulated circuit conductors with or without grounding conductors with an overall reinforced jacket. They employ flexible stranded copper conductors in a size range of 12 AWG to 500 kcmil (3.31 – 253 mm^2), except for single conductor Type W that employs flexible stranded copper conductors in sizes 12 AWG to 1000 kcmil (3.31 – 507 mm^2). This cable is rated 2000 V, 75°C (167°F) or 90°C (194°F) dry, and 60°C (140°F) or 75°C (167°F) where exposed to oil. For cable so marked, ratings of 60°C (140°F), 75°C (167°F), or 90°C (194°F) "wet" are also assigned. The term "wet" indicates that the cable is acceptable for immersion in water. Wet rated cable that has been additionally investigated for use where exposed to the direct rays of the sun is marked "Sunlight Resistant" or "Sun Res."

5.2 Portable power cables shall consist of the following circuit, grounding and ground-check conductors:

a) Type G – Contains two to six circuit conductors and a grounding conductor. The grounding conductor is either bare or covered with a green-colored braid or tape or extruded layer, and may either be a single conductor or be sectioned into two or more parts.

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b) Type G-GC – Same as Type G except that the cable also contains one 12 AWG (3.31 mm^2) or larger, yellow insulated conductor which is used as a ground check.

c) Type W – Contains one to six circuit conductors and may or may not contain a grounding conductor in cables with three or more conductors. If included, the grounding conductor is fully insulated and colored green.

d) Type PPE – Contains one to six circuit conductors and may or may not contain a grounding conductor in cables with three or more conductors. If included, the grounding conductor is fully insulated and colored green.

6 Conductors

6.1 General

6.1.1 The circuit conductors shall be annealed, stranded copper, bare, or tin-coated in accordance with the Standard for Thermoset-Insulated Wires and Cables, UL 44, in sizes 12 AWG to 1000 kcmil.

6.2 Coated copper conductors

6.2.1 Each tin-coated conductor shall comply with the requirements of the Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes, ASTM B33.

6.2.2 A tin coating is appropriate for use on individual wires (strands) or selected wires, such as the outer layer of wires of a stranded conductor. The tin coating shall comply with 6.2.1.

6.3 Uncoated copper conductors

6.3.1 Each wire in an uncoated copper conductor shall comply with the requirements of Standard Specification for Soft or Annealed Copper Wire, ASTM B3.

7 Conductor Assembly

7.1 General

7.1.1 Conductors shall be of an assembly indicated in Table 7.1.

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Table 7.1
Conductor Assembly

Conductor size range AWG or kcmil (mm^2)	Assembly
12 – 1000 (3.31 – 507)	Concentric rope lay and rope lay
12 – 9 (3.31 – 6.63)	Combination unilay
12 – 3 (3.31 – 26.7)	Concentric, compressed, bunched

7.2 Strands

7.2.1 Copper strands smaller than 36 AWG (0.0127 mm^2) shall not be used. Circuit and grounding conductors 12 – 9 AWG (3.31 – 6.63 mm^2) shall contain a minimum of 19 strands; 8 – 3 AWG (8.37 – 26.7 mm^2) circuit conductors shall contain a minimum of 49 strands; 2 AWG – 2/0 (33.6 – 67.4 mm^2) shall

contain a minimum of 133 strands; and 3/0 – 1000 kcmil (85 – 507 mm^2) shall contain a minimum 259 strands.

7.3 Length and direction of lay

7.3.1 Every stranded conductor or a bunch-stranded conductor twisted as a single bunch, shall comply with the following:

a) Rope-lay conductors in a 12 AWG – 1000 kcmil (3.31 – 507 mm^2) conductor with bunch-stranded or concentric-stranded members shall be either unidirectional or reversed. All unidirectional lays and the outer layer of reversed lays shall be in the left-hand direction.

b) For a bunch-stranded member of a rope-lay-stranded conductor in which the members are formed into rope-stranded components that are then cabled into the final conductor, the length of lay of the individual members within each component shall not be more than 30 times the outside diameter of one of those members.

c) For a concentric-stranded member of a rope-lay-stranded conductor, the length of lay of the individual strands in a member shall be 8 – 16 times the outside diameter of the member. The direction of lay of the strands in each member shall be reversed in successive layers of the member.

d) The length of lay of the strands in both layers of a 19-wire combination round-wire unilay-stranded copper conductor shall be 8 – 16 times the outside diameter of the completed conductor. Otherwise, the length of lay of the strands in every layer of a concentric-lay-stranded conductor consisting of fewer than 37 strands shall be 8 – 16 times the outside diameter of the conductor.

e) The length of lay of the strands in the outer two layers of a concentric-lay-stranded conductor consisting of 37 or more strands shall be 8 – 16 times the outside diameter of the conductor.

f) The length of lay of the outer layer of a rope-lay-stranded conductor shall be 8 – 16 times the outside diameter of that layer.

7.3.2 For bunch-stranded conductors, simple bunching (untwisted strands) shall not be used. The length of lay of the strands in a bunch-stranded conductor twisted as a single bunch shall not be greater than indicated in Table 7.2. The direction of lay of the strands in a bunch-stranded conductor shall be left-hand.

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Table 7.2
Length of Lay of Strands in a Bunch-Stranded Conductor Twisted as a Single Bunch[a]

Size of conductor AWG (mm^2)	Maximum acceptable length of lay inches (mm)
2.08 (14)	1.75 (44)
3.31 (12)	2.00 (51)
5.26 (10)	2.50 (64)
8.37 (8)	2.75 (70)
13.3 (6)	3.38 (86)
Larger than 13.3 (6)	16 times the conductor diameter

7.4 Grounding conductor

7.4.1 The grounding conductor where used, may be a single conductor or may be sectioned into two or more equal parts. The grounding conductor for Types W and PPE shall be the same size as the circuit

conductors. The grounding conductor for Types G and G-GC shall be sized in accordance with Table 7.3 – Table 7.6. If standard AWG sizes are not used for the grounding conductor, the grounding conductor shall be at least 60 percent of the size of the largest circuit conductor. The total circular mil area of a sectioned grounding conductor shall be equal to or greater than that of the corresponding size of a single conductor.

Table 7.3
Grounding conductors for Type G, round construction

	2 conductor	3 conductor	4 conductor	5 conductor	6 conductor
Circuit conductor size, AWG (mm^2) or kcmil	Size of sectioned grounding conductors, AWG (mm^2)	Size of sectioned grounding conductors, AWG (mm^2)	Size of sectioned grounding conductors, AWG (mm^2)	Size of central grounding conductor, AWG (mm^2)	Size of central grounding conductor, AWG (mm^2)
12 (3.31)	14 (2.08)	14 (2.08)	14 (2.08)	12 (3.31)	12 (3.31)
10 (5.26)	12 (3.31)	12 (3.31)	12 (3.31)	10 (5.26)	10 (5.26)
8 (8.37)	10 (5.26)	10 (5.26)	12 (3.31)	8 (8.37)	8 (8.37)
6 (13.3)	10 (5.26)	10 (5.26)	12 (3.31)	7 (10.6)	7 (10.6)
4 (21.2)	8 (8.37)	8 (8.37)	10 (5.26)	6 (13.3)	6 (13.3)
3 (26.7)	6 (13.3)	8 (8.37)	10 (5.26)	5 (16.8)	5 (16.8)
2 (33.6)	6 (13.3)	8 (8.37)	9 (6.63)	4 (21.2)	4 (21.2)
1 (42.4)	5 (16.8)	7 (10.6)	8 (8.37)	3 (26.7)	3 (26.7)
1/0 (53.5)	4 (21.2)	6 (13.3)	7 (10.6)	2 (33.6)	2 (33.6)
2/0 (67.4)	3 (26.7)	5 (16.8)	6 (13.3)	1 (42.4)	1 (42.4)
3/0 (85.0)	2 (33.6)	4 (21.2)	5 (16.8)	1/0 (53.5)	1/0 (53.5)
4/0 (107.2)	1 (42.4)	3 (26.7)	4 (21.2)	2/0 (67.4)	2/0 (67.4)
250 (127)	1/0 (53.5)	2 (33.6)	3 (26.7)	3/0 (85.0)	3/0 (85.0)
300 (152)	1/0 (53.5)	1 (42.4)	3 (26.7)	4/0 (107.2)	4/0 (107.2)
350 (177)	2/0 (67.4)	1 (42.4)	2 (33.6)	250 (127)	250 (127)
400 (203)	3/0 (85.0)	1/0 (53.5)	1 (42.4)	250 (127)	250 (127)
450 (228)	3/0 (85.0)	1/0 (53.5)	1 (42.4)	300 (152)	300 (152)
500 (253)	4/0 (107.2)	1/0 (53.5)	1/0 (53.5)	300 (152)	300 (152)

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Table 7.4
Grounding conductors for Type G, flat construction

	2 conductor		3 conductor	
Circuit conductor size, AWG or kcmil	Size of grounding conductor, AWG	Minimum number of strands per conductor	Size of each of 2 grounding conductors, AWG	Minimum number of strands per conductor
8 (8.37)	9 (6.63)	49	9 (6.63)	49
6 (13.3)	8 (8.37)	49	8 (8.37)	49
4 (21.2)	7 (10.6)	49	8 (8.37)	49
3 (26.7)	6 (13.3)	133	7 (10.6)	49
2 (33.6)	5 (16.8)	133	6 (13.3)	133
1 (42.4)	4 (21.2)	133	5 (16.8)	133
1/0 (53.5)	3 (26.7)	133	4 (21.2)	133
2/0 (67.4)	2 (33.6)	259	3 (26.7)	133
3/0 (85.0)	1 (42.4)	259	2 (33.6)	259
4/0 (107.2)	1/0 (53.5)	259	1 (42.4)	259

Table 7.5
Grounding conductors for Type G-GC, 3 conductor, round construction

Circuit conductor size, AWG or kcmil	Size of each of 2 grounding conductors, AWG (mm^2)	Minimum number of strands per conductor	Size of ground-check conductor, AWG (mm^2)	Minimum number of strands per conductor
12 (3.31)	12 (3.31)	19	12 (3.31)	19
10 (5.26)	10 (5.26)	19	12 (3.31)	19
8 (8.37)	10 (5.26)	19	10 (5.26)	19
6 (13.3)	10 (5.26)	19	10 (5.26)	19
4 (21.2)	8 (8.37)	49	10 (5.26)	19
3 (26.7)	8 (8.37)	49	10 (5.26)	19
2 (33.6)	7 (10.6)	49	10 (5.26)	19
1 (42.4)	6 (13.3)	133	8 (8.37)	49
1/0 (53.5)	5 (16.8)	133	8 (8.37)	49
2/0 (67.4)	4 (21.2)	133	8 (8.37)	49
3/0 (85.0)	3 (26.7)	259	8 (8.37)	49
4/0 (107.2)	2 (33.6)	259	8 (8.37)	49
250 (127)	2 (33.6)	259	8 (8.37)	49
300 (152)	1 (42.4)	259	8 (8.37)	49
350 (177)	1/0 (53.5)	259	8 (8.37)	49
400 (203)	1/0 (53.5)	259	8 (8.37)	49
450 (228)	2/0 (67.4)	259	8 (8.37)	49
500 (253)	2/0 (67.4)	259	8 (8.37)	49

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Table 7.6
Grounding conductors for Type G-GC, 3 conductor, flat construction

Circuit conductor size, AWG or kcmil	Size of grounding conductor, AWG	Minimum number of strands per conductor	Size of ground-check conductor	Minimum number of strands per conductor
8 (8.37)	10 (5.26)	19	10 (5.26)	19
6 (13.3)	8 (8.37)	49	8 (8.37)	49
4 (21.2)	7 (10.6)	49	8 (8.37)	49
3 (26.7)	7 (10.6)	49	8 (8.37)	49
2 (33.6)	6 (13.3)	133	8 (8.37)	49
1 (42.4)	5 (16.8)	133	8 (8.37)	49
1/0 (53.5)	4 (21.2)	133	8 (8.37)	49
2/0 (67.4)	3 (26.7)	133	8 (8.37)	49
3/0 (85.0)	2 (33.6)	259	8 (8.37)	49
4/0 (107.2)	1 (42.4)	259	8 (8.37)	49

7.4.2 The extruded, green-colored insulation on a single grounding conductor Type W or PPE shall have the same thickness and shall comply with the applicable requirements for the circuit conductor insulation. When used, the insulation on a sectioned grounding conductor in Type G or G-GC shall be of the same material as the circuit conductors and shall not be less than 30 mils. A green-colored braid or tape may be employed on the grounding conductor in types G or G-GC.

7.4.3 For a ground-check conductor, one 12 AWG (3.31 mm^2) or larger yellow insulated ground check conductor shall be provided in Type G-GC only. The insulation shall be polypropylene or of the same material as the circuit conductors and shall not be less than 30 mils min average for 10 AWG (5.26 mm^2) and 12 AWG (3.31 mm^2), and not less than 45 mils for 8 AWG (8.37 mm^2) and larger. The ground-check conductor shall have a minimum of 49 strands. If a larger sized ground-check conductor is used, the minimum number of strands shall not be less than that specified for a power conductor of the same size.

7.5 Insulation

7.5.1 The insulation shall be XL or EP for types G, G-GC, and W. Type PPE shall employ thermoplastic elastomer (TPE). Thicknesses shall be in accordance with Table 7.7.

Table 7.7
Insulation thickness

Size of circuit conductor, AWG (mm^2)	Minimum average thickness, inches (mm)	Minimum thickness at any point, inches (mm)
12 – 2 (3.31 – 33.6)	0.060 (1.52)	0.054 (1.37)
1 – 4/0 (42.4 – 107.2)	0.080 (2.03)	0.072 (1.83)
250 – 500 kcmil (127 – 253)	0.095 (2.41)	0.086 (2.18)
501 – 1000 (304 – 507)	0.110 (2.79)	0.099 (2.50)

7.6 Covering

7.6.1 An optional nonmetallic braid, tape or wrap may be employed as a covering. The covering shall not be green, except for grounding conductors.

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7.7 Overall assembly

7.7.1 For multi-conductor Type W and PPE constructions, a two, three, or four-conductor, flat cable is acceptable. For Type G, two and three conductor constructions are acceptable. For Type G-GC flat cable, a 3-conductor construction is acceptable. If the conductors are twisted, the length of lay of twisted conductors shall be ten (10) times the diameter of the cabled core. Fillers shall be used, when required, to ensure that the cable is round. The conductor assembly may be enclosed in a nonmetallic braid, tape or wrap. The direction of lay shall be left hand.

Table 7.8
Maximum length of lay

Number of circuit conductors	Length of lay of conductors
2	20 times diameter of individual circuit conductor
3	21 times diameter of individual circuit conductor
4	23 times diameter of individual circuit conductor
5	27 times diameter of individual circuit conductor
6	30 times diameter of individual circuit conductor

7.8 Jacket

7.8.1 The jacket material shall be neoprene, NBR/PVC, CPE, or CP for types G, G-GC, and W; or TPE for Type PPE. The jacket shall be applied in one or two layers. If applied in two layers, the outer layer shall constitute at least 50 percent of the total thickness of the overall jacket.

7.8.2 The jacket shall be reinforced by a tape, two servings, or braid of a natural or synthetic material. If two servings are used, they shall be applied in opposite directions of lay. The reinforcing layer shall be under a single layer jacket, or between the layers of a two-layered construction. The total jacket thickness shall be in accordance with Table 7.9.

Table 7.9
Thickness of jacket

Circuit conductor size, AWG (mm^2)	Single conductor		2-Conductor		3-Conductor		4-Conductor		5-Conductor		6-Conductor	
	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)
12 (3.31)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)
10 (5.26)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)	0.075 (1.91)	0.060 (1.52)
8 (8.37)	0.075 (1.91)	0.060 (1.52)	0.109 (2.77)	0.087 (2.20)	0.141 (3.58)	0.113 (2.87)	0.141 (3.58)	0.113 (2.87)	0.125 (3.18)	0.100 (2.54)	0.125 (3.18)	0.100 (2.54)
6 (13.3)	0.095 (2.41)	0.076 (1.93)	0.109 (2.77)	0.087 (2.20)	0.141 (3.58)	0.113 (2.87)	0.141 (3.58)	0.113 (2.87)	0.140 (3.56)	0.112 (2.84)	0.140 (3.56)	0.112 (2.84)
4 (21.2)	0.095 (2.41)	0.076 (1.93)	0.109 (2.77)	0.087 (2.20)	0.125 (3.18)	0.100 (2.54)	0.125 (3.18)	0.100 (2.54)	0.155 (3.94)	0.124 (3.15)	0.155 (3.94)	0.124 (3.15)
3 (26.7)	0.095 (2.41)	0.076 (1.93)	0.109 (2.77)	0.087 (2.20)	0.125 (3.18)	0.100 (2.54)	0.125 (3.18)	0.100 (2.54)	0.155 (3.94)	0.124 (3.15)	0.155 (3.94)	0.124 (3.15)

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Table 7.9 Continued

Circuit conductor size, AWG (mm^2)	Single conductor		2-Conductor		3-Conductor		4-Conductor		5-Conductor		6-Conductor	
	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)	MAT, inches (mm)	MAAP, inches (mm)
2 (33.6)	0.095 (2.41)	0.076 (1.93)	0.141 (3.58)	0.113 (2.87)	0.141 (3.58)	0.113 (2.87)	0.125 (3.18)	0.100 (2.54)	0.170 (4.32)	0.136 (3.45)	0.170 (4.32)	0.136 (3.45)
1 (42.4)	0.095 (2.41)	0.076 (1.93)	0.156 (3.96)	0.125 (3.18)	0.141 (3.58)	0.113 (2.87)	0.141 (3.58)	0.113 (2.87)	0.205 (5.20)	0.164 (4.17)	0.205 (5.20)	0.164 (4.17)
1/0 (53.5)	0.095 (2.41)	0.076 (1.93)	0.156 (3.96)	0.125 (3.18)	0.156 (3.96)	0.125 (3.18)	0.156 (3.96)	0.125 (3.18)	0.205 (5.20)	0.164 (4.17)	0.205 (5.20)	0.164 (4.17)
2/0 (67.4)	0.095 (2.41)	0.076 (1.93)	0.156 (3.96)	0.125 (3.18)	0.156 (3.96)	0.125 (3.18)	0.156 (3.96)	0.125 (3.18)	0.205 (5.20)	0.164 (4.17)	0.205 (5.20)	0.164 (4.17)
3/0 (85.0)	0.095 (2.41)	0.076 (1.93)	0.156 (3.96)	0.125 (3.18)	0.156 (3.96)	0.125 (3.18)	0.156 (3.96)	0.125 (3.18)	0.205 (5.20)	0.164 (4.17)	0.220 (5.59)	0.176 (4.47)
4/0 (107.2)	0.095 (2.41)	0.076 (1.93)	0.172 (4.37)	0.138 (3.50)	0.172 (4.37)	0.138 (3.50)	0.156 (3.96)	0.125 (3.18)	0.220 (5.59)	0.176 (4.47)	0.220 (5.59)	0.176 (4.47)
250 (127)	0.095 (2.41)	0.076 (1.93)	0.155 (3.94)	0.124 (3.15)	0.240 (6.10)	0.192 (4.88)	0.270 (6.86)	0.216 (5.49)	–	–	–	–
300 (152)	0.095 (2.41)	0.076 (1.93)	0.155 (3.94)	0.124 (3.15)	0.240 (6.10)	0.192 (4.88)	0.270 (6.86)	0.216 (5.49)	–	–	–	–
350 (177)	0.095 (2.41)	0.076 (1.93)	0.170 (4.32)	0.136 (3.45)	0.240 (6.10)	0.192 (4.88)	0.270 (6.86)	0.216 (5.49)	–	–	–	–
400 (203)	0.095 (2.41)	0.076 (1.93)	0.200 (5.08)	0.160 (4.06)	0.270 (6.86)	0.216 (5.49)	0.310 (7.87)	0.248 (6.30)	–	–	–	–
450 (228)	0.095 (2.41)	0.076 (1.93)	0.200 (5.08)	0.160 (4.06)	0.270 (6.86)	0.216 (5.49)	0.310 (7.87)	0.248 (6.30)	–	–	–	–
500 (253)	0.095 (2.41)	0.076 (1.93)	0.200 (5.08)	0.160 (4.06)	0.270 (6.86)	0.216 (5.49)	0.310 (7.87)	0.248 (6.30)	–	–	–	–
600 – 1000 (304 – 507)	0.110 (2.79)	0.088 (2.23)	–	–	–	–	–	–	–	–	–	–

MAT – Minimum average thickness

MAAP – Minimum thickness at any point

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TEST PROGRAM

8 Performance and Test Requirements

8.1 General

8.1.1 Construction requirements and the test program are summarized in Table 8.1. The test methods are indicated below.

Table 8.1
Portable power cable

	Type			
	G	G-GC	W	PPE
Temperature ratings, °C (°F) dry	75, 90 (167, 194)			
Temperature ratings, °C (°F) oil	60 or 75 (140, 167)			
Temperature ratings, °C (°F) wet, optional	60, 75, or 90 (140, 167, 194)			
Voltage rating, V	2000			
Size of conductors, AWG (mm^2)	12 AWG – 500 kcmil (3.31 – 253)	12 AWG – 500 kcmil (3.31 – 253)	12 AWG – 1000 kcmil (3.31 – 507)	12 AWG – 500 kcmil (3.31 – 253)
Number of circuit conductors	2 – 6	3	1 (12 AWG – 1000 kcmil) 2 – 6 (12 AWG – 500 kcmil)	1 – 6
Grounding conductor, Clause	7.4	7.4	Optional 7.4 (for three or more conductors only)	Optional 7.4 (for three or more conductors only)
Ground check conductor, Clause		7.4.3		
Conductor:				
Material, Clause	6.2.1, 6.2.2			
Stranding, Clause	7.2, 7.3			
Insulation, Clause	7.5.1			
Insulation class; Table	1, 2, or 3; Table 8.2	1, 2, or 3 5 (for GC only); Table 8.2	1, 2, or 3; Table 8.2	4; Table 8.2
Thickness, Table	Table 7.7			
Jacket, Clause	7.8.1			
Jacket class; Table	A, B; Table 8.3			C
Thickness, Table	Table 7.9			
Tests, Clause:				
Physical properties				
Insulation	8.2.1			
Jackets	8.2.2			
Copper corrosion	8.3			
Cold bend	8.4			
Jacket resistance	8.5			
Horizontal flame test – FT2	8.6			
Vertical flame test – FT1 optional	8.7			
Flame resistance of electrical cables – FT5 optional	8.8			
Dielectric strength for all finished types	8.9			
Insulation resistance	8.10			
Durability of ink printing	8.11			
Heat-shock resistance	–	–	–	8.16

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Table 8.1 Continued

	Type			
	G	G-GC	W	PPE
Deformation – Type PPE only	–	–	–	8.17
Additional tests for wet rated				
Capacitance and relative permittivity	8.12			
Long term insulation resistance in water	8.13			
Additional tests for sunlight resistance				
Weather resistance – cables marked sunlight resistant	8.14			
Swelling and blistering of thermoset jackets – Types W, G, G-GC marked sunlight resistant	8.15	8.15	8.15	–

8.2 Physical properties

8.2.1 Insulation

8.2.1.1 The physical properties of the various classes of insulation when tested before and after accelerated aging, shall comply with the applicable requirements given in Table 8.2. Compliance shall be determined in accordance with the test, Physical Properties (ultimate elongation and tensile strength), in UL 2556.

Table 8.2
Physical properties of insulation

		EP	XL		TPE	Polypropylene (ground check only)
		75 or 90°C (167 or 194°F) rated	75°C (167°F) rated	90°C (194°F) rated	75 or 90°C (167 or 194°F) rated	90°C (194°F) rated
Class		1	2	3	4	5
Condition	Test					
Before aging	Elongation, minimum	250 percent	150 percent	150 percent	200 percent	300 percent
	Tensile strength, minimum, lbf/in^2 (MPa)	700 (4.8 MPa)	1500 (10.3 MPa)	1500 (10.3 MPa)	800 (5.5 MPa)	3000 (20.6 MPa)
	Tensile stress at 100 percent elongation minimum, lbf/in^2					2500
After air oven accelerated aging		121 ±1°C (250 ±1.8°F) for 7 days	113 ±1°C (235 ±1.8°F) for 7 days	121 ±1°C (250 ±1.8°F) for 7 days	121 ±1°C (250 ±1.8°F) for 7 days	121 ±1°C (250 ±1.8°F) for 7 days
	Tensile strength, minimum	75 percent of unaged value	70 percent of unaged value	70 percent of unaged value	75 percent of unaged value	75 percent of unaged value
	Elongation, minimum	75 percent of unaged value	70 percent of unaged value	70 percent of unaged value	75 percent of unaged value	75 percent of unaged value

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8.2.2 Jackets

8.2.2.1 The physical properties of the various classes of jackets when tested before and after accelerated aging, shall comply with the applicable requirements given in Table 8.3. Compliance shall be determined in accordance with the test, Physical Properties (ultimate elongation and tensile strength), in UL 2556 conducted on die-cut samples.

Table 8.3
Physical properties of jackets

			Material and properties		
			Neoprene, CP, CPE, NBR/PVC		TPE
			75°C (167°F)	90°C (194°F)	75 or 90°C (167 or 194°F)
Class			A	B	C
Condition	Test				
Before aging	Elongation	Minimum	200 percent	200 percent	200 percent
	Tensile strength	Minimum	1200 lbf/in^2 (8.3 MPa)	1200 lbf/in^2 (8.3 MPa)	1200 lbf/in^2 (8.3 MPa)
	Air-oven test	Temperature	100 ±1°C (212 ±1.8°F)	110 ±1°C (230 ±1.8°F)	121 ±1°C (250 ±1.8°F)
	Time		10 days	10 days	7 days
After accelerated aging	Minimum percent of results obtained on unaged specimens	Elongation	50	50	75
		Tensile strength	50	50	75
Oil 60°C (140°F)	Temperature		121°C (250°F)		60°C (140°F)
	Time		18 hours		7 days
	Minimum percent of results obtained on unaged specimens	Elongation	60	50	75
		Tensile strength	60	50	75
Oil 75°C (167°F)			60 days		N/A
			75°C (167°F)		
	Minimum percent of results obtained on unaged specimens	Elongation	65	65	
		Tensile strength	65	65	

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8.3 Copper corrosion

8.3.1 A bare (uncoated) copper insulated conductor shall show no evidence of corrosion when tested in accordance with the test, Copper Corrosion, in UL 2556, and when performed at the temperature and for the duration under air oven test described in Table 8.3.

8.4 Cold bend

8.4.1 The insulation and jacket shall show no cracks when a specimen of the finished cable is conditioned at the temperature specified in Table 8.4 for 4 hours and, while still at the specified temperature, wound the required number of turns around the mandrel having a diameter as specified in Table 8.5. Compliance shall be determined in accordance with the test, Cold Bend, in UL 2556.

Table 8.4
Temperature for cold bend test

Type of cable	Test temperature
Any cable marked minus 40°C (minus 40°F)	minus 40°C (minus 40°F)
Any cable marked minus 50°C (minus 58°F)	minus 50°C (minus 58°F)
Any cable marked minus 60°C (minus 76°F)	minus 60°C (minus 76°F)
Any cable marked minus 70°C (minus 94°F)	minus 70°C (minus 94°F)
Any cable not marked with a temperature rating	minus 20°C (minus 4°F)

Table 8.5
Mandrel diameter for cold bend test

Minor diameter of flat cable or overall diameter of round finished cable, inches (mm)	Diameter of mandrel, inches (mm)	Number of turns around mandrel (see Note 1)
0.376 – 0.500 (9.53 – 12.70)	1.00 (25.4)	6
0.501 – 0.625 (12.71 – 15.88)	1.25 (31.8)	6
0.626 – 0.750 (15.89 – 19.05)	1.50 (38.0)	1
0.751 – 0.874 (19.06 – 22.22)	1.75 (44.5)	1
0.875 – 1.00 (22.23 – 25.40)	2.00 (50.8)	1
1.01 – 1.13 (25.41 – 28.58)	2.25 (57.1)	1
1.14 – 1.25 (28.59 – 31.75)	2.50 (63.5)	1
1.26 – 1.38 (31.76 – 34.92)	2.75 (69.9)	1
1.39 – 1.50 (34.93 – 38.10)	3.00 (76.2)	1
1.51 – 1.63 (38.11 – 41.28)	3.25 (82.6)	1
1.64 – 1.75 (41.29 – 44.45)	3.50 (88.9)	1
1.76 – 1.88 (44.46 – 47.62)	3.75 (95.2)	1
1.89 – 2.00 (47.63 – 50.8)	4.00 (101.6)	1
Larger than 2.00 (50.8)	2 X cable diameter	1
Note: The specimen shall be wound six close turns around the mandrel.		

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8.5 Jacket resistance

8.5.1 A nonintegral jacket shall exhibit 100 Mohm or more resistance when a specimen of the finished cable is tested in accordance with the test, Jacket resistance, in UL 2556.

8.6 Horizontal flame test – FT2

8.6.1 The length of the charred portion of the specimen of the finished cable shall not exceed 3.9 inches (100 mm), nor shall flaming particles ignite cotton. Compliance shall be determined when tested in accordance with the test, FT2/FH/Horizontal Flame, in UL 2556. In parallel constructions, the major diameter shall be in the vertical plane for testing.

8.7 Vertical flame test – FT1

8.7.1 Finished cables shall not convey flame, continue to burn for more than 60 seconds after five 15 second applications of a standard test flame. Compliance shall be determined in accordance with the test FT1 in UL 2556. A specimen shall be considered to have conveyed flame if more than 25 percent of the

extended portion of the indicator is burned. In parallel construction, the major diameter shall face the burner.

8.8 Flame resistance of electrical cables

8.8.1 Finished cables shall be tested in accordance with the Code of Federal Regulations, 30 CFR § 7.407. Upon completion of the test, the duration of burning shall not exceed 240 seconds, and the length of the burned (charred) area shall not exceed 6 inches.

8.9 Dielectric strength for all finished types

8.9.1 The finished individual insulated conductors of a multi-conductor cable and completed single conductor cables shall be capable of withstanding for 1 minute, without breakdown, the application of an alternating (rms) voltage as indicated in Table 8.6 between each insulated conductor and water in accordance with the test Dielectric Voltage-Withstand Method 1 in UL 2556.

8.9.2 For all cables, the dielectric strength test shall be performed in accordance with the test, Dielectric Voltage-Withstand Method 1, in UL 2556.

Table 8.6
Dielectric strength test voltage on finished types

Size of circuit conductor, AWG (mm^2)	Test voltage, V AC
12 – 10 (3.31 – 5.26)	3000
8 – 2 (8.37 – 33.6)	4000
1 – 4/0 (44.2 – 107)	5000
250 – 500 (127 – 253)	6000
550 – 1000 (279 – 507)	7000

8.10 Insulation resistance

8.10.1 Insulation resistance for all sunlight resistant cables

8.10.1.1 Before assembly into a sunlight resistant cable, finished individual insulated conductors (circuit and grounding, ground-check conductor) shall be capable of exhibiting an insulation resistance of not less than calculated in accordance with 8.10.1.2, when a specimen of at least 50 ft (15 m) is tested in water at 15°C (59°F) immediately following the dielectric strength test described in 8.9.

8.10.1.2 If tested at temperatures different than 15°C (59°F), the values shall be corrected to 15°C.

$$IR_T = K_{15} \times (TFC)^{-(T-15)} \times \log_{10}\frac{D}{d}$$

Where:

IR_T = Insulation resistance in GΩ·m at any temperature T°C

K_{15} = Constant for the insulation material at 15°C in GΩ·m

For EP and XL, K_{15} = 3050 GΩ·m

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For TPE, K_{15} = 610 GΩ·m

TCF = Temperature correction factor coefficient for 1°C for the material (see Annex E in UL 2556)

D = Diameter over the insulation (any units)

d = Diameter under the insulation (units identical to D)

or

IR_T = Insulation resistance in MΩ·1000 ft at any temperature T°C

K_{15} = Constant for the insulation material at 15°C in MΩ·1000 ft

For EP and XL, K_{15} = 10,000 MΩ·1000 ft

For TPE, K_{15} = 2000 MΩ·1000 ft

TCF = Temperature correction factor coefficient for 1°C for the material (see Annex E in UL 2556)

D = Diameter over the insulation (any units)

d = Diameter under the insulation (units identical to D)

8.10.2 Insulation resistance for all indoor cables

8.10.2.1 The insulation resistance between each insulated conductor and between the insulated conductors and any other conductive components and ground shall be not less than 2.5 Mohm·1000 ft (0.76 Gohm·m) at 15°C (59°F) when a specimen of the finished cable at least 50 ft (15 m) in length is tested in air after conditioning for at least 6 hours and immediately following the dielectric strength test described in 8.9.

8.10.3 Test method

8.10.3.1 Compliance with all insulation resistance tests shall be determined in accordance with the test, Insulation resistance, and Annex E (Determination of temperature correction factor) in UL 2556.

8.11 Durability of ink printing

8.11.1 Surface-printed legends shall be complete and legible after two samples have been tested in accordance with the test, Durability of ink printing, in UL 2556. One sample shall be conditioned at the dry rated temperature of the sample for 24 hours.

8.12 Capacitance and relative permittivity

8.12.1 The insulation, without the protective covering, of wet-rated single-conductor cable and of the individual single conductors of multiple-conductor cable immersed in water at the rated temperature of 75°C or 90°C (167 or 194°F), shall comply with each of the following:

a) The relative permittivity determined after immersion for 24 hours shall be 6.0 or less for EP and XL insulations, and shall not be more than 10 for TPE insulation.

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b) The capacitance for TPE, EP, and XL insulations after immersion for 14 days shall be no more than 10 percent higher than the capacitance after a 24 hour immersion.

c) The capacitance determined for EP and XL insulations after a 14 day immersion shall be no more than 4 percent higher than the capacitance determined after immersion for 7 days for EP and XL insulations and not more than 5 percent higher for TPE insulation.

8.12.2 Compliance shall be determined in accordance with the test, Capacitance and relative permittivity, in UL 2556.

8.13 Long-term insulation resistance in water

8.13.1 Thermoset insulation

8.13.1.1 The thermoset insulation, without the protective covering, of wet-rated single-conductor cable and of the individual single circuit conductors of multiple-conductor cable and the grounding conductors from Type W shall have an insulation resistance at the rated temperature in tap water not less than the value calculated using the equation below at any time during immersion. The period of immersion shall be 12 weeks or more if the insulation resistance during the last 6 weeks of the period is higher than 10 MΩ·1000 ft (3 GΩ·m). The period of immersion shall be at least 24 weeks and no more than 36 weeks, unless requested by the manufacturer, if the insulation resistance is less than 10 MΩ·1000 ft (3 GΩ·m) but equals or exceeds the value calculated from the formula below. An AC voltage equal to the voltage rating of the wire shall be applied to the insulated conductor at all times other than while measuring the insulation resistance. These tests are accelerated tests. Composite insulation systems shall be tested as a unit.

$$IR_T = K_{15} \times 6.37 \times 10^{-5} \times \log_{10} \frac{D}{d}$$

Where:

IR_T = Insulation resistance in MΩ·1000 ft at any temperature T°C

K_{15} = Constant for the insulation material at 15°C in MΩ·1000 ft

For EP and XL, K_{15} = 10,000 MΩ·1000 ft

D = Diameter over the insulation (any units)

d = Diameter under the insulation (units identical to D)

or

IR_T = Insulation resistance in GΩ·m at any temperature T°C

K_{15} = Constant for the insulation material at 15°C in GΩ·m

For EP and XL, K_{15} = 3050 GΩ·m

D = Diameter over the insulation (any units)

d = Diameter under the insulation (units identical to D)

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8.13.1.2 The maximum decrease in insulation resistance per week, as determined from a curve (derived from the best fit using the method of least squares representing the average of actual values), for every continuous period of 3 weeks during the latter half of the specified immersion time shall not be more than 4 percent if and while the insulation resistance is 10 MΩ·1000 ft (3 GΩ·m) or more; and shall not be more than 2 percent if the insulation resistance is less than 10 MΩ·1000 ft (3 GΩ·m) but more than the value calculated. If the results of the test do not meet either of these criteria, the period of immersion may be extended by one week intervals, subject to the minimum test period established in 8.13.1.1.

8.13.1.3 Any coil that shows a greater percent decrease in insulation resistance during the extended immersion period may be tested for additional 1 week immersion periods and judged on the basis of the results for every continuous period of 3 weeks during the last 6 weeks of immersion, provided that the final insulation resistance is not less than calculated.

8.13.1.4 Compliance with 8.13.1.1 – 8.13.1.3 shall be determined in accordance with the test, Long-term insulation resistance (Method 1), in UL 2556.

8.13.2 Thermoplastic elastomer insulation

8.13.2.1 The insulation of wet-rated single-conductor cable and of the individual single circuit conductors of multiconductor cable and the grounding conductors from Type PPF shall have insulation resistance at the rated temperature in tap water not less than calculated as indicated below at any time during immersion, in accordance with the test, Insulation resistance, in UL 2556. The period of immersion shall be 12 weeks or more if the insulation resistance during the last 6 weeks of the period is higher than 10 MΩ·1000 ft (3 GΩ·m). The period of immersion shall be 24 – 36 weeks if the insulation resistance is less than 10 MΩ·1000 ft (3 GΩ·m), but equals or exceeds the value calculated. An AC voltage equal to the voltage rating of the wire shall be applied to the insulation at all times other than while reading the insulation resistance.

$$IR_T = K_{15} \times 6.63 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

Where:

IR_T = Insulation resistance in MΩ·1000 ft at any temperature T°C

K_{15} = Constant for the insulation material at 15°C in MΩ·1000 ft

For TPE, K_{15} = 2000 MΩ·1000 ft

D = Diameter over the insulation (any units)

d = Diameter under the insulation (units identical to D)

or

IR_T = Insulation resistance in GΩ·m at any temperature T°C

K_{15} = Constant for the insulation material at 15°C in GΩ·m

For TPE, K_{15} = 610 GΩ·m

D = Diameter over the insulation (any units)

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