UL 1424

STANDARD FOR SAFETY

Cables for Power-Limited Fire-Alarm Circuits

UL Standard for Safety for Cables for Power-Limited Fire-Alarm Circuits, UL 1424

Fourth Edition, Dated January 22, 2015

Summary of Topics

This revision to ANSI/UL 1424 dated June 26, 2020 includes the addition of ST-1; 23.4, and 44.1(q).

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.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated January 14, 2020 and March 27, 2020.

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The most recent designation of ANSI/UL 1424 as an American National Standard (ANSI) occurred on June 5, 2020. 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 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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INTRODUCTION

1 Scope

1.1 These requirements cover 60 – 250°C (140 – 482°F) single- and multiple-conductor cables for use as fixed wiring within buildings (some are also marked for direct burial) principally for power-limited fire-alarm circuits as described in Article 760 and other applicable parts of the National Electrical Code (NEC). Cables covered by these requirements are:

a) Type FPLP (plenum cable),

b) Type FPLR (riser cable), and

c) Type FPL (cable for other than plenum and riser uses in general and in trays).

1.2 The cables covered in these requirements are rated for 300 volts but are not so marked. See 44.1(h).

1.3 A cable that contains one or more electromagnetic shields may be surface marked or have a marker tape to indicate that it is "shielded". A cable that contains one or more optical-fiber members has "-OF" supplementing the type letters and is marked in accordance with 45.1(d). A cable may consist of or contain one or more coaxial members.

1.4 The overall jacket on a cable that has "sun res" or "sunlight resistant" in a surface marking or on a marker tape complies with a 720-h sunlight-resistance test.

1.5 A cable that has "dir bur", "direct burial", or "for direct burial" in a surface marking or on a marker tape complies with a 1000-lbf crushing test. Direct-burial cable with wire armor, a metal braid, interlocked metal armor, or a smooth or corrugated metal sheath has a jacket over the metal covering.

1.6 Smoke and fire considerations are as follows for the cables covered in these requirements:

a) TYPE FPLP CABLE – Cable that is intended for installation in accordance with section 760-154 (A) of the National Electrical Code (ANSI/NFPA 70) in a duct, plenum, or other space used to transport environmental air without the cable being enclosed in a raceway in that space is to be tested for smoke and flame characteristics in accordance with the National Fire Protection Association Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces, ANSI/NFPA 262. A cable that complies exhibits a maximum flame-propagation distance that is not greater than 5 ft, 0 inch or 152 cm, a peak optical density of smoke produced of 0.50 or less (32 percent light transmission), and an average optical density of smoke produced of 0.15 or less.

b) TYPE FPLR CABLE – Cable that is intended for use in vertical runs in a shaft, or for installations in which the cable penetrates more than one floor, as specified in section 760-154 (B) of the National Electrical Code ANSI/NFPA 70. This cable is to be tested for flame-propagation characteristics in accordance with the Standard Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts, UL 1666. A cable that complies has a flame-propagation height less than 12 ft, 0 inch or 366 cm and temperatures are 850.0°F (454.4°C) or less at a height of 12 ft, 0 inch or 366 cm.

c) TYPE FPL CABLE – Type FPL cable complies with a 70,000 Btu/h (20.5 kW) vertical-tray flame test. The cable manufacturer chooses one of the following tests:

1) THE UL TEST REFERENCED IN 23.2.1 – This paragraph applies the test method described as the UL Flame Exposure (smoke measurements are not applicable) in the Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685, to cable that is surface marked or designated by a marker tape as

"FPL". A cable of a given construction shall not exhibit char that reaches the upper end of any specimen (a maximum of 8 ft, 0 inch or 244 cm).

2) THE FT4/IEEE 1202 TEST REFERENCED IN 23.3.1 – This paragraph applies the test method described as the FT4/IEEE 1202 Type of Flame Exposure (smoke measurements are not applicable) in the Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. This test differs from the UL tests in loading (more cables are used, with small cables bundled, and the spacing between cables or bundles is limited), burner angle, and failure criterion. For compliance, this test damages less than 150 cm (59 inches) of cable. A cable that complies either is not marked or it bears the designation "FT4/IEEE 1202" or "FT4" legible on or through the outer surface or on a marker tape [see marking in 44.1(i)].

d) Deleted

1.7 *Deleted*

1.8 *Deleted*

1.9 These requirements do not cover cables that contain conductors for electric-light, power, or Class 1 circuits. These requirements do not cover cables for Class 3 or Class 2 power-limited circuits (see the Standard for Power-Limited Circuit Cables, UL 13), communications cables (see the Standard for Communications Cables, UL 444), or cables for non-power-limited fire-alarm circuits (NPLF types).

1.10 These requirements do not cover the optical or other performance of any optical-fiber member or group of such members. See 8.3.

2 Units of Measurement

2.1 In addition to being stated in the inch/pound units that are customary in the USA, each of the requirements is also stated in units that make the requirement conveniently usable in countries employing the various metric systems (practical SI and customary). Equivalent – although not necessarily exactly identical – results are to be expected from applying a requirement in USA or metric terms. Equipment calibrated in metric units is to be used when a requirement is applied in metric terms.

3 References and Terms

3.1 Wherever the designation "UL 1581" is used in this wire standard, reference is to be made to the designated part(s) of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. Whenever the designation “UL 2556” is used in this standard, reference is to be made to the designated parts of the Standard for Wire and Cable Test Methods, UL 2556.

3.2 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.

3.3 Nylon designates a thermoplastic material whose characteristic constituent is a polyamide formed by the condensation of dibasic organic acids and diamines. Nylon used as a covering is unfilled and without reinforcement but may contain stabilizers, flame retardants, pigment, and/or other additives.

3.4 PBT designates a thermoplastic polyester material whose characteristic constituent is polybutylene terephthalate. PBT used as a covering is unfilled and without reinforcement but may contain flame retardants, pigment, and/or other additives.

CONSTRUCTION

4 Materials

4.1 Each material used in a cable shall be compatible with all of the other materials used in the cable.

4.2 The power-limited fire-alarm circuit cables covered in these requirements shall comply in all respects with the applicable requirements for construction details, test performance, and markings.

5 Conductors

5.1 The center conductor of a coaxial member shall be solid or stranded, shall be round, and either shall be of soft-annealed copper or shall be of copper-clad steel having 21 percent or higher conductivity in accordance with ASTM B 869. All other conductors in a cable shall be of round soft-annealed copper. A solid copper conductor and the individual wires (strands) of a stranded copper conductor shall be round and shall comply with ASTM B 3. The wires (strands) of a stranded conductor shall have a right- or left-hand direction of lay. The length of lay of the wires (strands) of a stranded conductor shall not exceed 20 times the calculated diameter over the assembled conductor for 19 – 10 AWG conductors and shall not exceed 30 times the calculated diameter over the assembled conductor for 26 – 20 AWG conductors. The nominal diameters of solid and stranded conductors that are indicated in Table 5.1 are not requirements but are for use in calculating the dimensions required for various parts of the cable when using Table 13.1, Table 13.2, Table 14.1, Table 14.2 and Table 18.1.

Table 5.1
Conductor diameters

AWG size of conductor	Solid conductor				Nominal diameter of stranded conductor	
	Nominal diameter		Minimum diameter			
	inch	mm	inch	mm	inch	mm
26[b]	0.0159	0.404	0.0151[a]	0.384[a]	0.0180	0.457
25[b]	0.0179	0.455	0.0170[a]	0.432[a]	0.0203	0.516
24	0.0201	0.511	0.0191[a]	0.485[a]	0.0228	0.579
23	0.0226	0.574	0.0215[a]	0.546[a]	0.0256	0.650
22	0.0253	0.643	0.0240[a]	0.610[a]	0.0287	0.729
21	0.0285	0.724	0.0271[a]	0.688[a]	0.0323	0.820
20	0.0320	0.813	0.0304[a]	0.772[a]	0.0362	0.919
19	0.0359	0.912	0.0341[a]	0.866[a]	0.0407	1.03
18	0.0403	1.02	0.0399	1.103	0.0456	1.16
17	0.0453	1.15	0.0448	1.138	0.0513	1.30
16	0.0508	1.29	0.0503	1.278	0.0576	1.46
15	0.0571	1.45	0.0565	1.435	0.0647	1.64
14	0.0641	1.63	0.0635	1.613	0.0727	1.85
13	0.0720	1.83	0.0713	1.81	0.0816	2.07
12	0.0808	2.05	0.0800	2.03	0.0915	2.32
11[c]	0.0907	2.30	0.0900	2.28	0.103	2.62
10[c]	0.102	2.59	0.1010	2.56	0.116	2.95

[a] The diameter (0.95 x nominal) and resistance (1.1 x nominal) requirements for the solid copper 26 – 19 AWG sizes are as established by the communications-cable industry. The diameter (0.99 x nominal) and resistance (1.02 x nominal) requirements for the solid copper 18 – 10 AWG sizes are the same as those established for other cables. The resistance values for stranded copper conductors in all sizes are the same as those established for other cables.

Table 5.1 Continued on Next Page

Table 5.1 Continued

AWG size of conductor	Solid conductor				Nominal diameter of stranded conductor	
	Nominal diameter		Minimum diameter			
	inch	mm	inch	mm	inch	mm

[b] 26 and 25 AWG copper conductors are only for either of the following:

a) In a cable that has a breaking strength shown by test to be at least 25.0 lbf or 111 N or 11.3 kgf in accordance with 41. The strength test is not required for cables with four or more conductors.

b) As the central conductor in a coaxial member.

[c] 11 and 10 AWG copper conductors and 10 and smaller AWG copper-clad steel conductors are only for the central conductor in a coaxial member.

5.2 Each conductor shall be continuous throughout the entire length of the finished cable – see test in 16.1 and 16.2.

5.3 All solid and stranded conductors are to be identified in the cable, tag, reel, and carton size markings as a particular AWG size. The size of the copper conductor shall be verified either by determination of the d-c resistance or, as described in 5.4, by determination of the diameter. The size of a stranded conductor shall be verified either by determination of the d-c resistance or by determination of the cross-sectional area as described in 5.4. Determination of the conductor size by measurement of the d-c resistance is to be as described in D-C Resistance Test of Copper Conductors, Section 17, and is the referee method in all cases.

5.4 In place of complying with the d-c resistance requirement in 17.1, at the cable manufacturer's option, a copper conductor may instead comply with the following requirement:

a) SOLID CONDUCTOR – The diameter of a solid copper conductor shall not be smaller than the minimum acceptable diameter indicated for the size in Table 5.1 (see 5.3) when the diameter of the conductor is determined from measurements as follows:

1) Measurements of the diameter of a solid copper conductor are to be made over the metal-coated (see 6.1 and 6.2) or uncoated copper by optical means or by means of a machinist's micrometer caliper having flat surfaces both on the anvil and on the end of the spindle. In either case, the equipment is to be calibrated to read directly to at least 0.001 inch or 0.01 mm, with each division of a width that facilitates estimation of each measurement to 0.0001 inch or 0.001 mm. The maximum and minimum diameters at a given point on the solid conductor are each to be recorded to the nearest 0.0001 inch or 0.001 mm, added together, and divided by 2 without any rounding off of the sum or resulting average.

2) Each minimum acceptable diameter indicated in Table 5.1 is an absolute minimum. The unrounded average of the two diameter readings is therefore to be compared directly with the minimum in the table for the purpose of determining whether the solid conductor does or does not comply with the diameter requirement.

b) STRANDED CONDUCTOR – The cross-sectional area of a stranded copper conductor of a standard (see 5.3) AWG size and having only round strands shall not be smaller than the minimum acceptable area indicated for the size in the 0.98 x nominal column in Table 20.1 of UL 1581. The cross-sectional area of the stranded conductor is to be determined as the sum of the areas of its component round strands.

5.5 A joint in a solid conductor or in one of the individual wires of a stranded conductor shall be made in a workmanlike manner, shall be smooth, and shall not have any sharp projections. A joint in a stranded conductor is to be made by separately joining each individual wire, or is to be made by machine brazing or welding of the conductor as a whole provided that the resulting solid section of the stranded conductor is not longer than 1/2 inch or 13 mm, there are no sharp points, and the distance between brazes or welds in a single conductor does not average less than 3000 ft or 915 m in any reel length of insulated single conductor. A joint made before insulation is applied to a conductor shall not increase the diameter of the solid conductor or individual wire (strand). A joint made after insulating shall not increase the diameter of the solid conductor or individual wire (strand) by more than 20 percent. Joints made after insulating shall be made prior to further processing and shall be insulated by heat-shrinkable tubing or by applying the original or investigated comparable insulation by means of a bonded patch or molding, and shall comply with the requirements in this Standard. A jacket that is damaged to the point that the underlying assembly is exposed or that is opened for the purpose of repairing a conductor either:

a) Shall be stripped and replaced in its entirety, or

b) A second duplicate jacket shall be applied over the first for the entire length of the cable.

The total jacket thickness shall not exceed any limitation determined for a particular cable in an applicable flame or smoke-and-flame test or other test specified in this Standard.

6 Metal Coating

6.1 If the insulation adjacent to a solid copper conductor or a conventional (not bunch-tinned) stranded copper conductor is of a material that corrodes unprotected copper in the test Copper Corrosion described in UL 2556, the solid conductor or the individual wires (strands) of the stranded conductor that is not bonded shall be individually covered with a coating of tin complying with ASTM B 33, of a tin/lead alloy complying with ASTM B 189, of nickel complying with ASTM B 355, of silver complying with ASTM B 298, or of another metal or alloy (evaluation required).

6.2 It is acceptable to metal-coat a solid conductor or the individual wires (strands) of a stranded conductor on which a coating is not needed for corrosion protection.

6.3 The maximum temperature rating of the cable is not specified relative to the diameter of copper wires used in the serving, wrap, or braid shielding described in 10.2(c). Otherwise, copper strands and solid copper conductors shall not be used in a cable with a temperature rating higher than indicated in Table 6.1.

Table 6.1
Maximum temperature rating of cable relative to diameter and coating of solid copper conductors or of copper conductor strands

Metal coating of copper strands or of solid copper conductor	Diameter of each strand or of the solid conductor	
	Smaller than 0.015 inch or 0.38 mm	At least 0.015 inch or 0.38 mm
Uncoated or coated with tin or a tin/lead alloy	150°C (302°F)	200°C (392°F)
Coated with silver	200°C (392°F)	200°C (392°F)
Coated with nickel	over 200°C (392°F)	over 200°C (392°F)

7 Insulation

7.1 Material and application

7.1.1 Each conductor shall be insulated for its entire length with one or more of the insulation materials indicated in Table 7.1 or referenced in note [a] to Table 7.1. The insulation shall be solid or, in the cases indicated in the second column of Table 7.1, may be expanded (foamed). In any case, a solid dielectric skin (a thin, solid, extruded layer that may or may not be separable) of the same or other material from Table 7.1 may be applied over the solid insulation or over the foam. The material insulation in an air-gap coaxial member shall consist of a solid tube over a solid spacer (thread) that has a nominally circular cross section and is applied to the conductor helically in a continuous length (length of lay is not specified). Otherwise, the insulation shall be applied directly to the conductor, shall have a circular cross section, and shall fit tightly to the conductor but shall not adhere excessively (no test). The insulation shall be uniform and shall not have any defects (bubbles, open spots, rips, tears, cuts, or foreign material) that are visible with normal or corrected vision without magnification.

7.1.2 Either of the following materials that the manufacturer wishes to use as insulation or a jacket shall be evaluated for the requested temperature rating as described in the test Dry Temperature Rating of New materials (Long Term Aging Test) in UL 2556:

a) Material generically different from any insulation or jacket material that is named in Table 7.1 for the construction (new material).

b) Material that is named in Table 7.1 yet does not comply with the short-term tests specified for the material in Specific Materials, Section 50 of UL 1581.

The temperature rating of materials (a) and (b) shall be the temperature rating for the cable determined as specified in 13.1. The thicknesses of insulation and/or jacket using materials (a) and/or (b) shall be as required for the specific cable type. Investigation of the electrical, mechanical, and physical characteristics of the cable using material (a) and/or (b) shall show the material(s) to be comparable in performance to an insulation or jacket material named in Table 7.1 for the required temperature rating. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage-withstand.

7.2 Properties

7.2.1 Unaged and heat-aged insulation requirements for all cables to be rated 60°C

7.2.1.1 Specimens of solid single-layered unaged insulation removed from finished insulated conductors shall have a minimum tensile strength of 1200 lbf/in^2 or 8.27 MN/m^2 or 827 N/cm^2 or 0.844 kgf/mm^2 and a minimum elongation of 100 percent when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength) in UL 2556. For all insulated conductor types, specimens approximately 12 inches or 300 mm long shall be placed in a circulating air oven conforming to ASTM D 5423 (Type II ovens) and D 5374 and maintained at a temperature of 100 ±2°C (212 ±3.6°F) for 7 d (168 h) or 121 ±2°C (249.8 ±3.6°F) for 48 h at the manufacturer's option. After removal from the oven, the specimens shall be allowed to cool to room temperature and then wound tightly, for six close turns, around a mandrel having a diameter no greater than that of the insulated conductor under test. The insulation shall be examined for cracks using a lens having magnification of 5X. The insulated conductor shall then be straightened, one side of the tube of insulation sliced off with a knife or razor-blade, and the conductor removed to permit examination of the inner surface of the insulation. There shall be no cracks on either the inside or the outside surface of the insulation.

7.2.2 Unaged and heat-aged insulation requirements for all cables to be rated 75°C or greater

7.2.2.1 Specimens of solid single-layered insulations removed from finished insulated conductors shall comply with the values of unaged elongation and tensile strength shown in the applicable physical-properties table for the material referenced in Table 7.1 when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength) in UL 2556. Specimens of solid single-layered insulations except PVDF and PVDF copolymer rated 125°C shall comply with the values of aged retention of elongation and tensile strength shown in the applicable physical-properties table for the material referenced in Table 7.1 when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength) in UL 2556. PVDF and PVDF copolymer rated 125°C, foamed, and multi-layered insulations shall comply with 7.2.2.2.

7.2.2.2 Specimens of PVDF and PVDF copolymer rated 125°C, foamed, or multiple-layered insulations approximately 300 mm (12 inches) long shall be placed in a circulating air oven conforming to ASTM D 5423 (Type II ovens) and D 5374 and aged for the appropriate time and temperature for the insulation adjacent to the conductor. When the insulation is foamed, the aging shall be as specified for the solid insulation. After removal from the oven, the specimens shall be allowed to cool to room temperature and then wound tightly, for six close turns, around a mandrel having a diameter no greater than that of the insulated conductor under test. The insulation shall be examined for cracks using a lens having magnification of 5X. The insulated conductor shall then be straightened, one side of the tube of insulation sliced off with a knife or razor-blade, and the conductor removed to permit examination of the inner surface of the insulation. There shall be no cracks on either the inside or the outside surface of the insulation.

7.2.3 Unaged and heat-aged jacket requirements for all cables to be rated 60°C

7.2.3.1 Specimens of jacket removed from completed cable shall comply with the unaged values shown in the applicable physical-properties table for the material referenced in Table 7.1 when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength) in UL 2556. For all jacketed conductor types, jacket material removed from a length of finished cable shall comply with the aging test as follows: 7 d (168 h), 100 ±2°C (212 ±3.6°F), and at least 50 percent retention of the unaged elongation and 75 per cent retention of unaged tensile strength when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength) in UL 2556.

7.2.4 Unaged and heat-aged jacket requirements for all cables to be rated 75°C or greater

7.2.4.1 Specimens of jacket removed from completed cable shall comply with the unaged values shown in the applicable physical-properties table for the material referenced in Table 7.1 when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength) in UL 2556. Specimens shall be aged for the length of time and at the temperature shown in the applicable physical-properties table for the material referenced in Table 7.1 and tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength) in UL 2556. Minimum retention of elongation and tensile strength requirements in the applicable physical-properties table referenced in Table 7.1 shall be used to determine compliance. This shall apply to all jacket materials except PVDF and PVDF copolymers rated 125°C. For these materials, the flexibility test described in 7.2.4.2 shall be used.

7.2.4.2 Aged specimens of PVDF and PVDF copolymer jackets rated 125°C in place on the cable shall not show any cracks on either the inside or outside surface after specimens are wound onto a cylindrical mandrel of the diameter indicated in 7.2.4.3.

7.2.4.3 The specimens that are to be aged shall be conditioned in accordance with the test Conditioning of Specimens in UL 2556 for the length of time and at the temperature indicated for the jacket material in Table 7.1 and Table 47.1 in UL 1581. The conditioning shall be followed by 16 – 96 h of rest in still air at room temperature before the specimens are wound onto a mandrel. The aged specimens shall be wound at room temperature for six complete turns (adjacent turns touching) onto a circular mandrel having a diameter twice that of the diameter over the overall jacket. Each specimen shall be unwound before being examined.

Table 7.1
Index to insulations and jackets

Material(s)[a]	Temperature Rating of Insulation	Temperature Rating of Jacket	Applicable table of physical properties in UL 1581 (see 7.2.1 and 7.2.2)
CP	90°C (194°F) solid	90°C (194°F) solid	50.1
	75°C (167°F) solid	75°C (167°F) solid	50.1
Thermoplastic CPE	–	90°C (194°F) solid	50.28
Thermoset CPE	–	90°C (194°F) solid	50.29
	–	75°C (167°F) solid	50.30
ECTFE ETFE	150°C (302°F) solid foamed	150°C (302°F) solid –	50.63 –
FEP	200°C (392°F) solid foamed	200°C (392°F) solid –	50.70 –
NBR/PVC	–	90°C (194°F) solid	50.83
	–	75°C (167°F) solid	50.80
Neoprene	–	90°C (194°F) solid	50.124
	–	75°C (167°F) solid	50.123
HDFRPE LDFRPE	75°C (167°F) solid foamed	75°C (167°F) solid –	50.133 –
HDPE	75°C (167°F) solid foamed	– –	50.136 –
LDPE	75°C (167°F) solid foamed	– –	50.136 –
PFA, MFA	200°C (392°F)[b] solid foamed 250°C (482°F)[b]	200°C (392°F) solid – 250°C (482°F)[b]	50.137 – 50.137
Polypropylene PP, FRPP	75°C (167°F) solid foamed	– –	50.139 –
PTFE	250°C (482°F)[b]	250°C (482°F)	50.219

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Table 7.1 Continued

Material(s)[a]	Temperature Rating of Insulation	Temperature Rating of Jacket	Applicable table of physical properties in UL 1581 (see 7.2.1 and 7.2.2)
TFE	solid foamed	solid –	 –
PVC	105°C (221°F) solid	105°C (221°F) solid	50.182
	90°C (194°F) solid	90°C (194°F) solid	50.182
	75°C (167°F) solid	75°C (167°F) solid	50.182
SRPVC (semirigid PVC)	105°C (221°F) solid	–	50.183
	90°C (194°F) solid	–	50.183
	75°C (167°F) solid	75°C (167°F) solid	50.183
PVDF and PVDF copolymer	150°C (302°F) solid foamed	150°C (302°F) solid –	50.185 –
	125°C (257°F) solid foamed	125°C (257°F) solid –	50.185 –
Silicone rubber	200°C (392°F) solid	200°C (392°F) solid	50.210
	150°C (302°F) solid	150°C (302°F) solid	50.210
TPE	105°C (221°F) solid	105°C (221°F) solid	50.223
	90°C (194°F) solid	90°C (194°F) solid	50.224
XL: XLPE XLPVC XLEVA blends of these	105°C (221°F) solid 90°C (194°F) solid	105°C (221°F) solid 90°C (194°F) solid	50.245 50.237
	75°C (167°F) solid	75°C (167°F) solid	50.241
XLPO	105°C (221°F) solid	105°C (221°F) solid	50.233

[a] See 7.1.2 for the long-term evaluation of an insulation or jacket material not named in the first column for not complying with the short-term tests referenced in the last column.

[b] 150°C (302°F) is the limit for the cable temperature rating [see 13.1(b)] where conductor strands are used that are smaller in diameter than 0.015 inch or 0.38 mm and are uncoated or are coated with tin or a tin/lead alloy. The indicated rating higher than 150°C (302°F) applies where, regardless of diameter, the strand are coated with silver [200°C or (392°F)] or nickel [250°C (482°F)]. See 6.3 and Table 6.1.

7.3 Thicknesses

7.3.1 The dimensions of the spacer (thread) portion of the material insulation in an air-gap coaxial member are not specified. The average thickness and the minimum thickness at any point of the tube portion of an air-gap coaxial member shall not be less than indicated in Table 7.3. The thicknesses of the integral insulation (solid) and jacket on a flat, parallel cable shall not be less than indicated in Table 7.2. The average thickness and the minimum thickness at any point of solid insulation (including any skin) on single-conductor cable shall not be less than indicated in Table 7.4. The average thickness and the minimum thickness at any point of solid insulation (including any skin) in a coaxial member and on every other conductor, including each conductor in nonintegral flat cable, shall not be less than indicated in Table 7.3. The thicknesses of foamed insulation (including any skin) shall be evaluated based on the performance of the finished cable when tested in accordance with this standard. In any case, the thicknesses of solid and foamed insulations (including any skin) are to be determined by means of measurements made as described in the test Thickness in UL 2556, with the following modifications for stranded conductors that leave one or more strand impressions in the insulation that are too small to accommodate a pin of 1 mm (0.04 in) in diameter:

a) The 0.003-inch (3-mil) or 0.08-mm thickness-reduction allowance mentioned in UL 2556 is applicable to both average and minimum at any point measurements, and is to be applied only to insulation that is from a stranded conductor as mentioned above and has an average thickness (including any skin) of at least 0.015 inch or 0.38 mm where the measurements are made using a micrometer microscope.

b) Only an optical method as applicable from 7.3.2 and 7.3.3 is to be used for thickness measurements of insulation that is from a stranded conductor as mentioned above and has an average thickness (including any skin) less than 0.015 inch or 0.38 mm.

7.3.2 Thickness measurements of a nylon or similar covering (see note [b] to Table 7.3 and note [b] to Table 7.4) of insulation having an average thickness or minimum thickness at any point of not more than 0.0060 inch or 0.152 mm (including any skin) are to be made by means of a micrometer microscope or other optical instrument that is calibrated to read directly to at least 0.0001 inch (0.1 mil) or 0.001 mm. Each of these measurements is to be recorded to the nearest 0.0001 inch or 0.001 mm. Otherwise, under 7.3.1(b), a simply manipulated optical device that is accurate to 0.001 inch (1 mil) or 0.01 mm may be used for insulation, with each measurement recorded to the nearest 0.001 inch or 0.01 mm.

7.3.3 For 7.3.1(b), the conductor and any covering over the insulation or skin are to be removed from the finished insulated conductor. A thin slice of the insulation plus any skin is then to be cut perpendicular to the longitudinal axis of the resulting hollow tube. Measurements are to be taken of the maximum and minimum wall thicknesses of the slice. The recorded maximum and minimum thicknesses are to be added together and divided by 2 without any rounding off of the sum but with the resulting average rounded off (see 7.3.4 – 7.3.7) to the same degree as stated in for the recorded measurements. The average thickness so determined and the recorded minimum thickness are to be taken as the average and minimum-at-any-point thicknesses that are to be compared with Table 7.3 or with whatever lesser thicknesses are established for the construction as the result of the insulation-crushing test described in Crushing Resistance Test of Insulation, Section 31.

Table 7.2
Thicknesses of integral insulation (solid) and jacket on 2-, 3-, or 4-conductor flat, parallel cable and distance between conductors

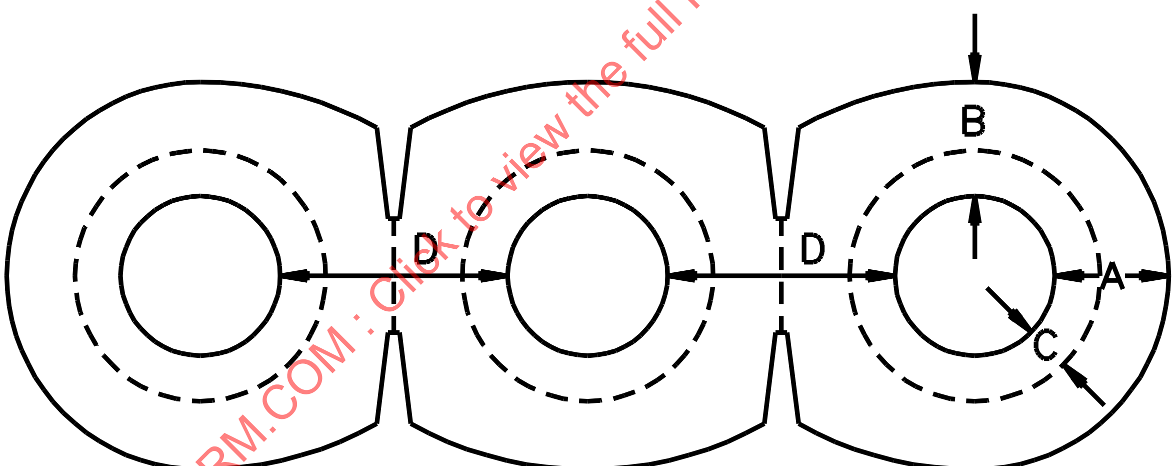
Size of conductors	Nominal thickness away from tear area(s) (vertical dashed line through web or webs in Figure 7.1) and outside Point P or X (Defined in Figure 7.2) A[a] (Information only – not a Requirement)		Minimum thickness at any point before separation measured outside Point P or X (Defined in Figure 7.2) B[a]		Minimum thickness at any point after separation C[a]		Minimum distance between copper conductors D[a]	
AWG	Inch	mm	Inch	mm	Inch	mm	in	mm
22–12	0.020	0.51	0.018	0.46	0.010	0.25	0.030	0.76

[a] Dimensions A – D are illustrated in Figure 7.1.

Figure 7.1

Integral flat cable

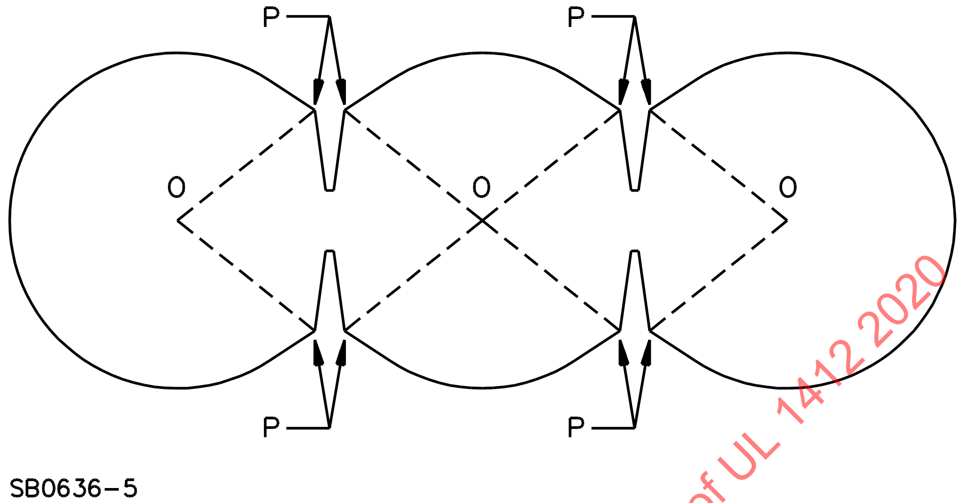
See Table 7.2 for dimensions A – D



SB0636-2

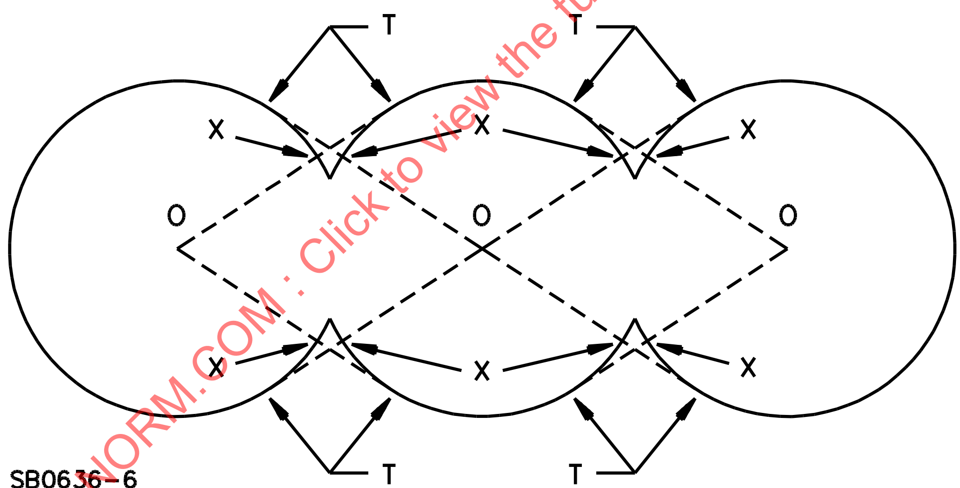
Figure 7.2

Definition of regions of valley slopes on which thickness measurements are not to be made in integral flat cables



Constructions with a Cross Section Having a Definite Point P at the Outer End of Each Valley Slope

OP in each case is a straight line from the center O of a conductor to P on the same segment of the cross section. Thickness measurements are not to be made on any valley slope.



Constructions with a Cross Section not Having a Definite Point to Mark the Outer End of Each Valley Slope

OP in each case is a straight line from the center O of a conductor to T, the point of tangency, on the adjacent segment of the cross section. Thickness measurements are not to be made deeper on a valley slope than point X, which is the intersection of the line OT with the valley slope. Thickness measurements are to be made on each slope segment TX.

Table 7.3
Thicknesses[a] of solid insulation (including any skin) in jacketed ribbon cable and in nonintegral round and flat multiple-conductor cable

Size of conductor	Insulation whose unaged tensile strength Is less than 2000 lbf/in^2 or 13.79 MN/m^2 or 1379 N/cm^2 or 1.41 kgf/mm^2						PVC (1) with an unaged tensile strength of at least 2000 lbf/in^2 or 13.79 MN/m^2 or 1379 N/cm^2 or 1.41 kgf/mm^2, and (2) with or without a covering[b] of nylon (see 3.3), PBT (see 3.4), or similar thermoplastic material or ECTFE, ETFE, FEP, HDPE, PFA, PTFE (TFE), PVDF, PVDF Copolymer, TFE, Semirigid PVC, PP, or XLPO D	
	CP or silicone rubber A		LDPE, PVC, or TPE (all without a nylon or similar covering) B		PVC with a covering[b] of nylon (see 3.3), PBT (see 3.4), or similar thermoplastics material or TPE with a covering[b] of Nylon or XL (without a nylon or similar covering) C			
	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point
AWG	Inch							
26 – 20	0.015	0.013	0.012	0.010	0.009	0.008	0.0060	0.0050
19 – 15	0.015	0.013	0.015	0.013	0.009	0.008	0.009	0.008
14 – 10[c]	0.020	0.018	0.020	0.018	0.012	0.010	0.012	0.010
AWG	mm							
26 – 20	0.38	0.33	0.30	0.25	0.23	0.20	0.152	0.127
19 – 15	0.38	0.33	0.38	0.33	0.23	0.20	0.23	0.20
14 – 10[c]	0.51	0.46	0.51	0.46	0.30	0.25	0.30	0.25

[a] Solid insulation for a given size range indicated in column 1 is for average and point thicknesses thinner than indicated in this table where the insulation on the smallest conductor in the indicated size range complies with the insulation crushing test described in Crushing Resistance Test of Insulation, Section 31.

[b] Measured by means of the micrometer microscope described in 7.3.2, the minimum thickness at any point of the nylon covering shall not be less than 0.0020 inch (2.0 mils) or 0.050 mm.

A covering of a material other than nylon is to be evaluated. The investigation is to demonstrate that the other material thickness, temperature rating, flexibility, flammability, and other characteristics critical to the application provide the particular construction with a comparable covering. Investigation of the mechanical-abuse characteristics is to include at least the crushing, impact, and abrasion comparison tests that are described in the tests Crush Resistance, Impact Resistance and Abrasion Resistance in UL 2556.

[c] 11 and 10 AWG copper conductors and 10 AWG and small copper-clad steel conductors are only for the central conductor in a coaxial member. Copper-clad steel conductors shall have 30 percent or higher conductivity in accordance with ASTM B 452

Table 7.4
Thicknesses[a] of solid insulation (including any skin) on 18 – 12 AWG conductors in single or multiple-conductor non-jacketed cable

Insulation Material		Minimum average thickness of insulation		Minimum thickness at any point of insulation	
		inch	mm	inch	mm
CP, HDFRPE, LDFRPE, HDPE, LDPE, PP,PVC, SRPVC, TPE, XL, or XLPO	Without a nylon or similar covering	0.020	0.51	0.018	0.46
	With a covering[b] of nylon (see 3.3), PBT (see 3.4), or similar thermoplastic material	0.015	0.38	0.010	0.25
ECTFE, ETFE, FEP, PA, PTFE (TFE), PVDF, or PVDF copolymer		0.015	0.38	0.013	0.33

[a] Thinner solid insulation is to be evaluated.

[b] Measured by means of the micrometer microscope described in 7.3.2, the minimum thickness at any point of the nylon or similar covering shall not be less than 0.0040 in (4.0 mils) or 0.102 mm. See the second paragraph of note [b] to Table 7.3

7.3.4 Rounding off to the nearest 0.0001 inch

7.3.4.1 A figure in the fourth decimal place is to remain unchanged:

a) If the figure in the fifth decimal place is 0 – 4 and the figure in the fourth decimal place is odd or even, or

b) If the figure in the fifth decimal place is 5 and the figure in the fourth decimal place is even (0, 2, 4, and so forth).

A figure in the fourth decimal place is to be increased by 1:

c) If the figure in the fifth decimal place is 6 – 9 and the figure in the fourth decimal place is odd or even, or

d) If the figure in the fifth decimal place is 5 and the figure in the fourth decimal place is odd (1, 3, 5, and so forth).

7.3.5 Rounding off to the nearest 0.001 inch

7.3.5.1 A figure in the third decimal place is to remain unchanged:

a) If the figure in the fourth decimal place is 0 – 4 and the figure in the third decimal place is odd or even, or

b) If the figure in the fourth decimal place is 5 and the figure in the third decimal place is even (0, 2, 4, and so forth).

A figure in the third decimal place is to be increased by 1:

c) If the figure in the fourth decimal place is 6 – 9 and the figure in the third decimal place is odd or even, or

d) If the figure in the fourth decimal place is 5 and the figure in the third decimal place is odd (1, 3, 5, and so forth).

7.3.6 Rounding off to the nearest 0.001 mm

7.3.6.1 A figure in the third decimal place is to remain unchanged:

a) If the figure in the fourth decimal place is 0 – 4 and the figure in the third decimal place is odd or even, or

b) If the figure in the fourth decimal place is 5 and the figure in the third decimal place is even (0, 2, 4 and so forth).

A figure in the third decimal place is to be increased by 1:

c) If the figure in the fourth decimal place is 6 – 9 and the figure in the third decimal place is odd or even, or

d) If the figure in the fourth decimal place is 5 and the figure in the third decimal place is odd (1, 3, 5, and so forth).

7.3.7 Rounding off to the nearest 0.01 mm

7.3.7.1 A figure in the second decimal place is to remain unchanged:

a) If the figure in the third decimal place is 0 – 4 and the figure in the second decimal place is odd or even, or

b) If the figure in the third decimal place is 5 and the figure in the second decimal place is even (0, 2, 4, and so forth).

A figure in the second decimal place is to be increased by 1:

c) If the figure in the third decimal place is 6 – 9 and the figure in the second decimal place is odd or even, or

d) If the figure in the third decimal place is 5 and the figure in the second decimal place is odd (1, 3, 5, and so forth).

8 Coaxial and Optical-Fiber Members

8.1 Each coaxial member shall consist of a single central conductor covered in turn with solid or foamed insulation (with or without a skin) complying (including thicknesses) with Insulation, Section 7, or the air-gap construction complying with 7.1; a shield(s) (outer conductor) complying with section 10; and a jacket, which is optional on a member used inside the cable (see Table 9.1) but is required on a member whose outer surface is the outer surface of the cable (see Table 12.1). The jacket on a coaxial member used within a cable shall comply with Table 9.1. The jacket on a coaxial member shall comply with section 13 if the jacket on the member constitutes the overall cable jacket.

8.2 An optical-fiber member shall consist of the following:

a) One or more glass fibers that are individually coated and tight buffered and then are jacketed in any thickness with one of the insulation materials named in Table 7.1 or referenced in note [a] to Table 7.1, or are enclosed in a nonmetallic tape, wrap, or braid that provides complete coverage and is electrically nonconductive.

b) One or more glass fibers that are individually coated, optionally tight buffered, and then are enclosed in a loose buffer tube. A loose buffer tube:

1) Shall be of any thickness of one of the insulations named or referenced in Table 7.1, or

2) Shall be enclosed in a jacket of one of the insulations named or referenced in Table 7.1, or

3) Shall be enclosed in a nonmetallic tape, wrap, or braid that provides complete coverage and is electrically nonconductive.

The construction of the glass fiber, of the coating, and of a tight buffer is not specified. The construction of a loose buffer tube that is covered by a jacket is not specified. The construction of a nonmetallic tape, wrap, or braid is not specified. Non-current-carrying metal or other electrically conductive parts may be included in an optical-fiber member but an optical-fiber member shall not have any electrical elements. An optical-fiber member may include one or more strength elements.

8.3 The energy that an optical-fiber cable carries in some laser systems presents a potential risk of eye, or other injury, to people. Consequently, where optical-fiber cables are installed in a laser system, the recommendations of the ANSI Z136 laser systems safety standards should be applied. To help protect optical-fiber cable installers, users, service personnel, and anyone who handles the optical-fiber cable component of the system after installation, 45.1 specifies a tag, reel, or carton marking.

9 Individual Covering

9.1 An individual covering shall comply with Table 9.1.

Table 9.1
Individual covering

Member or insulated conductor that is covered	Jacket	Nylon covering (not a jacket)	Nonmetallic braid	Coating for color coding (not a jacket)
Coaxial member used within a cable	Acceptable but not required[a]	–	–	–
Optical-fiber member	Jacket or other complete coverage required (see 8.2)	–	–	–
PVC insulation (other than semirigid) whose thicknesses comply with column C of Table 7.3	–	Required covering[b] of nylon (see 3.3), PBT (see 3.4), or similar thermoplastic material	–	–
Semirigid PVC insulation	–	Acceptable but not required[b] covering[b] of nylon (see 3.3), PBT (see 3.4) or, similar thermoplastic material	–	–
PVC insulation whose thicknesses comply with column B of Table 7.3	–	Acceptable but not required[b] covering[b] of nylon (see 3.3), PBT (see 3.4), or similar thermoplastic material	–	–

Table 9.1 Continued on Next Page

Table 9.1 Continued

Member or insulated conductor that is covered	Jacket	Nylon covering (not a jacket)	Nonmetallic braid	Coating for color coding (not a jacket)
Silicone insulation	–	Nylon[b] or braid is required[c]	Nylon[b] or braid is required[c]	–
Any insulation not having nylon or similar covering or a braid	–	–	–	Acceptable but not required[d]

[a] An individual jacket is not required on a coaxial member used within a cable but, if used, shall be of a material (TFE and nylon-covered or similarly covered PVC are not acceptable) and of the thicknesses specified in Table 7.3, and otherwise shall comply with Cable Jacket, Section 13. The thicknesses of the jacket are to be determined as described in the test Thickness in UL 2556.

[b] The thickness at any point of a required or optional nylon or similar covering shall not be less than 0.002 inch or 0.05 mm when measured as described in the test Thickness in UL 2556. See the second paragraph of note [b] to Table 7.3.

[c]The nylon or braid covering is optional on conductors with insulation that has a tensile strength of 1200 lbf/in^2 or greater or an insulation thickness at least 50% more than required in Table 7.3.

[d] No thicknesses are specified for a color coating.

10 Electromagnetic Shield(s)

10.1 An electromagnetic shield is not required other than as the outer conductor in a coaxial member but is acceptable over an individual insulated conductor, over a pair of insulated conductors, over one or several groups of insulated conductors with or without one or more optical-fiber members in any group, or over the entire cable assembly. Several shields may be used in a given cable. Insulating material as indicated in Table 7.1 or referenced in note [a] to Table 7.1 may be provided in any thickness between shields. The electrostatic/electromagnetic performance of a shield is not specified. When provided, the shield shall be electrically continuous throughout the entire length of the finished cable (see Continuity Test of Conductors, Section 16).

10.2 An electromagnetic shield shall be of metal and shall consist of one or more of the following but otherwise is not specified:

a) A laminated shield tape of polymeric material and metal(s) with or without a bare metal-coated or uncoated (uncoated not acceptable with an aluminum-faced tape) copper drain wire in contact with the metal(s) part of the tape. The tape may be applied with the metal(s) side in or out. The size of a drain wire is not specified. A drain wire may be solid or stranded.

b) A corrugated or smooth single-metal or bi-metal tape applied longitudinally, helically, or interlocked with or without a bare metal-coated or uncoated (uncoated not acceptable with an aluminum tape) copper drain wire in contact with the metal tape (a specific version of this shield is described in 10.3). The tape may be polymer-coated on one side if there is a drain wire or on both sides if a drain wire is not used. Any inward-facing coating may bond to the insulation in the case of a coaxial member but, where the metal tape is applied over more than one conductor or member, any inward-facing coating shall not bond to the conductors or coaxial members or optical-fiber members in the cable. The size of a drain wire is not specified. A drain wire may be solid or stranded. Interlocked aluminum tape shall comply with the requirements for a metal covering but, if the cable has an overall cable jacket, the strip thickness and width are not specified. Interlocked zinc-coated steel tape shall comply with the requirements for a metal covering (see Metal Covering, Section 14), with the following modifications for cable that has an overall cable jacket:

1) NOT SPECIFIED for DIRECT-BURIAL CABLE – Strip thickness and strip width.

2) NOT SPECIFIED for OTHER CABLE – Edge coating, strip thickness, and strip width.

c) A serving, wrap, or braid of aluminum wires or of metal-coated or uncoated (uncoated not acceptable in contact with aluminum wires) copper wires. See 6.3. If the overall cable jacket is thinner in average thickness than 0.013 inches or 0.33 mm and is thinner at any point than 0.010 inch or 0.25 mm, a wrap or other protective covering shall be provided over the wire serving, wrap, or braid (see note [b] to Table 12.1). The construction of the protective covering is not specified but the covering shall keep bobbin ends and other wire projections from penetrating the overall cable jacket during and after application of the overall jacket.

d) An investigated equivalent of any of the above.

10.3 The specific metal sheath to which reference is made in 19.2 is to be a version of the shield covered in 10.2(b). The metal sheath shall consist of a metal tape that is 0.008 inch or 0.2 mm thick with or without a coating on one side of vinyl or other resin that is bonded to the metal. The tape shall be corrugated or smooth and shall be applied longitudinally to the cable assembly with a positive overlap. Any bonded coating used shall face outward. An inward-facing coating may be used but shall not bond to the conductors or coaxial members or optical-fiber members in the cable.

11 Binder(s)

11.1 Any group of conductors (with or without one or more optical-fiber members in the group), or several such groups within the cable, may be enclosed in a binder consisting of a binder jacket (extruded binder) or an open, skeleton wrap of nonmetallic threads or tape. Except for thickness, a binder jacket shall comply with Cable Jacket, Section 13. The average thickness of a binder jacket shall not be less than 0.010 inch or 0.25 mm. The minimum thickness at any point of a binder jacket shall not be less than 0.008 inch or 0.20 mm. The thicknesses of a binder jacket are to be determined as described in the test Thickness in UL 2556. The material, construction, manner of application, and other details of a thread or tape binder are not specified. See note [c] to Table 12.1 for core and cable wraps. A metal shield as described in 10.1 and 10.2 may serve as a binder.

12 Assembly of Multiple-Conductor Cable

12.1 A multiple-conductor cable is to be constructed essentially flat or round as described in Table 12.1. The use of fillers is optional. The conductors or members shall be cabled in any group or assembly but the length and direction of lay are not specified. Any group or assembly shall be essentially round. Preassemblies of two or more cabled conductors or members may be used in a group or assembly. A jacketed round cable consisting of 12 or fewer twisted pairs or 2, 3, or 4 single insulated conductors may have the pairs or insulated conductors laid straight but otherwise all conductors, groups of conductors, members, and groups of members shall not be laid straight. In any case, the length of lay is not specified. In any parallel or cabled nonintegral cable, different conductors and members may be insulated with different materials. The conductors in a multiple-conductor cable may be of any mixture of sizes, stranding, and metal complying with Table 6.1.

Table 12.1
Assembly of Cable

Conductors and members	Acceptable constructions of cable
2 or more insulated copper conductors	JACKETED RIBBON CABLE: Insulated conductors complying with Table 7.3 laid parallel and bonded together or conductors laid parallel and insulated in accordance with Table 7.3 with an integral extruded web of unspecified thickness between them. In each case, the flat assembly shall be covered with an overall, nonintegral jacket that complies section 13. Fillers integral with the jacket are not required.
2, 3, or 4 insulated copper conductors	INTEGRAL FLAT CABLE: Conductors laid parallel and extruded with integral insulation and jacket complying with Table 7.2.
2 or more insulated copper conductors or 2 or more thermocouple-extension wires or 2 or more coaxial members or 1 or more coaxial member and 1 or more optical-fiber member or 1 or more twisted pairs of insulated copper conductors and 1 or more optical-fiber of coaxial members	NONINTEGRAL FLAT CABLE: The separate insulated conductors members complying with Table 7.3, or the twisted pairs and the members, paid parallel under an overall, nonintegral jacket that complies with Cable Jacket, Section 13. Either the jacket shall come down to an interconnecting web of unspecified thickness between the conductors, wires, or members, or fillers that are integral with the jacket are to be provided[d]. The degree to which the integral fillers fill the valleys is not specified except that the fill shall maintain the stability of the flat construction.
2 or more coaxial members or 1 or more coaxial member and 1 or more optical-fiber members or 1 or more cabled groups (cores) consisting of one or more twisted pairs of insulated copper conductors and additional groups (cores) consisting of coaxial or optical-fiber members an assembly of coaxial and/or optical-fiber members, or a cabled group(s) of one or more twisted insulated pairs.	MULTIPLE CORE FLAT CABLE: The jacketed members laid parallel or the jacketed single or assembly of members and the jacketed groups[c] of pairs laid parallel. The overall jackets are to comply with Cable Jacket, Section 13, and are to be bonded together or extruded with an integral web between them. Upon separation, the jackets shall not be reduced in thickness, torn, or otherwise adversely affected.
1 or more insulated copper conductors[a,b] and/or 2 or more thermocouple-extension wires[a,b] and/or 1 or more coaxial member(s)[a,b]	ROUND CABLE: The single insulated conductor, or the single round assembly[c] of conductors and/or member(s) cables as described in 12.1, under an overall nonintegral jacket that complies with Cable Jacket, Section 13.

[a] A single insulated conductor, added for use in voice communications during installation of a cable (conductor then abandoned), may be surface marked as a communications conductor. The conductor shall comply with the requirements in this Standard for an insulated copper circuit conductor and is not required to be included in the cable surface marking.

[b] Plus one or more optical-fiber member(s), however the cable shall not consist of only an optical-fiber member(s). Each optical-fiber member shall be assembled into the cable as if it were an electrical conductor– that is, the optical-fiber member(s) shall be laid parallel with the coaxial member(s) or cabled with the same direction and length of lay as the electrical conductors, as indicated for the construction. It is appropriate for a group of optical-fiber members that does not have an electrical conductor or conductors in the group to include one or more non-current-carrying electrically conductive parts such as a metal strength element or a metal vapor barrier. The construction of these parts is not specified.

[c] It is sppropriate for an assembly or a group under a jacket to be enclosed in a core wrap (cable wrap) consisting of a serving, wrap, tape, or other construction. The core wrap shall completely cover the assembly or group. The material, construction, manner of application, and other details of a nonmetallic core wrap are not specified. A metal shield as described in 10.1 and 10.2 is appropriate as a core wrap. See 11.1 for binders.

[d] Not required on constructions having only two separate insulated conductors.

13 Cable Jacket

13.1 In the absence of any metal covering on the cable, an overall cable covering consisting of a jacket complying with (a) or (b) of this paragraph, as applicable, shall be extruded over each multiple-conductor nonintegral construction described in Table 12.1. Any jacket that is provided shall be tight enough to maintain the configuration however it shall not adhere to the underlying assembly (no test). The assembly shall be completely covered and well centered in the jacket. The jacket shall not have any defects (bubbles, open spots, rips, tears, cuts, or foreign material) that are visible with normal or corrected vision without magnification.

a) For a cable in which the insulation is rated 60 – 105°C (140 – 221°F), the jacket shall be of one of the jacket materials indicated in Table 7.1 or referenced in note [a] to Table 7.1 and shall be of the thicknesses indicated in Table 13.1 (fluoropolymer) or Table 13.2 (other than fluoropolymer) or in Table 13.2 (heavier jacket) when measured as described in the test Thickness in UL 2556. The jacket material shall have a temperature rating that is not more than 15°C (27°F) lower than the temperature rating of the insulation in the cable. The temperature rating of the cable is the same as the temperature rating of the insulation. See 7.1.2.

b) For a cable in which the insulation is rated for 125 – 250°C (257 – 482°F), the jacket shall be of one of the jacket materials indicated in Table 7.1 or referenced in note [a] to Table 7.1 and shall be of the thicknesses indicated in Table 13.1 (fluoropolymer) or Table 13.2 (other than fluoropolymer) or in Table 13.2 (heavier jacket) when measured as described in the test Thickness in UL 2556. The relationship between the temperature ratings of the insulation and the cable jacket is not specified but the temperature rating of the cable is that of whichever insulation or jacket in the cable has the lowest temperature rating. See note [b] to Table 7.1 and also 7.1.2.

13.2 Cables on which a jacket thicker than indicated in Table 13.1 or Table 13.2 is necessary to enable the cable to comply with any applicable flame or other test described or referenced in these requirements shall be made with whatever greater thicknesses of jacket may be needed for this purpose. In this case, the minimum thickness at any point of the heavier jacket shall not be less than 80 percent of the average thickness of the heavier jacket.

Table 13.1
Thicknesses[a, d] of nonintegral fluoropolymer cable jacket of ECTFE, FEP, PFA, PVDF, PVDF COPOLYMER, or TFE

Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket see 5.1	Minimum acceptable average thickness of jacket	Minimum acceptable thickness at any point of jacket
inch	inch	
0 – 0.250	0.008[c]	0.006[c]
Over 0.250 but not over 0.350	0.010[c]	0.008[c]
Over 0.350 but not over 0.500	0.013	0.010
Over 0.500 but not over 0.700	0.015	0.012
Over 0.700 but not over 1.500	0.020	0.016
mm	mm	
0 – 6.35	0.20[c]	0.15[c]
Over 6.35 but not over 8.89	0.25[c]	0.20[c]
Over 8.89 but not over 12.70	0.33	0.25
Over 12.70 but not over 17.78	0.38	0.30

Table 13.1 Continued on Next Page

Table 13.1 Continued

Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket see 5.1	Minimum acceptable average thickness of jacket	Minimum acceptable thickness at any point of jacket
Over 17.78 but not over 38.10	0.51	0.41

[a] A thicker jacket may be required to enable the cable to comply with one or more tests. See 13.2

[b] The equivalent diameter of a flat assembly is to be calculated as 1.1284 x $(TW)^{1/2}$, in which T is the thickness of the assembly and W is the width of the assembly.

[c] A jacket that is applied directly over the wire serving, wrap, or braid mentioned in 10.2(c) (no intervening wrap or other protective covering) shall not be thinner in average thickness than 0.013 inch or 0.33 mm and shall not be thinner at any point than 0.010 inch or 0.25 mm.

[d] A jacket of thickness other than indicated in this table is acceptable if, upon evaluation, it has been found to comply with the applicable requirements of this standard. Evaluation of thinner jackets may include but not be limited to crush, impact, and abrasion tests.

Table 13.2
Thicknesses[a, c] of nonintegral cable jacket of CP, thermoset CPE, thermoplastic CPE, NBR/PVC, neoprene, PVC, semirigid PVC, silicone rubber, TPE, XL, LDFRPE, HDFRPE, or XLPO

Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket see 5.1	Jacket whose tensile strength is less than 2500 lbf/in² or 17.21 MN/m² or 1724 N/cm² or 1.76 kgf/mm²				Jacket whose tensile strength is at least 2500 lbf/in² or 17.21 MN/m² or 1724 N/cm² or 1,76 kgf/mm²	
	PVC		Other material			
	Minimum average thickness of jacket	Minimum thickness at any point of jacket	Minimum average thickness of jacket	Minimum thickness at any point of jacket	Minimum average thickness of jacket	Minimum thickness at any point of jacket
inch	inch					
0 – 0.350	0.023	0.018	0.030	0.024	0.013	0.010
Over 0.350 but not over 0.400	0.027	0.022	0.030	0.024	0.018	0.014
Over 0.400 but not over 0.700	0.032	0.026	0.030	0.024	0.018	0.014
Over 0.700 but not over 1.000	0.045	0.036	0.045	0.036	0.030	0.024
Over 1.000 but not over 1.500	0.045	0.036	0.060	0.048	0.030	0.024
Over 1.500 but not over 1.800	0.060	0.048	0.075	0.060	0.045	0.036
mm	mm					
0 – 8.89	0.58	0.46	0.76	0.61	0.33	0.25
Over 8.89 but not over 10.16	0.69	0.56	0.76	0.61	0.46	0.36
Over 10.16 but not over 17.78	0.81	0.66	0.76	0.61	0.46	0.36
Over 17.78 but not over 25.40	1.14	0.91	1.14	0.91	0.76	0.61
Over 25.40 but not over 38.10	1.14	0.91	1.52	1.22	0.76	0.61

Table 13.2 Continued on Next Page

Table 13.2 Continued

Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket see 5.1	Jacket whose tensile strength is less than 2500 lbf/in^2 or 17.21 MN/m^2 or 1724 N/cm^2 or 1.76 kgf/mm^2				Jacket whose tensile strength is at least 2500 lbf/in^2 or 17.21 MN/m^2 or 1724 N/cm^2 or 1,76 kgf/mm^2	
	PVC		Other material			
	Minimum average thickness of jacket	Minimum thickness at any point of jacket	Minimum average thickness of jacket	Minimum thickness at any point of jacket	Minimum average thickness of jacket	Minimum thickness at any point of jacket
Over 38.10 but not over 45.72	1.52	1.22	1.90	1.52	1.14	0.91

[a] A thicker jacket is required to enable some cables to comply with one or more tests. See 13.2

[b] The equivalent diameter of a flat assembly is to be calculated as 1.1284 x $(TW)^{1/2}$, in which T is the thickness of the assembly and W is the width of the assembly.

[c] A jacket thickness other than indicated in this table is acceptable if, upon evaluation, it has been found to comply with the applicable requirements of this standard. Evaluation of thinner jackets may include but not be limited to crush, impact, and abrasion tests.

14 Metal Covering

14.1 General

14.1.1 Wire armor, a metal braid, interlocked metal armor, or a metal sheath is acceptable on any round cable. See tests in Crushing Test for Cable Marked for Direct Burial, Section 32, Tension Test of Interlocked Steel or Aluminum Armor, Section 36, and Flexibility Test for Cable Having Interlocked Armor or a Smooth or Corrugated Metal Sheath, Section 37. Any metal covering that is provided shall be as follows:

a) A smooth metal sheath shall comply with 14.1.2 and 14.2.1 – 14.2.4.

b) A welded and corrugated metal sheath shall comply with 14.1.2, 14.1.3, 14.3.1, and 14.3.2.

c) An extruded and corrugated metal sheath shall comply with 14.1.2, 14.1.3, 14.4.1, and 14.4.2.

d) Interlocked metal armor shall comply with 14.1.2 and 14.5.1 – 14.5.9. See 10.2(b).

e) Wire armor or a metal braid shall be applied over a jacket that complies with Cable Jacket, Section 13.

14.1.2 The sheath, or the strip forming the interlocked armor, shall be continuous throughout the length of the cable. A sheath shall not have flaws that affect its integrity – that is, a sheath shall not have any weld openings, cracks, splits, foreign inclusions, or the like. The strip from which interlocked armor is formed may be spliced (see 14.5.3) but there shall not be any cut or broken ends.

14.1.3 The number of convolutions per unit length of a welded or extruded corrugated metal sheath is not specified but is to be judged on the basis of the performance of the finished cable in the tests specified in this standard.

14.2 Smooth metal sheath

14.2.1 A smooth metal sheath shall be of an aluminum-base alloy having a copper content of 0.40 percent or less, of commercially pure lead, or of an alloyed lead. The sheath shall be tightly formed around the underlying cable.

14.2.2 The metal sheath shall be applied over a jacket complying with Cable Jacket, Section 13; over a separator, binder, or other covering; or directly over the cable construction described in Table 12.1 without any intervening jacket, separator, or other covering.

14.2.3 The average thickness and the minimum thickness at any point of the smooth sheath shall not be less than indicated in Table 14.1. The thicknesses of the smooth sheath are to be determined by means of a machinist's micrometer caliper that has a hemispherical surface on the anvil, has a flat surface on the end of the spindle, and is calibrated to read directly to at least 0.001 inch or 0.01 mm. The spindle shall be round.

Exception: When the performance of the sheath meets the requirements in the Standard for Metal-Clad Cables, UL 1569, dimensions of the sheath may differ from those shown in Table 14.1.

14.2.4 A smooth or corrugated metal sheath that does not comply with the requirements in this standard may be stripped from the entire length of the cable and the cable may be resheathed.

14.3 Welded and corrugated metal sheath

14.3.1 A welded and corrugated metal sheath shall be of an aluminum-base alloy having a copper content of 0.40 percent or less, a copper alloy, or a bronze alloy. The sheath shall be tightly formed around the underlying cable and shall be welded and corrugated. The sheath shall be applied as indicated in 14.2.2. See 14.2.4.

14.3.2 The minimum thickness at any point of the unformed metal tape from which the welded and corrugated sheath is made shall not be less than 0.022 inch or 0.56 mm. The thickness of the unformed tape is to be determined by means of a machinist's micrometer caliper having an anvil and spindle that are round and are not larger than 0.200 inch or 5.1 mm in diameter, with flat surfaces on each.

Exception: When the performance of the metal sheath meets the requirements in the Standard for Metal-Clad Cables, UL 1569, dimensions of the metal tape may differ from those required in 14.3.2.

14.4 Extruded and corrugated metal sheath

14.4.1 An extruded and corrugated metal sheath shall be of an aluminum-base alloy having a copper content of 0.40 percent or less. The sheath shall be tightly formed around the underlying cable. The sheath shall be applied as indicated in 14.2.2. See 14.2.4.

Table 14.1
Thicknesses of smooth aluminum sheath

Calculated diameter under aluminum see 5.1		Mils		mm	
inch	mm	Minimum acceptable average thickness	Minimum acceptable thickness at any point	Minimum acceptable average thickness	Minimum acceptable thickness at any point
0 – 0.400	0 – 10.16	35	32	0.89	0.81
Over 0.400 but not over 0.740	Over 10.16 but not over 18.80	45	41	1.14	1.04

Table 14.1 Continued on Next Page

Table 14.1 Continued

Calculated diameter under aluminum see 5.1		Mils		mm	
inch	mm	Minimum acceptable average thickness	Minimum acceptable thickness at any point	Minimum acceptable average thickness	Minimum acceptable thickness at any point
Over 0.740 but not over 1.050	Over 18.80 but not over 26.67	55	50	1.40	1.27
Over 1.050 but not over 1.300	Over 26.67 but not over 33.02	65	59	1.65	1.50
Over 1.300 but not over 1.550	Over 33.02 but not over 39.67	75	68	1.90	1.73
Over 1.550 but not over 1.800	Over 39.37 but not over 45.72	85	77	2.16	1.96
Over 1.800	Over 45.72	95	86	2.41	2.18

14.4.2 The minimum thickness at any point of the unformed metal tube from which the extruded and corrugated sheath is made shall not be less than 0.022 inch or 0.56 mm when determined as indicated in 14.2.3.

Exception: When the performance of the metal sheath meets the requirements in the Standard for Metal-Clad Cables, UL 1569, dimensions of the metal tube may differ from those required in 14.4.2.

14.5 Interlocked armor

14.5.1 Armor shall consist of interlocked steel or aluminum strip and shall comply with 14.1.2 and 14.5.2 – 14.5.9. Dimensions of the metal strip shall comply with 14.5.9. The strip shall be applied as indicated for a metal sheath in 14.2.2.

14.5.2 The strip shall be made of steel or of an aluminum-base alloy with a copper content of 0.40 percent or less. Steel strip shall be protected against corrosion by a coating of zinc on all surfaces, including edges and splices. The coating on each surface shall be evenly distributed, shall adhere firmly at all points, and shall be smooth and free from blisters and all other defects that can diminish the protective value of the coating.

14.5.3 The steel or aluminum strip shall be uniform in width, thickness, and cross section and shall not have any burrs, sharp edges, pits, scars, cracks, or other flaws that can damage the underlying cable or any jacket over the armor. Splices shall not materially increase the width or thickness of the strip nor shall they lessen the mechanical strength of the strip or adversely affect the formed armor.

14.5.4 Zinc-coated steel strip shall have a tensile strength of not less than 40,000 lbf/in^2 or 276 MN/m^2 or 27,600 N/cm^2 or 28.1 kgf/mm^2 and not more than 70,000 lbf/in^2 or 483 MN/m^2 or 48,300 N/cm^2 or 49.2 kgf/mm^2. The tensile strength shall be determined on longitudinal specimens consisting of the full width of the strip when practical and otherwise on a straight specimen slit from the center of the strip. The test shall be made prior to application of the strip to the cable.

Table 14.2
Dimensions of metal strip for interlocked armor

Calculated diameter under armor see 5.1	Maximum acceptable width of unformed strip[a]	Minimum acceptable thickness at any point of the formed strip removed from the finished cable	
		Steel	Aluminum
inch	mils		
0 – 0.500	500	17	22
Over 0.500 but not over 1.000	750	17	22
Over 1.000 but not over 1.500	875	17	22
Over 1.500 but not over 2.000	875	22	27
Over 2.000	1000	22	27
mm	mm		
0 – 12.7	12.7	0.43	0.56
Over 12.7 but not over 25.4	19.0	0.43	0.56
Over 25.4 but not over 38.1	22.2	0.43	0.56
Over 38.1 but not over 50.8	22.2	0.56	0.69
Over 50.8	25.4	0.56	0.69

[a] The acceptable tolerances for the width of steel strip are plus 10 mils and minus 5 mils or plus 0.2 mm and minus 0.1 mm. The acceptable tolerances for the width of aluminum strip are plus and minus 10 mils or plus and minus 0.2 mm.

14.5.5 Zinc-coated steel strip shall have an elongation of not less than 10 percent in 10 inches or not less than 10 percent in 254 millimeters. The elongation shall be determined as the permanent increase in length of a marked section of the strip (originally 10 inches or 254 mm in length) measured after the specimen has fractured. The test shall be made prior to application of the strip to the cable.

14.5.6 Finished zinc-coated steel strip, prior to being applied to the cable, shall have a zinc coating that remains adherent without flaking or spalling when the strip is subjected to a 180° bend over a mandrel that is 1/8 in or 3.2 mm in diameter. The zinc coating is to be considered as complying with this requirement if, when the strip is bent around the specified mandrel, the coating does not flake or fly off and none of it can be removed from the strip by rubbing with the fingers.

14.5.7 Loosening or detachment during the adherence test and superficial (small) particles of zinc formed by mechanical polishing of the surface of the zinc-coated steel strip do not constitute reason for rejection.

14.5.8 Unformed and formed zinc-coated steel strip shall comply with the copper sulphate test of the zinc coating described in Copper Sulphate Test of Zinc Coating on Steel Strip for and from Interlocked Steel Armor, Section 34.

14.5.9 The width of unformed aluminum strip or of unformed zinc-coated steel strip shall not be greater than indicated in Table 14.2. The minimum thickness at any point of the formed metal strip removed from the finished cable shall not be less than indicated in Table 14.2 when measured by means of a machinist's micrometer caliper having an anvil and spindle that are round and are not larger than 0.020 inch or 5.1 mm in diameter, with flat surfaces on each.

Exception: When the performance of the armor meets the requirements in the Standard for Metal-Clad Cables, UL 1569, dimensions of the armor may differ from those shown in Table 14.2.

15 Jacket over Metal Covering

15.1 A jacket is required over a metal covering that is on any cable intended for direct burial. A jacket is not required over a metal covering on other cable [see 10.2(b)]. Any jacket provided over a metal covering shall comply with Cable Jacket, Section 13. The same calculated (see 5.1) core dimension that is used in determining the thicknesses of a section 13 cable jacket that is not over a metal covering is to be used in determining the thicknesses required for an over-metal jacket – that is, an over-metal jacket need not be thicker than a cable jacket that is not over a metal covering.

PERFORMANCE

16 Continuity Test of Conductors and Shields

16.1 The cable shall be tested for continuity of each conductor and shield before the Dielectric Voltage-Withstand Test is performed. The continuity testing is to be conducted in one of the following ways on 100 percent of production by the cable manufacturer at the cable factory:

a) The finished cable is to be tested on each master reel before the final rewind operation or as individual shipping lengths after the final rewind operation. A master reel is any reel containing a single length of finished cable that is intended to be cut into shorter lengths for shipping.

b) The assembled cable is to be tested before the overall covering is applied. In this case, one shipping length from each master reel of the finished cable is also to be tested. If any conductor or shield in the finished cable in that length is found not to be continuous, 100 percent of the finished cable on the master reel from which the length was taken is to be tested.

16.2 To determine whether or not the finished cable complies with the requirement in 5.2 or 10.1, each conductor or shield taken separately is to be connected in series with a light-emitting diode (LED), lamp, buzzer, bell, or other indicator, and an appropriate low-voltage a-c or d-c power supply.

17 D-C Resistance Test of Copper Conductors

17.1 The direct-current resistance of any length of metal- coated or uncoated copper conductor in ohms per 1000 conductor feet or in ohms per conductor kilometer shall not be higher than the maximum acceptable value indicated for the marked size of the conductor (see 5.3) in Table 17.1 (solid conductors) or 17.2 (stranded conductors) when measured at or adjusted to a temperature of 20°C (68°F) or 25°C (77°F). The direct-current resistance of each conductor in a finished multiple-conductor cable shall not exceed the single-conductor value in Table 17.1 or Table 17.2 multiplied by whichever of the following factors is applicable:

Construction	Multiplier
Cabled in one layer	1.02
Cabled in more than one layer	1.03
Cabled as one pair	1.04
Cabled as an assembly of pairs or other precabled units	1.04

17.2 The method is not specified but measurements are to be made to an accuracy of 2 percent or better by means of a Kelvin-bridge ohmmeter or its equivalent (see 17.3 concerning measurement at other temperatures). If the results of any measurement are not acceptable, the results of referee measurements made under the conditions outlined in 17.4 – 17.10 are to be taken as conclusive. An option of determining the conductor diameter or area instead of its d-c resistance is described in paragraph 5.4 for solid and stranded copper conductors of a standard (see 5.2) AWG size.

17.3 The resistance of an uncoated or metal-coated copper conductor measured at any temperature other than 20°C (68°F) or 25°C (77°F) is to be adjusted to the resistance at 20°C (68°F) or 25°C (77°F) by means of the applicable multiplying factor from Table 17.3. If the resistance measurements are made at a temperature higher than 20°C (68°F) and the resistance values read are less than those specified in Table 17.1 or Table 17.2, the conductor is acceptable without use of the factors in Table 17.3.

17.4 A referee determination of the direct-current resistance of a conductor is to be made to an accuracy of 0.2 percent or better by means of the general-purpose Kelvin-bridge or its investigated equivalent using a straight specimen of the conductor that is 24 – 48 inches or 610 – 1220 mm long. See note [a] to Table 17.3.

17.5 Each general-purpose Kelvin-bridge current electrode is to be attached to a specimen in a way – conductor not damaged or bent, conductor in full-length contact with the electrode, uniform pressure by the electrode at all points of contact, and so forth – that results in an essentially uniform distribution of current.

17.6 The distance between each general-purpose Kelvin-bridge potential electrode and its corresponding current electrode is to equal or exceed 1.5 times the circumference of the conductor specimen. The resistance of the Kelvin-bridge yoke between the reference standard and the specimen is not to be more than 0.1 percent of the resistance of the reference standard or the specimen, whichever is less, unless compensation is made for the potential leads or the coil and lead ratios are balanced.

17.7 Each general-purpose Kelvin-bridge potential electrode shall contact the conductor specimen with a surface that is a sharp knife edge (see 17.10). The length of the conductor specimen between the knife edges is to be measured to the nearest 0.01 inch or 0.2 mm.

17.8 When using the general-purpose Kelvin-bridge, the conductor specimen, all equipment, and the surrounding air are to be in thermal equilibrium with one another at one temperature in the range of 15–30°C (59 – 86°F). All of the referee resistance measurements are to be made at that one temperature. See 17.3 and note [a] to Table 17.3.

Table 17.1
Maximum acceptable direct-current resistance of solid copper conductors

AWG size of conductor	Uncoated				Coated			
	20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per kilometer	Ohms per 1000 feet	Ohms per kilometer	Ohms per 1000 feet	Ohms per kilometer	Ohms per 1000 feet	Ohms per kilometer
28	66.6	219	67.9	223	69.3	227	70.6	232
27	52.4	172	53.4	175	54.4	179	55.5	182
26	45.1	148	46.0	151	46.9	154	47.8	157
25	35.6	117	36.3	119	37.0	121	37.7	124
24	28.6	93.8	29.2	95.8	31.5	103	32.1	105
23	22.3	73.2	22.7	74.5	23.2	76.1	23.7	77.8
22	18.0	59.1	18.4	60.4	19.8	65.0	20.2	66.3
21	14.1	46.3	14.4	47.2	14.7	48.2	15.0	49.2
20	11.1	36.4	11.3	37.1	11.6	38.1	11.8	38.7
19	8.86	29.1	9.04	29.7	9.21	30.2	9.39	30.8
18	6.52	21.4	6.64	21.8	6.78	22.2	6.91	22.7
17	5.15	16.9	5.25	17.2	5.36	17.6	5.46	17.9

Table 17.1 Continued on Next Page

Table 17.1 Continued

AWG size of conductor	Uncoated				Coated			
	20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per kilometer	Ohms per 1000 feet	Ohms per kilometer	Ohms per 1000 feet	Ohms per kilometer	Ohms per 1000 feet	Ohms per kilometer
16	4.10	13.5	4.18	13.7	4.26	14.0	4.35	14.3
15	3.24	10.6	3.30	10.8	3.37	11.1	3.43	11.3
14	2.57	8.45	2.62	8.61	2.68	8.78	2.72	8.96
13	2.04	6.69	2.08	6.82	2.12	6.96	2.16	7.09
12	1.62	5.31	1.65	5.42	1.68	5.53	1.71	5.64
11	1.29	4.22	1.32	4.30	1.34	4.39	1.37	4.48
10	1.02	3.34	1.04	3.41	1.06	3.48	1.08	3.55

Table 17.2
Maximum acceptable direct-current resistance of stranded copper conductors

AWG size of conductor	Uncoated				Coated			
	20°C		25°C		20°C		25°C	
	Ohms per 1000 feet	Ohms per kilometer	Ohms per 1000 feet	Ohms per kilometer	Ohms per 1000 feet	Ohms per kilometer	Ohms per 1000 feet	Ohms per kilometer
28	67.9	223	69.3	227	70.7	232	72.0	236
27	53.4	175	54.5	179	55.6	182	56.6	186
26	42.7	140	43.6	143	44.4	145	45.2	148
25	33.7	111	34.4	113	35.0	115	35.7	117
24	26.7	87.6	27.2	89.2	27.7	90.9	28.4	93.2
23	21.1	69.2	21.5	70.5	21.9	71.9	22.3	73.2
22	16.9	55.4	17.2	56.4	17.5	57.4	17.9	58.7
21	13.3	43.6	13.6	44.6	13.9	45.6	14.1	46.3
20	10.5	34.4	10.7	33.1	10.9	35.8	11.1	36.4
19	8.39	27.5	8.66	28.4	8.71	28.6	8.87	29.1
18	6.66	21.9	6.79	22.3	6.92	22.7	7.04	23.1
17	5.29	17.4	5.40	17.7	5.47	17.9	5.57	18.3
16	4.19	13.7	4.27	14.0	4.35	14.3	4.44	14.6
15	3.30	10.8	3.37	11.1	3.44	11.3	3.50	11.5
14	2.62	8.60	2.67	8.76	2.73	8.96	2.77	9.09
13	2.08	6.82	2.12	6.96	2.16	7.09	2.20	7.22
12	1.65	5.41	1.68	5.51	1.71	5.61	1.74	5.71
11	1.32	4.33	1.35	4.43	1.37	4.49	1.40	4.59
10	1.04	3.41	1.06	3.48	1.08	3.54	1.10	3.61

Table 17.3
Factors for adjusting d-c resistance of conductors[a]

Temperature of conductor		Multiplying factor for adjustment to resistance at		Temperature of conductor		Multiplying factor for adjustment to resistance at	
°C	°F	25°C (77°F)	20°C (68°F)	°C	°F	25°C (77°F)	20°C (68°F)
0	32.0	1.107	1.085	45	113.0	0.928	0.911
1	33.6	1.102	1.081	46	114.8	0.925	0.908
2	35.6	1.098	1.076	47	116.6	0.922	0.905
3	37.4	1.093	1.072	48	118.4	0/918	0.901
4	39.2	1.089	1.067	49	120.2	0.915	0.898
5	41.0	1.084	1.063	50	122.0	0.912	0.895
6	42.8	1.079	1.059	51	123.8	0.909	0.892
7	44.6	1.075	1.054	52	125.6	0.906	0.889
8	46.4	1.070	1.050	53	127.4	0.902	0.885
9	48.2	1.066	1.045	54	129.2	0.899	0.822
10	50.0	1.061	1.041	55	131.0	0.896	0.879
11	51.8	1.057	1.037	56	132.8	0.893	0.876
12	53.6	1.053	1.033	57	134.6	0.890	0.873
13	55.4	1.048	1.028	58	136.4	0.887	0.870
14	57.2	1.044	1.024	59	138.2	0.884	0.867
15	59.0	1.040	1.020	60	140.0	0.881	0.864
16	60.8	1.036	1.016	61	141.8	0.878	0.861
17	62.6	1.032	1.012	62	143.6	0.875	0.858
18	64.4	1.028	1.008	63	145.4	0.872	0.856
19	66.2	1.024	1.004	64	147.2	0.869	0.853
20	68.0	1.020	1.000	65	149.0	0.866	0.850
21	69.8	1.016	0.996	66	150.8	0.863	0.847
22	71.6	1.012	0.992	67	152.6	0.860	0.844
23	73.4	1.008	0.989	68	154.4	0.858	0.842
24	75.2	1.004	0.985	69	156.2	0.855	0.839
25	77.0	1.000	0.981	70	158.0	0.852	0.836
26	78.8	0.996	0.977	71	159.8	0.849	0.833
27	80.6	0.992	0.973	72	161.6	0.846	0.830
28	82.4	0.989	0.970	73	163.4	0.844	0.828
29	84.2	0.985	0.966	74	165.2	0.841	0.825
30	86.0	0.981	0.962	75	167.0	0.838	0.822
31	87.8	0.977	0.958	76	168.8	0.835	0.819
32	89.6	0.974	0.955	77	170.6	0.833	0.817

Table 17.3 Continued on Next Page

Table 17.3 Continued

Temperature of conductor		Multiplying factor for adjustment to resistance at		Temperature of conductor		Multiplying factor for adjustment to resistance at	
°C	°F	25°C (77°F)	20°C (68°F)	°C	°F	25°C (77°F)	20°C (68°F)
33	91.4	0.970	0.951	78	172.4	0.830	0.814
34	93.2	0.967	0.948	79	174.2	0.828	0.812
35	95.0	0.963	0.944	80	176.0	0.825	0.809
36	96.8	0.959	0.941	81	177.8	0.822	0.807
37	98.6	0.956	0.937	82	179.6	0.820	0.804
38	100.4	0.952	0.934	83	181.4	0.817	0.802
39	102.2	0.949	0.930	84	183.2	0.815	0.799
40	104.0	0.945	0.927	85	185.0	0.812	0.797
41	105.8	0.942	0.924	86	186.8	0.810	0.794
42	107.6	0.938	0.921	87	188.6	0.807	0.792
43	109.4	0.935	0.917	88	190.4	0.805	0.789
44	111.2	0.931	0.914	89	192.2	0.802	0.787
				90	194.0	0.800	0.784

[a] No referee resistance measurement is to be made at a temperature outside the range of 15 – 30°C (59 – 86°C). See 17.8.

17.9 Because the general-purpose Kelvin-bridge measuring current raises the temperature of the specimen, the magnitude of the current is to be as low as possible and the time of its use is to be brief. Too much current, too much time, or both, are being used for a measurement if any change in resistance is detected with the galvanometer in two successive readings.

17.10 The contact surfaces of the general-purpose Kelvin-bridge current electrodes, the surface of the conductor specimen, and the knife edges of the general-purpose Kelvin-bridge potential electrodes are to be clean and undamaged. Contact-potential imbalance is to be minimized by having the potential electrodes made of the same material. Contact-potential error is to be eliminated by taking two readings in direct succession: the first with the current flowing in one direction and the second with the current flowing in the other direction. If the two readings are within 0.25 percent of one another, the average of the two readings is to be taken as the referee value of the resistance of the specimen. If the two readings differ from one another by 0.25 percent or more, the specimen is to be turned end for end and two additional readings identified as the third and fourth readings are to be taken in direct succession: the third with the current flowing in one direction and the fourth with the current flowing in the other direction. If the third and fourth readings are within 0.25 percent of one another, the average of the third and fourth readings is to be taken as the referee value of resistance of the specimen. If the third and fourth readings differ from one another by 0.25 percent or more, the equipment and procedure are to be checked for compliance with 17.4– 17.9 and the referee determination is to be repeated (two or four readings as necessary) using the same specimen or a new specimen.

18 Cold Bend Test of Insulation

18.1 After being conditioned for 4 h in circulating air that is precooled to and maintained at a temperature of −20.0°C, +3.0°C, −2.0°C (−4.0°F, +5.4°F, −3.6°F), the insulation or integral insulation and jacket on specimens removed from the finished cable (before being conditioned) shall not crack on the inside or outside surface when the specimens are individually wound onto a round mandrel in the cold chamber as described in 18.2– 18.4.

18.2 A circular metal mandrel is to be used in this test. The diameter of the mandrel is to be as indicated in Table 18.1. The single mandrel is to be securely mounted in the chamber in a position that facilitates the winding.

18.3 For testing the integral insulation and jacket of flat cable, 24-inch or 610-mm lengths of the complete flat cable are to be used as flat specimens. The insulated conductors and any coaxial members are to be removed from a 24-inch or 610-mm length of other finished cable and are to be separated from one another and individually placed as round specimens in the precooled cold chamber. Any jacket and the shield (s) are to be removed from coaxial members before these members are placed in the cold chamber. The specimens and mandrel are to be conditioned for 4 h in circulating air that is precooled to and maintained at a temperature of −20.0°C, +3.0°C, −2.0°C (−4.0°F, +5.4°F, −3.6°F). At the end of the fourth hour, the specimens are to be wound individually, and in quick succession, for 5 full turns onto the mandrel, with adjacent turns touching (1 complete turn is to be used for flat cable). The winding of each specimen is to be at an approximately uniform rate of 5 seconds per turn. The winding is to be done in the cold chamber.

18.4 With a minimum of handling and while remaining in the coiled form, each specimen is to be slid from the mandrel, removed from the test chamber, and placed on a horizontal surface. The specimens are to rest on that surface undisturbed for at least 60 min in still air to warm to a room temperature of 24.0 ±8.0°C (75.2 ±14.4°F). Each specimen is then to be examined for cracks on the inside and outside surfaces of the insulation or of the integral insulation and jacket. Cracks on the inside surface can be detected as circumferential depressions in the outer surface of a specimen of material other than a fluoropolymer. Circumferential depressions in a fluoropolymer surface are likely to be yield marks (locally stronger points) rather than indicators of cracking.

Table 18.1
Cold bend mandrel diameter

Calculated diameter over round specimen or calculated length of minor axis of flat cable See 5.1		Diameter of mandrel	
inch	mm	inch	mm
0 – 0.083	0 – 2.11	0.250	6.35
Over 0.083 but not over 0.104	Over 2.11 but not over 2.64	0.313	7.95
Over 0.104 but not over 0.125	Over 2.64 but not over 3.18	0.375	9.53
Over 0.125 but not over 0.146	Over 3.18 but not over 3.71	0.438	11.1
Over 0.146 but not over 0.167	Over 3.71 but not over 4.24	0.500	12.7
Over 0.167 but not over 0.188	Over 4.24 but not over 4.78	0.563	14.3
Over 0.188 but not over 0.208	Over 4.78 but not over 5.28	0.625	15.9
Over 0.208 but not over 0.229	Over 5.28 but not over 5.82	0.688	17.5
Over 0.229 but not over 0.250	Over 5.82 but not over 6.35	0.750	19.1
Over 0.250 but not over 0.271	Over 6.35 but not over 6.88	0.813	20.7
Over 0.271 but not over 0.292	Over 6.88 but not over 7.42	0.875	22.2
Over 0.292 but not over 0.333	Over 7.42 but not over 8.46	1.000	25.4

19 Cold Bend Test of Complete Cable

19.1 After being conditioned for 4 h in circulating air that is precooled to and maintained at a temperature of −20.0°C (-4.0°F), -30.0°C (-22.0°F), -40.0°C (-40.0°F), -50.0°C (-58.0°F), -60.0°C (-76.0°F), or -70.0°C (-94° F), specimens of the complete cable shall not be damaged when the specimens are individually wound onto a round mandrel as described in 19.2 and 19.3. See 44.1(o) and (p) regarding marking or not marking the cable with its low-temperature rating.

19.2 Four straight test lengths of the complete finished cable are to be cooled for 4 h in circulating air that is precooled to and maintained at one of the following temperatures: −20.0°C (-4.0°F), -30.0°C (-22.0°F), -40.0°C (-40.0°F), -50.0°C (-58.0°F), -60.0°C (-76.0°F), or -70.0°C (-94°F). Tolerances of +3.0, -2.0°C (+5.4°F, -3.6°F) apply to each of these temperature. At the end of the fourth hour, the specimens are to be removed from the cold chamber one at a time and are to be wound individually for 3 full turns around a circular wooden mandrel of a diameter equal to 8 times the calculated diameter or length of minor axis of the outside of a cable that does not contain any shield, 15 times the calculated diameter or length of minor axis of the outside of a cable that contains the specific metal sheath described in 10.3, or equal to 12 times the calculated diameter or length of minor axis of the outside of a cable that contains one or more shields (coaxial members are included here if they are not covered under x 15). There is not to be any more tension applied to a specimen than is necessary to keep the surface of the specimen in contact with the mandrel. Adjacent turns are to touch one another. The winding of each specimen is to be conducted at an approximately uniform rate of 5 seconds per turn, and the time taken to remove a specimen from the cold chamber and complete the winding is not to exceed 30 s. As an alternative, the test may be performed in the cold chamber using wood or metal mandrels.

19.3 With a minimum of handling and while remaining in the coiled form, each specimen is to be slid from the mandrel and placed on a horizontal surface. The specimens are to rest on the surface undisturbed for at least 4 h in still air to warm to a room temperature of 24.0 ±8.0°C (75.2 ±14.4°F) before being examined for surface damage. Each specimen is then to be disassembled and examined further for damage. The cable is acceptable if, for the first length tested, there aren't any cracks, splits, tears, or other openings in any part of the cable. Cracks on the inside surface of a jacket or of the insulation can be detected as circumferential depressions in the outer surface of a jacket or insulation of material other than a fluoropolymer. Circumferential depressions in a fluoropolymer surface are likely to be yield marks (locally stronger points) rather than indicators of cracking. If the first test length has any of these faults, acceptance is to be governed by the results obtained from the three remaining test lengths. The cable is not acceptable if any of the three additional test lengths have one or more faults. The examinations are to be made with normal or corrected vision without magnification.

20 Smoke and Fire Testing of Type FPLP Cable

20.1 Type FPLP cable shall comply with the flame-spread and smoke-density limits stated in Appendix A of the National Fire Protection Association Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces, ANSI/NFPA 262, when specimens of the finished cable are tested in sets as described in NFPA 262. Typically, the test specimens of this cable are the smallest and largest diameters of the cable that the manufacturer intends to produce in the construction.

21 Fire Testing of Type FPLR Cable

21.1 Type FPLR cable shall comply with the flame-propagation limits stated in the Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts (UL 1666) when specimens of the finished cable are tested in sets as described in UL 1666. See 1.6(b). For cables whose insulated conductors comply with the FT2/Horizontal Flame as described in UL 2556, the results of this test using (typically) the smallest diameter of cable that the manufacturer intends to produce in the construction are to be considered representative of the performance of finished cables of the same construction that are of any diameter.

21.2 For cables with HDPE, LDPE, or PP insulation, and for cables whose insulated conductors comply with the FT2/Horizontal Flame as described in UL 2556, the test specimens are to be representative of the entire size range in each construction. Typically, the test specimens of this cable are the smallest and largest diameters of cable that the manufacturer intends to produce in the construction.

22 VW-1 (Vertical-Specimen) Flame Test

Deleted

23 Alternative Vertical-Tray Flame Tests on Type FPL Cable

23.1 General

23.1.1 Choice of test

23.1.1.1 The cable manufacturer shall specify either the UL test referenced in 23.2.1 or the FT4/IEEE 1202 test referenced in 23.3.1 for each construction of that manufacturer's cable that is surface marked or designated by a marker tape as "FPL". The same test is not required for all constructions.

23.1.2 Changes in construction

23.1.2.1 The construction of a cable is changed (and therefore the flame test is to be repeated) where different materials and/or different amounts of the same materials are introduced that affect the flame characteristics of the cable.

23.1.2.2 For a cable that contains a metal or metalized tape shield or a wire shield, the flame test is to be conducted with the thinnest metal in the shield tape, smallest-diameter shield wire, and least shield coverage that the manufacturer intends to use in production. The performance of the cable in the flame test is affected by any change that reduces the tape metal thickness, shield wire size, and/or coverage of the shield. Any reduction in one or more of these elements during production requires re-evaluation of the cable in a repeat of the flame test.

23.2 UL test

23.2.1 Type FPL cable of a given construction shall not exhibit char that reaches the upper end of any specimen (a maximum of 8 ft, 0 inch or 244 cm) when sets of cable specimens as described in 23.2.2 or 23.2.3 are separately installed in a vertical ladder type of cable tray and are subjected to 20 min of flame as described under UL Flame Exposure (smoke measurements are not applicable) in the Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685.

23.2.2 For cables whose insulated conductors comply with the FT2/Horizontal Flame as described in UL 2556, the results of a vertical-tray flame test using two sets of specimens of the cable that are 0.500 inches or 12.7 mm in diameter (equivalent diameter for a cable that is not round: calculated as 1.1284 x $(TW)^{1/2}$, in which T is the thickness of the cable, and W is the width of the cable) typically represent the performance of the finished cable of the same construction that are of any diameter. A tested size does not comply when the damage to the insulation and/or the overall cable jacket reaches the upper end ot the individual cable length.

23.2.3 For cables with HDPE, LDPE, or PP insulation, and for cables whose insulated conductors do not comply with the FT2/Horizontal Flame as described in UL 2556, the test specimens are to be representative of the entire size range in each construction. Typically, the test specimens of this cable are two sets each of the smallest and largest diameters (see parenthetical note in 23.2.2) of cable that the manufacturer intends to produce in the construction. A tested size does not comply when the damage to the insulation and/or the overall cable jacket reaches the upper end of the individual cable length.

23.3 FT4/IEEE 1202 Test

23.3.1 Finished cable that is surface marked or designated by a marker tape as "FPL" shall not exhibit a char length in excess of 1.5 m or 4 ft, 11 inches when each of five sets of specimens as detailed in 23.2.2 or 23.2.3 is tested as described under FT4/IEEE 1202 Type of Flame Exposure (smoke measurements are not applicable) in the Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. Where char length in excess of 1.5 m or 4 ft, 11 inches is reached on any individual cable in any set of specimens tested, compliance in tests of additional sets of specimens is required to qualify the full size range desired by the manufacturer. See 44.1(i).

23.4 Vertical-tray fire and smoke-release test for cables with "ST-1" marking

23.4.1 Each type of power limited fire alarm cable that is surface marked "ST-1" in accordance with 44.1 (q) shall comply with the limits for smoke release and cable char height stated in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685, when sets of specimens as described in 23.4.2 are tested in either of the flame exposures described in UL 1685 with smoke measurements included.

23.4.2 The test specimens shall be of the complete, finished cable. The test specimens shall be representative of the entire size range that the manufacturer intends to produce in each construction made. Specimens for a UL 1685 fire test typically consist of the smallest, largest, and an intermediate diameter that the manufacturer intends to produce in each construction made. Where the UL 1685 limits are exceeded by the smoke released and/or the cable char height for any set of specimens tested, compliance in tests of additional sets of specimens is required to qualify the full size range desired by the manufacturer.

24 Sunlight Resistance Test

24.1 Any cable that is marked for sunlight-resistant use is to be considered acceptable for use in sunlight if the ratio of the average tensile strength and ultimate elongation of five conditioned specimens of the overall jacket to the average tensile strength and ultimate elongation of five unconditioned specimens of the overall jacket is 0.80 or more when the finished cable is conditioned and tested as described in the test Physical Properties (Ultimate Elongation and Tensile Strength) using 720 hours of carbon-arc exposure or xenon-arc exposure.

25 Spark Test after Insulating

25.1 The insulation on each conductor and coaxial member for and in every length of cable shall comply with a spark test. One hundred percent of production shall be tested by the manufacturer at the factory. No faults are acceptable in any insulated conductor for a direct-burial cable; in a cable for wet locations; in a coaxial member; in a single-conductor cable; or in an integral flat cable. For other cables, no insulated conductor shall show more than an average of one fault per 3000 ft or 915 m in any reel length of single insulated conductor.

25.2 The spark test indicated in 25.1 is to be a d-c spark test of 2500 V or an a-c rms spark test of 1750 V or, as an alternative for cable employing foamed insulation that is not more than 0.008 in or 0.20 mm in average thickness, does not have a skin, and complies with the a-c dielectric voltage-withstand requirement in 26.2, a spark test employing an essentially sinusoidal 48 – 62 Hz rms potential of 1250 V, or 1750 V d-c. The test is to be conducted on each conductor and coaxial member after it is insulated and before any subsequent operation. The test equipment and method are to be as described in the test Spark in UL 2556.

26 Dielectric Voltage-Withstand Test

26.1 The insulation on each conductor and coaxial member in every length of finished nonintegral cable shall withstand without breakdown either a direct potential of 2500 V applied for at least 2 s, or a 48 – 62 Hz essentially sinusoidal rms test potential of 1500 V applied for at least 2 s. In the case of a coaxial member or a single, shielded, insulated conductor, the test potential shall be applied between the conductor and the shield, with the shield connected to earth ground. In all other cases, the test potential shall be applied between each conductor taken separately and all other conductors and any shield(s) and/or metal covering connected together and to earth ground. The test equipment and method are to be as described in the test Dielectric Voltage-Withstand in UL 2556. The equipment is to apply the test potential automatically for each 2 s test. The test potential may be applied manually for tests longer than 2 s. In all cases, the full test potential is to be applied throughout the test interval that is chosen by the cable manufacturer.

26.2 For cable employing foamed insulation that is not more than 0.008 inch or 0.20 mm in average thickness, does not have a skin, and has been subjected to a spark test at an a-c potential of 1250 V or, at a d-c potential of 1750 V, the cable manufacturer shall conduct the following dielectric voltage-withstand test in place of the d-c test at 2500 V or the a-c test at 1500 V described in 26.1. The insulation shall withstand, without breakdown, a 48 – 62 Hz essentially sinusoidal rms potential of 2000 V, or a d-c potential of 2850 V, applied for at least 2 s.

26.3 The dielectric testing is to be conducted in one of the following ways on 100 percent of production by the cable manufacturer at the cable factory:

a) The finished cable is to be tested on each master reel before the final rewind operation or as individual shipping lengths after the final rewind operation. A master reel is any reel containing a single length of finished cable that is intended to be cut into shorter lengths for shipping.

b) The assembled cable is to be tested before the overall covering is applied. In this case, one shipping length from each master reel of the finished cable is also to be tested. If there is a dielectric breakdown of the insulation on any conductor in the finished cable in that length, 100 percent of the finished cable on the master reel from which the length was taken is to be tested.

27 Test for Insulation Resistance at 60.0°F (15.6°C)

27.1 The insulation on each conductor and coaxial member in finished cable shall exhibit an insulation resistance at 60.0°F (15.6°C) of not less than 100 megohms based on 1000 conductor feet, or not less than 30.5 megohms based on a conductor kilometer, when the cable is tested as described in 27.2– 27.8.

27.2 The insulation-resistance test is not a routine production test at the factory. It is to be conducted as a routine part of the factory-inspection follow-up work.

27.3 The measuring equipment and test procedure shall be applicable but otherwise are not specified. A megohm bridge used for these measurements shall be of applicable range and calibration, shall present readings that are accurate to 10 percent or less of the value indicated by the meter, and shall have a 100 – 550-V or higher open-circuit potential.

27.4 Coaxial cable is to be tested dry with the insulation-resistance readings made between the center and outer conductors on specimens that are at least 50 ft or 15 m long. Flat, parallel cable and individually insulated conductors (any nylon or similar covering is to be in place) are to be immersed in tap water for at least 6 h at room temperature before the insulation-resistance reading is taken. The immersion vessel is to have an electrode for grounding the water to the earth (this may be the inside surface of a metal tank if that surface is not painted or otherwise insulated from the water). For the test in water, the immersed length of each specimen is to be at least 50 ft or 15 m, and at least 2.5 ft or 750 mm at each end of each specimen is to extend out of the water and is to be kept dry as leakage insulation.

27.5 If at the time of immersion the temperature of any part of the coil or reel of finished cable differs by more than 5.0°F (2.8°C) from the temperature of the water, one of the following is to be done to make certain that the water, the insulation, and the conductor are at the same temperature at the time that the insulation resistance is measured:

a) The insulation and the conductor are to be considered to be at the same temperature as the water in which they are immersed whenever the same d-c resistance of the conductor is obtained in each of three successive measurements made at intervals of 30 min by means of a Kelvin-bridge ohmmeter that presents readings accurate to 2 percent or less of the value indicated by the meter.

b) The water is to be heated or cooled, as necessary, to within 5.0°F (2.8°C) of the temperature of the insulation and conductor before the coil or reel is immersed.

27.6 The water and the entire length of the immersed insulated conductor, nylon or similarly covered insulated conductor, or flat cable are to be at any one temperature in the range of 40.0 – 95.0°F (4.4 – 35.0°C) at the time that the insulation resistance is measured. If their temperature at this time is other than 60.0°F (15.6°C), the resulting insulation resistance is to be multiplied by the applicable factor M indicated in Table 27.1.

27.7 A test at 60.0°F (15.6°C) is to be made for a coil or reel that does not show acceptable results when the water temperature is other than 60.0°F (15.6°C).

27.8 If coils or reels are connected together for the insulation-resistance test and acceptable results are not obtained, the individual coils or reels are to be retested to determine which ones have at least the required insulation resistance.

Table 27.1
Multiplying factor M[a] for adjusting insulation resistance to 60°F (15.6°C) from another room temperature

Temperature		M[a]				
		CP, XL, and XLPO	PVC[b] and semirigid PVC[b]			
°F	°C		I	II	III	IV
40	4.4	0.53	0.12	0.17	0.21	0.31
41	5.0	0.55	0.13	0.19	0.23	0.33
42	5.6	0.57	0.15	0.21	0.25	0.35
43	6.1	0.59	0.16	0.22	0.27	0.37
44	6.7	0.60	0.18	0.25	0.29	0.39
45	7.2	0.62	0.20	0.27	0.31	0.42
46	7.8	0.64	0.23	0.29	0.34	0.44
47	8.3	0.66	0.25	0.32	0.36	0.47
48	8.9	0.68	0.28	0.35	0.39	0.49
49	9.4	0.70	0.31	0.38	0.43	0.53
50	10.0	0.73	0.35	0.42	0.46	0.56
51	10.6	0.76	0.39	0.46	0.50	0.59
52	11.1	0.78	0.43	0.50	0.54	0.63
53	11.7	0.80	0.48	0.55	0.58	0.67
54	12.2	0.83	0.54	0.60	0.63	0.70
55	12.8	0.86	0.60	0.65	0.68	0.75
56	13.3	0.88	0.66	0.71	0.74	0.79
57	13.9	0.91	0.73	0.78	0.80	0.84

Table 27.1 Continued on Next Page

Table 27.1 Continued

Temperature		M[a]				
		CP, XL, and XLPO	PVC[b] and semirigid PVC[b]			
°F	°C		I	II	III	IV
58	14.4	0.94	0.82	0.85	0.86	0.90
59	15.0	0.97	0.90	0.92	0.93	0.95
60	15.6	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.11	1.09	1.08	1.06
62	16.7	1.07	1.24	1.19	1.17	1.13
63	17.2	1.10	1.38	1.30	1.26	1.19
64	17.8	1.13	1.53	1.41	1.36	1.26
65	18.3	1.17	1.70	1.54	1.47	1.34
66	18.9	1.20	1.88	1.69	1.59	1.42
67	19.4	1.24	2.09	1.84	1.72	1.51
68	20.0	1.28	2.31	1.99	1.85	1.60
69	20.6	1.32	2.57	2.18	2.00	1.69
70	21.1	1.36	2.85	2.38	2.17	1.79
71	21.7	1.40	3.17	2.34	2.34	1.90
72	22.2	1.45	3.52	2.53	2.53	2.02
73	22.8	1.50	3.90	3.08	2.72	2.14
74	23.3	1.55	4.31	3.35	2.94	2.27
75	23.9	1.59	4.78	3.65	3.18	2.40
76	24.4	1.64	5.30	3.98	3.43	2.54
77	25.0	1.69	5.88	4.34	3.70	2.70
78	25.6	1.75	6.51	4.73	4.00	2.86
79	26.1	1.80	7.27	5.16	4.33	3.03
80	26.7	1.86	8.07	5.61	4.67	3.21
81	27.2	1.90	8.98	6.12	5.04	3.40
82	27.8	1.97	9.92	6.69	5.45	3.60
83	28.3	2.02	11.0	7.28	5.89	3.82
84	28.9	2.10	12.2	7.92	6.35	4.05
85	29.4	2.15	13.5	8.67	6.84	4.30
86	30.0	2.23	14.9	9.31	7.30	4.53
87	30.6	2.30	16.6	10.1	7.93	4.81
88	31.1	2.37	18.5	11.0	8.50	5.09
89	31.7	2.43	20.6	12.0	9.23	5.40

Table 27.1 Continued on Next Page

Table 27.1 Continued

Temperature		M[a]				
		CP, XL, and XLPO	PVC[b] and semirigid PVC[b]			
°F	°C		I	II	III	IV
90	32.2	2.53	23.0	13.1	9.95	5.72
91	32.8	2.60	25.3	14.3	10.7	6.08
92	33.3	2.68	28.2	15.6	11.6	6.44
93	33.9	2.76	31.2	17.0	12.5	6.83
94	34.4	2.86	35.0	18.5	13.5	7.24
95	35.0	2.94	39.00	20.3	14.6	7.68

[a] M = 1.00 for silicone rubber, ECTFE, ETFE, FEP, FRPE, HDPE, LDPE, PFA, PP, PVDF, PVDF copolymer, PTFE, and TFE. M is to be determined individually for each TPE compound by means of the method described in Test Procedure for Determining the Multiplying-Factor Column for Adjusting Insulation Resistance, Section 29.

[b] Normally, one of the four columns, I, II, III, IV in this table is to be assigned to each PVC and semirigid PVC compound used. However, if a PVC compound or a semirigid PVC compound cannot be made to fit into any of the four patterns (columns in this table), applicable values of M are to be determined by means of the method described in Test Procedure for Determining the Multiplying-Factor Column for Adjusting Insulation Resistance, Section 29.

28 Long Term Insulation-Resistance Test in Water

28.1 Insulated conductors from cable that is marked to indicate that it is rated for use in wet locations shall have an insulation resistance in tap water that is not less than indicated in the applicable formulas in 28.2 at any time during immersion. The tap water is to have a temperature of 50 ±1.0°C (122 ±1.8°F). The period of immersion is 12 weeks or more. See 28.3 for the requirement covering the maximum rate of decrease of the insulation resistance.

28.2 The insulation-resistance values are to be calculated by using one of the following formulas, whichever is applicable:

a) (Inch-pound):

$$IR_{50\,°C} = 0.166 \times \log_{10}\frac{D}{d}$$

in which:

$IR_{50°C}$ is the minimum insulation resistance in megohms based on 1000 conductor feet for wire in water at 50°C (122°F).

D is the diameter over the insulation in inches; and

d is the diameter of the metal conductor in inches;

b) (SI)

$$IR_{50\,°C} = 0.051 \times \log_{10}\frac{D}{d}$$

in which:

$IR_{50°C}$ is the minimum insulation resistance in megohms based on a conductor kilometer for wire in water at 50°C (122°F).

D is the diameter over the insulation in mm; and

d is the diameter of the metal conductor in mm;

28.3 For every continuous period of 3 weeks during the latter half of the 12-week immersion, a smooth curve drawn covering the entire immersion period and showing the average of the measured readings of insulation resistance shall not decrease at a rate exceeding 4 percent per week. A coil that shows a greater percent decrease in insulation resistance during the extended immersion than specified in 28.2 shall be tested for additional 1-week immersion periods and the coil is to be evaluated based on the last 12 weeks of immersion.

28.4 To determine whether or not the insulation complies with the requirements in 28.2 and 28.3 the center 50-foot (20-meter) sections of three 55-foot (22-meter) coils of the insulated conductor are to be immersed in tap water at the specified temperature for the duration of the test. The ends of each specimen are to be brought well away from the tank, and the water is to be maintained at the specified temperature.

28.5 The insulation-resistance test equipment and procedures shall be applicable. Otherwise they are not specified. A megohm bridge used for this purpose shall be of applicable range and calibration and shall present readings that are accurate to 10 percent or less of the value indicated by the meter. A d-c potential of 100 – 500 V shall be applied to the insulation for 60 s prior to each reading. Each galvanometer indication shall be given 60 s to stabilize before the reading is recorded. The duration of each reading shall be 60 s in the case of range switching or for metering equipment requiring time to achieve a null. Delay is not required for instant-reading equipment that has been demonstrated to produce correct readings without a 60-s delay.

29 Test Procedure for Determining the Multiplying-Factor Column for Adjusting Insulation Resistance

29.1 Two specimens, conveniently of a 16 – 20 AWG solid conductor with a wall of insulation whose average thickness is 10 – 15 mils or 0.25 – 0.38 mm are to be selected as representative of the insulation under consideration. The specimens are to be of a length (at least 200 ft or 60 m) that yields insulation-resistance values that are stable within the calibrated range of the measuring instrument at the lowest water-bath temperature.

29.2 The two specimens are to be immersed in a water bath equipped with heating, cooling, and circulating facilities. The ends of the specimens are to extend at least 2 ft or 600 mm above the surface of the water to reduce electrical leakage. The specimens are to be left in the water at room temperature for 16 h before adjusting the bath temperature to 50.0°F (10.0°C) or before transferring the specimens to a 50.0°F (10.0°C) bath.

29.3 The d-c resistance of the metal conductor is to be measured at applicable intervals of time until the temperature remains unchanged for at least 5 min. The insulation is then to be considered as being at the temperature of the bath indicated on the bath thermometer.

29.4 Each of the two specimens is to be exposed (29.3 applies) to successive water temperatures of 50.0, 61.0, 72.0, 82.0, and 95.0°F (10.0, 16.1, 22.2, 27.8, and 35.0°C) and returning, 82.0, 72.0, 61.0, and 50.0°F (27.8, 22.2, 16.1, and 10.0°C). Insulation-resistance readings are to be taken at each temperature after equilibrium is established.

29.5 The two sets of readings (four readings in all) taken at the same temperature are to be averaged for the two specimens. These four average values and the average of the single readings at 95.0°F (35.0°C) are to be plotted on semilog paper. A continuous curve (usually a straight line) is to be drawn through the five points. The value of insulation resistance at 60.0°F (15.6°C) is then to be read from the graph.

29.6 The resistivity coefficient C for a 1.0°F (0.55°C) change in temperature is to be calculated to two decimal places by dividing the insulation resistance at 60.0° F (15.6° C) read from the graph by the insulation resistance at 61.0°F (16.1°C). In Table 29.1, C heads the column of multiplying factors M that applies to the particular insulation.

Table 29.1
Multiplying factor M[a] for adjusting insulation resistance to 60.0°F (15.6°C)

Temperature		Resistivity Coefficient C for 1.0°F (0.55°C)									
°F	°C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
40	4.4	0.55	0.46	0.38	0.31	0.26	0.22	0.18	0.15	0.12	0.10
41	5.0	0.48	0.40	0.33	0.28	0.28	0.23	0.19	0.16	0.14	0.12
42	5.6	0.59	0.49	0.42	0.35	0.30	0.25	0.21	0.18	0.15	0.13
43	6.1	0.60	0.51	0.44	0.37	0.32	0.27	0.23	0.20	0.17	0.15
44	6.7	0.62	0.53	0.46	0.39	0.34	0.29	0.25	0.22	0.19	0.16
45	7.2	0.64	0.56	0.48	0.42	0.36	0.32	0.28	0.24	0.21	0.18
46	7.8	0.66	0.58	0.50	0.44	0.39	0.34	0.30	0.26	0.23	0.20
47	8.3	0.68	0.60	0.53	0.47	0.42	0.37	0.33	0.29	0.26	0.23
48	8.9	0.70	0.56	0.56	0.50	0.44	0.40	0.36	0.32	0.29	0.26
49	9.4	0.72	0.65	0.59	0.53	0.48	0.42	0.39	0.35	0.32	0.29
50	10.0	0.74	0.68	0.61	0.56	0.51	0.46	0.42	0.39	0.35	0.32
51	10.6	0.77	0.70	0.64	0.59	0.54	0.50	0.46	0.42	0.39	0.36
52	11.1	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.43	0.40
53	11.7	0.81	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45
54	12.2	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.54	0.51
55	12.8	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.59	0.57
56	13.3	0.89	0.86	0.82	0.79	0.76	0.74	0.71	0.68	0.66	0.64
57	13.9	0.92	0.89	0.86	0.84	0.82	0.79	0.77	0.75	0.73	0.71
58	14.4	0.94	0.93	0.91	0.89	0.87	0.86	0.84	0.83	0.81	0.80
59	15.0	0.97	0.95	0.94	0.95	0.94	0.93	0.92	0.91	0.90	0.89
60	15.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
62	16.7	1.06	1.08	1.10	1.12	1.17	1.17	1.19	1.21	1.23	1.25
63	17.2	1.09	1.12	1.16	1.19	1.23	1.26	1.30	1.33	1.37	1.40
64	17.8	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.46	1.52	1.57
65	18.3	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.61	1.69	1.76
66	18.9	1.19	1.27	1.34	1.42	1.50	1.59	1.68	1.77	1.87	1.97
67	19.4	1.23	1.32	1.41	1.50	1.61	1.71	1.83	1.95	2.08	2.21
68	20.0	1.27	1.37	1.48	1.59	1.72	1.85	1.99	2.14	2.20	2.48

Table 29.1 Continued on Next Page

Table 29.1 Continued

Temperature		Resistivity Coefficient C for 1.0°F (0.55°C)									
°F	°C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
69	20.6	1.30	1.42	1.55	1.69	1.84	2.00	2.17	2.36	2.56	2.77
70	21.1	1.34	1.48	1.63	1.79	1.97	2.16	2.37	2.59	2.84	3.11
71	21.7	1.38	1.54	1.71	1.90	2.10	2.33	2.58	2.85	3.15	3.48
72	22.2	1.43	1.60	1.80	2.01	2.25	2.52	2.81	3.14	3.50	3.90
73	22.8	1.47	1.67	1.89	2.13	2.41	2.72	3.07	3.45	3.88	4.36
74	23.8	1.51	1.73	1.98	2.26	2.58	2.94	3.34	3.80	4.31	4.89
75	23.9	1.56	1.80	2.08	2.40	2.76	3.17	3.64	4.18	4.78	5.47
76	24.4	1.60	1.87	2.18	2.54	2.95	3.43	3.97	4.59	5.31	6.13
77	25.0	1.65	1.95	2.29	2.69	3.16	3.70	4.33	5.05	5.90	6.87
78	25.6	1.70	2.03	2.41	2.85	3.38	4.00	4.72	5.56	6.54	7.69
79	26.1	1.75	2.11	2.53	3.03	3.62	4.32	5.14	6.12	7.26	8.61
80	26.7	1.81	2.19	2.65	3.21	3.87	4.66	5.60	6.73	8.06	9.65
81	27.2	1.86	2.28	2.79	3.40	4.14	5.03	6.11	7.40	8.95	10.8
82	27.8	1.92	2.37	2.93	3.60	4.43	5.44	6.66	8.14	9.93	12.1
83	28.3	1.97	2.46	3.07	3.82	4.74	5.87	7.26	8.95	11.0	13.6
84	28.9	2.03	2.56	3.23	4.05	5.07	6.34	7.91	9.85	12.2	15.2
85	29.4	2.09	2.67	3.39	4.29	5.43	6.85	8.62	10.8	13.6	17.0

[a] Calculated from the formula $M = C^{(t-60)}$ in which C is determined as described in 29.1 – 29.6 and t is the temperature of the cable in degrees F.

30 Shrinkback Test on Thermoplastic Insulation

30.1 With any skin over it in place, the insulation indicated in Table 30.1 on 6-inch or 150-mm specimens of each coaxial member and of each base color of insulated conductor from the finished cable shall not shrink back from the ends of the conductor a total length greater than 3/8 inch or 9.5 mm when any shield, jacket, or other covering over the insulation is removed and the specimens are conditioned in a preheated full-draft circulating-air oven for 1 h at the temperature indicated for the insulation in Table 30.1 and then are cooled to room temperature by still air outside the oven. The test is to be conducted as described in 30.2 – 30.4.

Table 30.1
Conditioning temperature[a]

Insulation	Conditioning temperature
Insulation that melts or deforms at 121°C	115.0 ±2.0°C (239.0 ±3.6°F)
Cables rated 60 – 105°C	121.0 ±2.0°C (249.8 ±3.6°F)

Table 30.1 Continued on Next Page

Table 30.1 Continued

Insulation	Conditioning temperature
Cables rated 125 – 250°C	150.0 ±2.0°C (302.0 ±3.6°F)

[a] Insulation consisting of more than one material is to be conditioned at the lowest temperature indicated for any of the materials used.

30.2 The center 8-inch or 200-mm portions are to be cut from several straight lengths of the finished cable that are 5 – 6 ft or 1.5 – 1.8 m long. Each cut is to be clean and perpendicular to the longitudinal axis of the cable. The ends of the conductor(s) are to be clean and square. The conductors of a flat, parallel cable are to be separated. All parts of the cable other than the insulated conductor(s) are to be discarded. The insulated conductors are to be separated from one another without any of the twist in them being straightened and without the conductors being bent. Each 8-inch or 200-mm length of insulated conductor is to be shortened to 6 inches or 150 mm by cleanly and squarely trimming both ends. An equal quantity of each base color of insulated conductor from the cable is to be taken for the test.

30.3 A full-draft circulating-air oven with a flat, horizontal bed of ceramic or glass beads, of asbestos-free talc (see 30.4), or of felt in place in the oven is to be preheated for 60 min to the temperature indicated for the insulation in Table 30.1. The specimens are then to be placed on the bed in the oven without touching one another or anything else other than the bed. The oven is to be operated at the indicated temperature for 60 min additional time, and then, without disturbing the specimens on the bed, the bed and specimens together are to be removed and placed on a flat, horizontal surface that is in still air at room temperature, each specimen is to be measured for shrinkage of the insulation back from each end of the conductor. The total of the two measurements on each specimen is not to be greater than 3/8 inch or 9.5 mm.

30.4 The talc used in this test is to be certified by the supplier as being in compliance with the Occupational Safety and Health Administration (US Department of Labor) standard for occupational exposure to asbestos 29 CFR Part 1910 (OSHA regulation 1910.93a and OSHA Field Directive #74-92). The certification is to be made on the basis that the talc contains no asbestos or asbestiform materials within detectable limits when examined by X-ray diffraction and electron microscopy.

31 Crushing Resistance Test of Insulation

31.1 An average of at least 300 lbf or 1334 N or 136 kgf shall be necessary to crush the insulation on a conductor taken from the finished nonintegral flat cable, 2-core flat cable, or round cable to the point that the conductor contacts the earth-grounded metal of the testing machine. The test is to be made on an insulated solid conductor as described in 31.3 – 31.5, with the results qualifying both solid and stranded conductors having the same form of insulation (solid or foamed) of the same material in the same thicknesses. See 31.2.

31.2 Solid insulations that have thicknesses complying with Table 7.3 (nonintegral cable) have acceptable crushing strength without this test. All foamed insulation is to be tested.

31.3 The insulated conductors and/or coaxial members are to be removed from a length of the finished nonintegral cable having solid conductors and are to be individually straightened with the fingers after all coverings over the insulation other than any skin are removed. Specimens 7 inches or 180 mm long are to be cut from the straight insulated conductors. Each of the five specimens is to be tested separately by being crushed twice between 2-inch-wide or 50-mm-wide, flat, horizontal steel plates in a compression machine whose jaws close at the rate of 0.20 ±0.02 in/min or 5.0 ±0.5 mm/min. The edges of the plates are not to be sharp. The length of a specimen is to be parallel to the 2-inch or 50-mm dimension of the plates, 1 inch or 25 mm of the specimen is to extend outside the plates at one end of the specimen, and 4 inches or 100 mm of the specimen to extend outside the plates at the other end of the specimen.

31.4 The plates are to be connected together, to the metal of the testing machine, and to earth ground. The specimens, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) throughout the test. The machine is to be started and the specimen is to be subjected to the increasing force of the plates moving toward one another until a short circuit occurs (as indicated by a low-voltage indicator such as a buzzer, lamp, or LED) between the conductor in the specimen and one or both of the earth-grounded plates. The maximum force exerted on the specimen before the short circuit occurs is to be recorded as the crushing force for that end of the specimen.

31.5 After the short circuit occurs, the machine is to be reversed and the plates separated. The specimen is to be turned end for end, rotated 90°, reinserted (from the end opposite the one originally inserted) between the plates as described in 31.3, and crushed as described in 31.4. The two crushing forces are to be averaged for each specimen. The average of all ten of the crushing forces obtained for the five specimens is to be used as the value to compare with the requirement.

32 Crushing Test for Cable Marked for Direct Burial

32.1 Finished cable that is marked [see 44.1 (f)] to indicate that the cable is for direct burial shall withstand without rupture of the outermost cable covering, and without rupture of the insulation on any conductor, 1000 lbf or 4448 N or 454 kgf applied for 60 s by a flat horizontal steel plate that crushes the cable at the point at which the cable is laid over a steel rod. The test shall be conducted and the results evaluated as described in 32.2 – 32.6.

32.2 The results of this test for a given construction are to be taken as representative of the performance of all other cables of the same construction containing either more conductors of the same size or the same or a larger number of conductors in a round cable is to be considered representative of the performance of those conductors in both round and flat cables.

32.3 The cable is to be crushed between a flat, horizontal steel plate and a solid steel rod mounted on a second, identical plate. The crushing is to be achieved by the application of dead weight or in a compression machine whose jaws close at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min. Each plate is to be 2 inches or 50 mm wide. A solid steel rod 3/4 inches or 19 mm in diameter and of a length equal to at least 6 inches or 150 mm is to be bolted or otherwise secured to the upper face of the lower plate. The longitudinal axes of the plates and the rod are to be in the same vertical plane. The specimens, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) throughout the test.

32.4 The cable is to be tested in a continuous length of at least 36 inches or 915 mm, with the cable being crushed at three points along that length. The points at which the cable is to be crushed are to be measured and marked with chalk or another innocuous means on the test length before the test is begun. The first mark is to be placed 9 inches or 230 mm from one end of the test length and the two remaining marks are to be made at succeeding intervals of 9 in or 230 mm down the length of the cable.

32.5 The cable at the first mark is to be placed and held on the steel rod, with the longitudinal axis of the cable horizontal, perpendicular to the longitudinal axis of the rod, and in the vertical plane that laterally bisects the upper and lower plates and the rod. Flat parallel cable with integral insulation and jacket is to be tested flatwise. The upper steel plate is to be made snug against the cable. In a test using a dead weight or weights, weight exerting the force indicated in 32.1 is to be placed gently on the upper plate. In a test using a compression machine, the upper plate is to be moved downward at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min thereby increasing the force on the cable until the level indicated in 32.1 is reached. That level of force is to be held constant for 60 s and is then to be reduced to zero by removing the dead weight(s) or, in the compression machine, by raising the upper steel plate at the rate of 0.50 ±0.05 ±in/min or 10 ±1 mm/min until the cable is free.

32.6 The test length of the cable is to be advanced and crushed at each of the successive marks for a total of three crushes. The overall jacket or metal covering and the insulation on each conductor are to be examined at each of the three points at which the cable was crushed. The cable is not acceptable if the overall covering or any of the insulation is split, torn, cracked, or otherwise ruptured at any of the three points. Flattening of the jackets, or the insulation, or both of these without rupture is acceptable.

33 Mechanical Water Absorption Test of Insulation in Direct-Burial Cable

33.1 The mechanical water absorption (MWA) of the insulation on the conductors in a direct-burial cable shall not be more than 20.0 milligrams mass per square inch of exposed surface or shall not be more than 3.1 milligrams mass per square centimeter of exposed surface, when specimens of the insulated conductors are tested as described in 33.2 – 33.7.

33.2 The cable jacket and any other covering (s) outside of the insulation are to be removed, or specimens are to be selected before application of the jacket and other covering(s), leaving the insulation completely exposed. The surface of each finished, insulated conductor is to be cleaned of all fibers and particles of foreign material by means of a cloth wet with ethyl alcohol. Three specimens 11 in or 280 mm long are then to be cut from conductors having each different insulation. The specimens are to be dried in a vacuum of 29 – 30 mmHg over calcium chloride for 48 h at 70.0 ±1.0° C (158.0 ±1.8° F) and are subsequently to be cooled to room temperature in a desiccator. Each specimen is to be weighed to the nearest milligram mass promptly after removal from the desiccator, and this weight is to be designated as W_1. Each specimen is then to be bent into the form of a U around a circular mandrel having a diameter four times that of the specimen.

33.3 The water bath is to consist of a vitreous-enameled-steel or glass vessel containing tap water and is to be automatically controlled to maintain the water at a temperature of 82.0 ±1.0°C (179.6 ±1.8°F). The vessel is to be provided with a close-fitting sheet-metal cover plate of brass or other nonferrous metal having holes that accommodate the specimens.

33.4 The ends of each specimen are to be inserted through two holes in the cover plate, with 10 inches or 250 mm of each specimen exposed below the plate. Rubber stoppers having holes bored to fit the specimens tightly, or accurately drilled close-fitting metal washers of the same nonferrous metal as the cover plate mentioned in 33.3 are to be used to complete closure of the holes in the cover plate and to assist in holding the specimens in place. The water level is to be maintained flush with the underside of the cover plate. No water is to touch the ends of the specimen above the cover plate.

33.5 The specimens are to remain in the water for 168 h, after which the cover plate and specimens are to be removed from the vessel and transferred to a similar vessel filled with tap water at room temperature. The rubber stoppers or the metal washers are then to be taken off of one specimen at a time, each specimen is to be removed and shaken to dispose of loose water, and any remaining surface moisture is to be blotted off lightly with a clean, lintless, absorbent cloth. Each specimen is to be weighed again to the nearest milligram mass within 3 min after removal from the water, and this weight is to be designated as W_2.

33.6 The specimens are then to be dried in a vacuum of 29 – 30 mmHg over calcium chloride for 48 h at a temperature of 70.0 ±1.0°C (158.0 ±1.8°F), cooled to room temperature in a desiccator, and weighed to the nearest milligram mass promptly after removal from the desiccator. This weight is to be designated as W_3.

33.7 Moisture absorption (MWA) in milligrams mass per square inch of exposed surface or in milligrams mass per square centimeter of exposed surface is to be determined for each specimen by means of whichever of the following formulas is applicable

$$MWA = \frac{W_2 - W_3}{S}, \text{ if } W_3 \text{ is less than} W_1$$

$$MWA = \frac{W_2 - W_1}{S}, \text{ if } W_3 \text{ is less than } W_1$$

in which:

W_1 is the original weight of the specimen in milligrams mass,

W_2 is the weight of the specimen in milligrams mass after immersion,

W_3 is the weight of the specimen in milligrams mass after final drying, and

S is the area of the immersed surface of the specimen in square inches or in square centimeters (circumference x length immersed).

The insulation is not acceptable for use in direct-burial cable if the MWA for any specimen of that insulation exceeds the limit specified in 33.1.

34 Copper Sulphate Test of Zinc Coating on Steel Strip for and from Interlocked Steel Armor

34.1 The coating of zinc on steel strip for and from interlocked steel armor shall enable specimens of the strip to comply with all of the following requirements. This is indicated in 14.5.8.

a) A specimen of the zinc-coated steel strip tested before forming shall not show a bright, adherent deposit of copper on any surface, including edges, after two 60-s immersions in a solution of copper sulphate.

b) A specimen of the partially uncoiled steel armor from finished cable:

1) Shall not show a bright, adherent deposit of copper after one 60-s immersion in a solution of copper sulphate, and

2) Shall not show a bright, adherent deposit of copper on more than 25 percent of any surface, including edges, after two 60-s immersions in the copper sulphate solution.

34.2 The solution of copper sulphate is to be made from distilled water and the American Chemical Society (ACS) reagent grade of cupric sulphate ($CuSO_4$). In a copper container or in a glass, polyethylene, or other chemically nonreactive container in which a bright piece of copper is present, a quantity of the cupric sulphate is to be dissolved in hot distilled water to obtain a solution that has a specific gravity slightly higher than 1.186 after the solution is cooled to a temperature of 18.3°C (65.0°F). Any free acid that might be present is to be neutralized by the addition of approximately 1 gram of cupric oxide (CuO) or 1 gram of cupric hydroxide [$Cu(OH)_2$] per liter of solution. The solution is to be diluted with distilled water to obtain a specific gravity of exactly 1.186 at a temperature of 18.3°C (65.0°F). The solution is then to be filtered.

34.3 At one end of a length of finished cable that has armor formed of zinc-coated steel strip, the armor is to be unwound from the outside:

a) To expose to view both edges and the inner surface of the formed strip, and

b) To facilitate working cheesecloth between the turns onto the inner surface to dry that surface during the test.