UL 1425

STANDARD FOR SAFETY

Cables for Non-Power-Limited Fire-Alarm Circuits

UL Standard for Safety for Cables for Non-Power-Limited Fire-Alarm Circuits, UL 1425

Third Edition, Dated January 26, 2015

Summary of Topics

This revision of ANSI/UL 1425 dated January 14, 2022 includes the introduction of optional suffixes HF, LSHF and ST1 and deletion of limited combustible; 25.1, Section 38, 41.1(m)

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 revised requirements are substantially in accordance with Proposal(s) on this subject dated November 5, 2021.

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UL 1425

Standard for Cables for Non-Power-Limited Fire-Alarm Circuits

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This ANSI/UL Standard for Safety consists of the Third Edition including revisions through January 14, 2022.

The most recent designation of ANSI/UL 1425 as an American National Standard (ANSI) occurred on January 14, 2022. 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 This Standard states the construction, test, and marking requirements covering the safety of electrical and electrical/optical-fiber cables rated 60°C to 250°C and intended for 150-volt and lower-potential non-power-limited circuits that are controlled and powered by a fire-alarm system. These cables are for installation in buildings as specified in Article 760 and other applicable parts of the National Electrical Code (NEC), NFPA 70. Cables covered by these requirements are:

a) Type NPLFP – These cables are for installation in "other spaces used for environmental air" [See NEC 300-22(c)].

b) Type NPLFR – These cables are for installation in vertical runs in a shaft or for installation in vertical runs that penetrate more than one floor.

c) Type NPLF – These cables are for general-purpose fire-alarm use in buildings. General purpose does not include use as plenum or riser cable.

1.2 These cables contain two or more insulated circuit conductors with or without one or more insulated or bare equipment-grounding conductor(s). Each insulated circuit and grounding conductor is rated for 600 volts. These cables do not contain any coaxial members. These cables are rated for 150 volts and are so marked.

1.3 Armored cables are covered by interlocked metal strip or a smooth or corrugated metal sheath with or without a jacket over the armor. Cables for encasement in concrete, mortar, other masonry, plaster, or similar construction have metal armor and a jacket over the armor. Cables for direct burial in the earth (see markings in 1.8) are subject to a 1000-pound crushing test. Cables for direct burial are not required to be armored. Cables for direct burial that are armored have a jacket over the armor. All other cables (unarmored, flat or round) have an overall jacket.

1.4 Cables of materials that qualify for temperatures above 60°C (140°F) are marked with a temperature rating. Temperature marking is not required for cables that qualify for a temperature rating of 60°C (140°F).

1.5 Cables that contain one or more electromagnetic shields (see 8.1 – 8.3 regarding constructions) are not required to be marked to indicate the presence of the shielding. A shielded cable that is marked has "shielded" on the tag and either on the overall cable jacket or legible through the jacket.

1.6 Cables that qualify for exposure to sunlight (720-hour sunlight-resistance test – see 25.1) have "sun res" or "sunlight resistant" on the tag and either on the overall cable jacket or legible through the jacket.

1.7 Cables that qualify for burial directly in the earth (1000-pound crushing test – see 29.1) have "dir bur", "direct burial", or "for direct burial" on the tag and either on the overall cable jacket or legible through the jacket. Each insulated circuit and grounding conductor in direct-burial cables is insulated for wet locations (see 7.3.1 and 30.1 – 30.8).

1.8 A cable that contains one or more optical-fiber members has “OF “ supplementing the type letters and is marked in accordance with 42.1(c).

1.9 These requirements do not cover cables that contain only optical fibers. Optical-fiber cables without electrical conductors are covered in the Standard for Optical Fiber Cable, UL 1651.

1.10 These requirements do not cover cables for electric-light, power, control, Class 1, Class 2, or Class 3 circuits.

1.11 These requirements do not cover cables for power-limited fire-alarm circuits (see UL 1424).

1.12 Smoke and flame tests are as follows for the cables covered in these requirements:

a) PLENUM CABLES – All Type NPLFP cables are tested for smoke and flame characteristics as specified in Smoke and Flame Testing of Plenum Cables, Section 22, which references 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) RISER CABLES – Jacketed Type NPLFR cables are tested for flame-propagation characteristics as specified in Flame Testing of Riser Cables, Section 23, which references the Standard Test for Flame-Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts, UL 1666. A cable that complies exhibits a flame-propagation height under 12 ft, 0 inch or 366 cm and attains a temperature no higher than 850.0°F (454.4°C) at a height of 12 ft, 0 inch or 366 cm.

c) GENERAL-PURPOSE CABLES – Jacketed Type NPLF cables comply with one of the two 70,000 Btu/h (20.5 kW) vertical-tray flame tests specified in Alternative Vertical-Tray Flame Tests of General-Purpose Cables, Section 24. The cable manufacturer chooses one of the following tests:

1) The UL test referenced in 24.1.2 – 24.3.3. These paragraphs apply the test method described as the UL Flame Exposure (smoke measurements are not applicable) in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685.

2) The FT4/IEEE 1202 test referenced in 24.1.2 and 24.4.1. These paragraphs apply the test method described as the FT4/IEEE 1202 Type of Flame Exposure (smoke measurements are not applicable) in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. This test differs from the UL test in loading (a greater number of cable lengths are used, with small cables bundled, and the spacing between cables or bundles is limited), burner angle, and failure criterion. A cable that complies is eligible to be marked "FT4/IEEE 1202" or "FT4" on the surface or on a marker tape as indicated in 41.1(i).

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 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

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.

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.

CONSTRUCTION

4 Materials

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

4.2 Cables for non-power-limited fire-alarm circuits shall comply in all respects with the applicable requirements for construction details, test performance, and markings.

5 Circuit and Grounding Conductors

5.1 Each circuit and grounding conductor shall be of soft-annealed copper that complies with the American Society for Testing and Materials Standard Specification for Soft or Annealed Copper Wire, ASTM B 3. See Electromagnetic Shields, Section 8, concerning drain wires (copper).

5.2 Each circuit and grounding conductor shall be round.

5.3 Each circuit and grounding conductor shall be solid or stranded. A stranded conductor shall consist of round strands with 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. Seven strands, concentric, is the stranding assumed in these requirements; however, individual strand diameter, any mix of different strand diameters, the number of strands, and the stranding type are not specified. See Metal Coating of Conductors, Section 6.

5.4 Circuit and grounding conductors shall be of standard 18 – 12 AWG sizes. See the final sentence of 12.2 regarding grounding conductor size relative to the size(s) of the circuit conductors.

5.5 All solid and stranded circuit conductors are to be identified as a particular AWG size in the marking [see 41.1(b)] on or in the cable and on the tag, reel, or carton. The size of a solid conductor shall be verified either by determination of the d-c resistance or, as described in 5.6, 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 5.7. Determination of the conductor size by measurement of the d-c resistance as described in D-C Resistance Test of a Conductor, Section 17, is the referee method in all cases.

5.6 Where measured as the means of size verification (see 5.5), the diameter of a solid circuit or grounding conductor shall not be smaller than the minimum diameter indicated for the size in Table 5.1 when the diameter of the conductor is determined from measurements made as follows:

a) Measurements of the diameter of a solid conductor are to be made over the metal-coated or uncoated conductor 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 (0.1 mil) or 0.001 mm, added together, and divided by 2 without any rounding of the sum or resulting average.

b) Each minimum 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.

5.7 Where measured as the means of size verification (see 5.5), the cross-sectional area of a stranded circuit or grounding conductor shall not be smaller than the minimum area indicated for the size in Table 5.1. The cross-sectional area of a stranded conductor is to be determined as the sum of the areas of its component round strands. However, where the sum of the strand areas does not comply, the conductor area is to be determined by the weight method outlined in Conductor Cross-Sectional Area by the Weight Method, Section 210 of UL 1581.

5.8 The nominal diameters indicated in Table 5.1 for solid and stranded circuit and grounding conductors are to be used in calculating the dimensions needed for various parts of the cable when using Table 13.1, Table 13.2, Table 14.1, Table 14.2, Table 18.1, and Table 20.1.

Table 5.1
Dimensions of conductors

	Diameter of solid conductor				Cross-sectional area of stranded conductor				Nominal diameter of stranded conductor (7 strands)	
	Nominal See 5.8		Minimum See 5.6(b)		Nominal		Minimum			
AWG size of conductor	mils	mm	mils (0.99 × nominal)	mm	cmil	mm^2	cmil (0.98 × nominal)	mm^2	mils	mm
18	40.3	1.02	39.9	1.013	1620	0.823	1588	0.807	45.6	1.16
17	45.3	1.15	44.8	1.138	2050	1.04	2009	1.02	51.3	1.30
16	50.8	1.29	50.3	1.278	2580	1.31	2528	1.28	57.6	1.46
15	57.1	1.45	56.5	1.435	3260	1.65	3195	1.62	64.7	1.64
14	64.1	1.63	63.5	1.613	4110	2.08	4028	2.04	72.7	1.85
13	72.0	1.83	71.0	1.81	5180	2.63	5076	2.58	81.6	2.07
12	80.8	2.05	80.0	2.03	6530	3.31	6399	3.24	91.5	2.32

5.9 Each circuit and grounding conductor and each shield shall be continuous throughout the entire length of the finished cable as determined by the Continuity Test of Conductors and Shields, Section 16.

5.10 A joint in a solid circuit or grounding conductor or in one of the individual wires of a stranded circuit or grounding 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 by machine brazing or welding of the conductor as a whole so 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 insulated by applying a bonded patch or by molding. The insulation shall comply with the requirements in this Standard. An individual member jacket or an overall cable jacket that is damaged to the point of exposing the underlying assembly or that is opened for the purpose of making any repair under the jacket either shall be stripped and replaced in its entirety or a second, duplicate jacket shall be applied over the first for the entire length of the member or cable. The total thickness of the two jackets 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.

5.11 Any section of a circuit or grounding conductor that includes a factory joint shall have a tensile strength that is not less than 85 percent of the tensile strength of an adjacent section of the conductor not having a joint.

6 Metal Coating of Conductors

6.1 Where any copper circuit or grounding conductor contacts insulating, jacketing, or other nonmetallic cable material that corrodes unprotected copper in the test described in Conductor Corrosion, Section 500 of UL 1581, the copper conductor shall be covered with a coating of tin, a tin/lead alloy, nickel, silver, or of another (evaluation required) metal or alloy.

6.2 Use of a metal coating is not specified on a solid circuit or grounding conductor or the individual wires (strands) of a stranded circuit or grounding conductor on which a metal coating is not required for corrosion protection.

6.3 The temperature rating of the cable shall not exceed the temperature indicated in Table 6.1 for the diameter and metal coating of the individual strands.

Table 6.1
Maximum temperature rating of cable relative to diameter and metal coating of conductor strands

Metal coating of copper strands	Diameter of each strand	
	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 General

7.1.1 Each circuit conductor and insulated grounding conductor shall be insulated for its entire length.

7.1.2 The insulated circuit and grounding conductors used in the cable shall consist of either or both of the following conductors (the mix is not specified):

a) CONDUCTORS OTHER THAN NEC WIRES – Insulated conductors that are unmarked except for size where used as a circuit conductor [the size marking is not required – see 40.1(b)] and that comply with the construction requirements in 7.2.1.1 and 7.2.1.2 and the performance requirements (six tests) referenced in 7.2.1.2 (a) – (f).

b) NEC WIRES – Constructions of NEC wires that are as specified in 7.3.1 and are unmarked except for size where used as a circuit conductor [the size marking is not required – see 40.1(b)]. The six tests referenced in 7.2.1.2 (a) – (f) do not apply to NEC wires.

7.2 Conductors other than NEC wires

7.2.1 Material and application

7.2.1.1 Where, for an insulated circuit or grounding conductor, the cable manufacturer chooses to use an insulated conductor (non-NEC conductor) other than an unmarked National Electrical Code wire (NEC wire) constructed as specified in 7.3.1, the conductor shall be insulated with a material appropriate for insulating a 600-volt fixture wire or branch-circuit wire; the material shall be one of the insulation materials specified in Table 7.1 or referenced in note (a) to Table 7.1. An overall nonmetallic braid shall be used on conductors insulated with silicone rubber. The braid on a conductor insulated with silicone rubber shall be a single braid complying with the Standard for Fixture Wire, UL 66.

Exception: A protective covering is not required for silicone insulation that has a tensile strength of at least 1200 lbf/in^2 or 8.27 MN/m^2 or 827 N/cm^2 or 0.844 kgf/mm^2 or an insulation thickness at least 50% more than required in Table 7.3.

Table 7.1
Index to insulation and jacket materials

Material(s)[a]	Temperature rating of insulation	Temperature rating of jacket	Applicable table of physical properties in UL 1581 (see 7.2.2.1 and 7.2.2.2)
CP	90°C (194°F)	90°C (194°F)	50.1
	75°C (167°F)	75°C (167°F)	50.1
Thermoplastic CPE	–	90°C (194°F)	50.28
Thermoset CPE	–	90°C (194°F)	50.29
	–	75°C (167°F)	50.30
ECTFE	150°C (302°F)	150°C (302°F)	50.63
ETFE			
EPCV	90°C (194°F)	90°C (194°F)	50.62
	75°C (167°F)	75°C (167°F)	50.62
FEP	200°C (392°F)[b]	200°C (392°F)[b]	50.70
NBR/PVC	–	90°C (194°F)	50.83
LDFRPE and HDFRPE	–	75°C (167°F)	50.133
	–	75°C (167°F)	50.80
Neoprene	–	90°C (194°F)	50.124
	–	75°C (167°F)	50.123
PTFE (TFE)	250°C (482°F)[b]	250°C (482°F)[b]	50.219
PFA and MFA	200°C (392°F)[b]	200°C (392°F)	50.137
	250°C (482°F)[b]	250°C (482°F)	50.137
PVC	105°C (221°F)	105°C (221°F)	50.182
	90°C (194°F)	90°C (194°F)	50.182
	75°C (167°F)	75°C (167°F)	50.182
	60°C (140°F)	60°C (140°F)	50.182
PVDF and PVDF copolymer	–	150°C (302°F)	50.185
	–	125°C (257°F)	50.185
SRPVC (semirigid PVC)	105°C (221°F)	–	50.183
	90°C (194°F)	–	50.183
	75°C (167°F)	75°C (167°F)	50.183
	60°C (140°F)	60°C (140°F)	50.183
Silicone rubber	200°C (392°F)[b]	200°C (392°F)[b]	50.210
	150°C (302°F)	150°C (302°F)	50.210
TPE	105°C (221°F)	105°C (221°F)	50.223
	90°C (194°F)	90°C (194°F)	50.224
XL:			
XLPE			
XLPVC	105°C (221°F)	105°C (221°F)	50.245

Table 7.1 Continued on Next Page

Table 7.1 Continued

Material(s)[a]	Temperature rating of insulation	Temperature rating of jacket	Applicable table of physical properties in UL 1581 (see 7.2.2.1 and 7.2.2.2)
XLEVA	90°C (194°F)	90°C (194°F)	50.237
blends of these	75°C (167°F)	75°C (167°F)	50.241

[a] See 7.2.1.2 for a long-term evaluation of an insulation or jacket material not named in the first column (new material) or not complying with the short-term tests referenced in the last column.

[b] 150° (302°F) is stated in Table 6.1 as the limit for the cable temperature rating (see 13.3.3) 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 solid conductor or strands are coated with silver [200°C (302°F)] or nickel [250°C (482°F)].

7.2.1.2 The insulation shall be solid with or without a solid dielectric skin (a thin, solid, extruded layer that is or is not separable) applied over the solid insulation. A skin is not required to be of the same material as the insulation. The insulation shall be applied directly to the metal conductor, shall have a circular cross section, and shall fit tightly to the conductor with no more than nominal adherence (a test is not specified). 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. The insulation shall comply with the physical property requirements in 7.2.2, and the following performance tests apply to the insulated conductors (non-NEC conductors) described in this paragraph and in 7.2.1.3:

a) Heat Shock Test, Section 18.

b) Deformation Test, Section 19.

c) Cold Bend Test of Insulation, Section 20.

d) Test for Insulation Resistance at 60.0°F (15.6°C), Section 27.

e) Mechanical Water Absorption Test of Insulation in Direct-Burial Cable, Section 30. (Not required if conductors comply with the requirements in item (f).

f) Long Term Insulation Resistance in Water Test of conductors in cables marked "Wet Location", Section 31.

7.2.1.3 Insulation or a jacket that is of material generically different from any insulation/jacket material named in Table 7.1 (new material), or that is of material named in Table 7.1 yet does not comply with the applicable short-term tests, shall be of a material and in thicknesses and with a temperature rating appropriate for a non-power-limited fire-alarm cable. The material shall be evaluated for the requested temperature rating as described in Long-Term Aging, Section 481 of UL 1581. Long-term air-oven aging is not required for any material for which Table 47.1 of UL 1581 indicates a table of physical properties requirements under Specific Materials, Section 50 of UL 1581. Investigation of the electrical, mechanical, and physical characteristics of the cable using either material shall show the material to be comparable in performance to an insulation or jacket material named in Table 7.1 for the applicable temperature rating. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, and dielectric voltage-withstand.

7.2.2 Physical properties tests

7.2.2.1 Specimens prepared from samples of the insulation and overall jacket shall have values of tensile strength and ultimate elongation that comply with the applicable table of physical properties in UL 1581 referenced in Table 7.1 (see 7.2.1.2 regarding noncompliance with these short-term tests). The samples are to be taken from the finished cable. The specimens are to be prepared from the samples and the testing is to be conducted as indicated in 7.2.2.2.

7.2.2.2 The methods of preparation of samples, of selection and conditioning of specimens, and of making the measurements and calculations for ultimate elongation and tensile strength shall be as indicated under the heading "Physical Properties Tests of Insulation and Jacket" in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. For jackets from cables having an overall diameter not greater than 0.200 inch or 5.1 mm, tubular or die-cut specimens are to be tested. Tubular specimens are not to be prepared from jackets of larger cables.

7.2.3 Thicknesses

7.2.3.1 General

7.2.3.1.1 The average thickness and the minimum thickness at any point of the insulation (including any skin) shall not be less than indicated in Table 7.2.

Table 7.2
Thicknesses[a] of insulation (including any skin) on 18 – 12 AWG conductors

Material in Table 7.1	Minimum average		Minimum at any point	
	inch	mm	inch	mm
Silicone rubber	0.030	0.76	0.027	0.69
FEP, ETFE, ECTFE, PTFE, TFE	0.020	0.51	0.018	0.46
PVC under a nylon[a] jacket	0.015	0.38	0.012	0.30
PVC not under a nylon jacket, TPE	0.030	0.76	0.027	0.69
Any material named or referenced in Table 7.1 yet not named in this table	0.030	0.76	0.027	0.69

[a] The thickness of the nylon is to be measured 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 0.010 mm. The measurement at the thinnest point of the nylon is to be recorded to the nearest 0.0001 inch or 0.010 mm and shall not be less than 0.0040 inch (4.0 mils) or 0.10 mm.

7.2.3.1.2 The thicknesses are to be determined by means of measurements made as described in Thicknesses of Insulation on Flexible Cord and on Fixture Wire, Section 250 of UL 1581. The 0.003-inch (3-mil) or 0.08-mm thickness-reduction allowance in 250.5 of UL 1581 is to be applied only to insulation that has an average thickness (including any skin) of at least 0.015 inch or 0.38 mm and that is from a stranded conductor that leaves one or more strand impressions in the insulation that are too small to accommodate the smaller pin referred to in 250.11 of UL 1581. For this application, the pin is to be 0.0200 inch (20.0 mils) or 0.508 mm in diameter.

7.2.3.1.3 The average thickness resulting from the five sets of measurements taken as described in 250.3 of UL 1581 is to be rounded to the same number of decimal places as the average thickness is stated in Table 7.2. The rounding is to be done as described in 7.2.3.2 – 7.2.3.5, which apply the American Society of Testing and Materials Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications, ASTM E 29.

7.2.3.2 Rounding to the nearest 0.0001 inch

7.2.3.2.1 A figure in the fourth decimal place is to remain unchanged where the figure in the fifth decimal place is 0 – 4 and the figure in the fourth decimal place is odd or even, or where 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 where the figure in the fifth decimal place is 6 – 9 and the figure in the fourth decimal place is odd or even, or where 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).

7.2.3.3 Rounding to the nearest 0.001 inch

7.2.3.3.1 A figure in the third decimal place is to remain unchanged where the figure in the fourth decimal place is 0 – 4 and the figure in the third decimal place is odd or even, or where 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 where the figure in the fourth decimal place is 6 – 9 and the figure in the third decimal place is odd or even, or where 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).

7.2.3.4 Rounding to the nearest 0.001 mm

7.2.3.4.1 A figure in the third decimal place is to remain unchanged where the figure in the fourth decimal place is 0 – 4 and the figure in the third decimal place is odd or even, or where 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 where the figure in the fourth decimal place is 6 – 9 and the figure in the third decimal place is odd or even, or where 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).

7.2.3.5 Rounding to the nearest 0.01 mm

7.2.3.5.1 A figure in the second decimal place is to remain unchanged where the figure in the third decimal place is 0 – 4 and the figure in the second decimal place is odd or even, or where 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 where the figure in the third decimal place is 6 – 9 and the figure in the second decimal place is odd or even, or where 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).

7.3 NEC wires

7.3.1 Where the cable manufacturer chooses to use a National Electrical Code wire (NEC wire) as an insulated circuit or grounding conductor, the wire used shall be one of the constructions of 600-volt NEC fixture wire or branch-circuit wire specified in Table 7.3. The conductor shall be of copper. The finished insulated conductor shall comply with the wire Standard indicated in Table 7.3 except that there shall not be any marking or temperature identification. Conductors insulated for wet locations (the first column of Table 7.3 shows a "W" in the type letters for these conductors) shall be used in cables that are marked [see marking in 41.1(f)] for burial directly in the earth. The six performance tests referenced in 7.2.1.2 (a) – (f) do not apply to NEC wires.

Table 7.3
600-volt NEC constructions

Type	Constructions for the UL 1425 application	Standard[a]
PAF, PTF	250°C (482°F) dry, 18 or 16 AWG	UL 66
KF-2, KFF-2	200°C (392°F) dry, 18 or 16 AWG	UL 66
PAFF	150°C (302°F) dry, 18 or 16 AWG	UL 66
PF, PGF	200°C (392°F) dry, 18 or 16 AWG	UL 66
FEP	200°C (392°F) dry, 14 or 12 AWG	UL 83
SF-2	200°C (392°F) dry, 18 or 16 AWG	UL 66
PTFF	150°C (302°F) dry, 18 or 16 AWG	UL 66

Table 7.3 Continued on Next Page

Table 7.3 Continued

Type	Constructions for the UL 1425 application	Standard[a]
PFF, PGFF	150°C (302°F) dry, 18 or 16 AWG	UL 66
SFF-2	150°C (302°F) dry, 18 or 16 AWG	UL 66
ZF, ZFF	150°C (302°F) dry, 18 or 16 AWG	UL 66
Z	150°C (302°F) dry, 14 or 12 AWG	UL 83
XHHW-2	90°C (194°F) wet or dry, 14 or 12 AWG	UL 44
RHW-2	90°C (194°F) wet or dry, 14 or 12 AWG	UL 44
RFHH-2	90°C (194°F) dry, 18 or 16 AWG	UL 66
RFHH-3	90°C (194°F) dry, 18 or 16 AWG	UL 66
TFN, TFFN	90°C (194°F) dry, 18 or 16 AWG	UL 66
THHN	90°C (194°F) dry, 14 or 12 AWG	UL 83
XHH	90°C (194°F) dry, 14 or 12 AWG	UL 44
RHH	90°C (194°F) dry, 14 or 12 AWG	UL 44
THHW	75°C (167°F) wet or 90°C (194°F) dry, 14 or 12 AWG	UL 83
XHHW	75°C (167°F) wet or 90°C (194°F) dry, 14 or 12 AWG	UL 44
THWN	75°C (167°F) wet or dry, 14 or 12 AWG	UL 83
THW	75°C (167°F) wet or dry, 14 or 12 AWG	UL 83
RHW	75°C (167°F) wet or dry, 14 or 12 AWG	UL 44
RFH-2	75°C (167°F) dry, 18 or 16 AWG	UL 66
SA	90°C (194°F) dry, 14 or 12 AWG	UL 44
TW	60°C (140°F) wet or dry, 14 or 12 AWG	UL 83
TF, TFF	60°C (140°F) dry, 18 or 16 AWG	UL 66

[a] Standard for Thermoset-Insulated Wires and Cables, UL 44; Standard for Fixture Wire, UL 66; Standard for Thermoplastic-Insulated Wires and Cables, UL 83.

8 Electromagnetic Shields

8.1 An electromagnetic shield is not required. Except that a reduction in metal-shield mass and/or coverage affects the performance of the cable in the applicable flame test (see 24.2.2), the construction is not specified for any shield that is applied 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. The number of shields in a cable is not specified. Material applied as insulation between shields shall be an insulation grade of one of the materials named or referenced in Table 7.1 (thickness not specified). These requirements (UL 1425) do not specify or test for the electrostatic/electromagnetic performance of a shield. Each shield shall be continuous throughout the entire length of the finished cable as determined by the continuity test described in Continuity Test of Conductors and Shields, Section 16.

8.2 An electromagnetic shield shall be of metal. The following constructions are typical:

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

b) A corrugated or smooth single-metal or bi-metal tape applied longitudinally or helically with or without a bare metal-coated or uncoated (uncoated copper is not to be used with an aluminum tape) copper drain wire in contact with the metal tape (a specific version of this shield is described in 8.3). A jacket or other covering is not required under this shield. A polymer coating is not required. Where used, a polymer coating is to be on only one side of a tape that is applied with a drain wire. In the case of an inward-facing coating on a metal tape applied over the insulation, bonding of the coating to the insulation is not specified. Any inward-facing coating on a metal tape applied over more than one optical-fiber member or insulated conductor is not to bond to the conductors or members. The size of a drain wire is not specified. A drain wire is to be solid or stranded (the stranding is not specified). A metal sheath used as a shield shall comply with 14.1.1 (a), (b), or (c) as applicable.

c) A serving, wrap, or braid of aluminum wires or of metal-coated or uncoated (uncoated copper is not to be in contact with aluminum wires) copper wires (see 6.3). A braid floodant is not required and is not specified. Where the overall cable jacket is thinner in average thickness than 0.013 inch 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 c to Table 13.1 and Table 13.2). The construction of the protective covering is not specified. The protective covering shall keep bobbin ends and other wire bulges or projections from penetrating the overall cable jacket during and after application of the overall jacket.

d) An investigated equivalent of (a), (b), or (c).

8.3 The specific metal sheath to which reference is made in 21.2 (regarding use of a 15-times-cable-diameter mandrel in the cold-bend testing of the cable) is to be a version of the shield covered in 8.2(b). A jacket or other covering is not required under this shield. The metal sheath is to consist of a metal tape that is 0.008 inch or 0.2 mm thick with or without a coating on one side. The coating is to be of vinyl or other resin that is bonded to the metal. The tape is to be corrugated or smooth and is to be applied to the cable assembly longitudinally using a positive overlap. Any bonded coating used is to face outward. An inward-facing coating is not to bond to the conductors or optical-fiber members in the cable.

9 Optical-Fiber Members

9.1 Each optical-fiber member shall consist of one of the following and shall be separated from the rest of the cable by material that is electrically nonconductive (an insulation grade is not required):

a) One or more glass fibers that are individually coated and tight buffered and then are covered by a nonmetallic tape, wrap, or braid (complete coverage is required) or by a jacket. Except that the covering shall be electrically nonconductive, the materials, thickness, and other features of these elements are not specified.

b) One or more glass fibers that are individually coated, are or are not tight buffered, are enclosed with or without a gel in a loose buffer tube, and then are or are not covered by a nonmetallic tape, wrap, or braid (complete coverage is required) or by a jacket. Any covering applied shall be electrically nonconductive. A covering is not required over a loose buffer tube that is electrically nonconductive. Except that the tube or covering shall be electrically nonconductive, the materials, thickness, and other features of these elements are not specified.

9.2 No electrical element of the cable shall be located in an optical-fiber member or group of optical-fiber members. Strength members, moisture barriers, heat shields, and other nonelectrical parts of an optical-fiber member are not specified; however, where any such part is of metal or other electrically conductive material, its presence shall be indicated by a marking as detailed in 42.1(d).

9.3 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 system 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, 42.1(c) specifies a tag, reel, or carton marking.

10 Binders

10.1 Use of a binder is not specified over any group of conductors (with or without one or more optical-fiber members in the group) or optical-fiber members, or several such groups within the cable. Where used, a binder shall consist of a binder jacket (extruded binder); an open, skeleton wrap of nonmetallic threads or tape; a metal shield as described in Electromagnetic Shields, Section 8; or a core wrap as described in Core Wrap, Section 11. Except for thickness, which is not specified, a binder jacket shall comply with Overall Cable Jacket, Section 13. The average thickness and the minimum thickness at any point of a binder jacket shall be determined as described in Thicknesses of Jacket on Flexible Cord, Fixture Wire, and Elevator Cable, Section 280 of UL 1581. The material, construction, manner of application, and other details of a thread or tape binder are not specified.

11 Core Wrap

11.1 Enclosure of an assembly or group of conductors (with or without one or more optical-fiber members in the group or assembly) or optical-fiber members under a core wrap (cable wrap) consisting of a serving, wrap, tape, or other construction, or under a metal shield as described in Electromagnetic Shields, Section 8, is not specified. Any core wrap used shall completely cover the assembly or group. The material, construction, manner of application, and other details of a nonmetallic core wrap are not specified. See Binders, Section 10.

12 Assembly of the Cable

12.1 A cable shall not consist of optical-fiber members alone. Non-current-carrying electrically conductive parts such as a metal strength element and/or a metal vapor barrier shall not be in a group of optical-fiber members that contains one or more electrical conductors. Where metal parts are used in a group of only optical-fiber members, the construction of the metal parts is not specified.

12.2 A cable shall be constructed flat or round. Fillers are not specified. All of the insulated circuit and grounding conductors, bare grounding conductor(s), and optical-fiber member(s) in any group or assembly shall be cabled with the length and direction of lay not specified. Any group or assembly shall be round. Preassembly of two or more cabled conductors or members into a group or other assembly is not specified. In a cable consisting of 12 or fewer twisted circuit-conductor pairs or 2, 3, or 4 single conductors [insulated circuit conductors and any insulated or bare grounding conductor(s)], the pairs or conductors shall be cabled or laid straight. In other cables, all elements (individual insulated conductors, individual bare grounding conductors, individual optical-fiber members, groups, and assemblies) shall be cabled. In any case, the length of lay is not specified. Changes in the direction of lay are not specified. The change intervals are not required to be identical in length. The elements are not required to be of the same dimensions or of the same materials. Except that the grounding conductor(s) in a cable shall not be of any size that is smaller than the size of the smallest circuit conductor, the mixture of conductor insulation, temperature ratings, sizes, stranding, and metal and optical-fiber member materials and sizes is not specified in a cable.

13 Overall Cable Jacket

13.1 Material, application, and thicknesses

13.1.1 An overall jacket is required on each flat or round unarmored cable and on each armored cable intended (see 15.1) for encasement in concrete, mortar, other masonry, plaster, or similar construction [a cable jacket or other covering is not required under any form of armor (see 14.1.2) or under any of the shields discussed in 8.2(b)]. The overall cable jacket shall be of one of the jacket materials named in Table 7.1 or referenced in note a to Table 7.1 (see 7.2.1.2, 7.2.2.1, and 7.2.2.2 regarding compliance with physical properties requirements).

13.1.2 The overall jacket shall be of the thicknesses indicated in inches in Table 13.1 or in millimeters in Table 13.2 or the overall jacket shall be thicker as indicated in 13.2.1 when measured as described in Thicknesses of Jacket on Flexible Cord, Fixture Wire, and Elevator Cable, Section 280 of UL 1581. See 40.2 regarding the color of an overall jacket.

Table 13.1
Jacket thicknesses[a, d] in inches

Calculated[b] diameter of round assembly under jacket or Calculated[b] equivalent diameter of flat assembly under jacket		Jacket of ECTFE, ETFE, FEP, PFA, MFA, PTFE, TFE, PVDF, or PVDF copolymer		Jacket of CP, thermoplastic CPE, thermoset CPE, EPCV, HDFRPE, LDFRPE, NBR/PVC, neoprene, PVC, SRPVC, TPE, or XL	
		Minimum average	Minimum at any point	Minimum average	Minimum at any point
Over ... inches	But not over ... inches	Inch	Inch (0.80 × average)	Inch	Inch (0.80 × average)
0	0.200	0.008[c]	0.006[c]	0.035	0.028
0.200	0.250	0.008[c]	0.006[c]	0.040	0.032
0.250	0.300	0.010[c]	0.008[c]	0.040	0.032
0.300	0.350	0.010[c]	0.008[c]	0.050	0.040
0.350	0.500	0.013	0.010	0.050	0.040
0.500	0.700	0.015	0.012	0.060	0.048
0.700	0.750	0.020	0.016	0.060	0.048
0.750	1.100	0.020	0.016	0.070	0.056
1.100	1.450	0.020	0.016	0.080	0.064
1.450	1.500	0.020	0.016	0.090	0.072
1.500	1.800	0.025	0.020	0.090	0.072
1.800	2.250	0.025	0.020	0.110	0.088

[a] A thicker jacket is required to enable some cables to comply with one or more tests. See 13.2.1.

[b] See 5.8 regarding the conductor diameter(s) to use in the calculation. The equivalent diameter of a flat assembly is to be calculated as 1.1284× $(TW)^{1/2}$, 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 8.2(c) as not having any intervening wrap or other protective covering shall not be thinner in average thickness than 0.013 inch and shall not be thinner at any point than 0.010 inch.

[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
Jacket thicknesses[a, d] in millimeters

Calculated[b] diameter of round assembly under jacket or Calculated[b] equivalent diameter of flat assembly under jacket		Jacket of ECTFE, ETFE, FEP, PFA, MFA, PTFE, TFE, PVDF, or PVDF copolymer		Jacket of CP, thermoplastic CPE, thermoset CPE, EPCV, HDFRPE, LDFRPE, NBR/PVC, neoprene, PVC, SRPVC, TPE, or XL	
		Minimum average	Minimum at any point	Minimum average	Minimum at any point
Over ... mm	But not over ...mm	mm	mm	mm	mm
0	5.08	0.20[c]	0.15[c]	0.89	0.76
5.08	6.35	0.20[c]	0.15[c]	1.02	0.81
6.35	7.62	0.25[c]	0.20[c]	1.02	0.81

Table 13.2 Continued on Next Page

Table 13.2 Continued

Calculated[b] diameter of round assembly under jacket or Calculated[b] equivalent diameter of flat assembly under jacket		Jacket of ECTFE, ETFE, FEP, PFA, MFA, PTFE, TFE, PVDF, or PVDF copolymer		Jacket of CP, thermoplastic CPE, thermoset CPE, EPCV, HDFRPE, LDFRPE, NBR/PVC, neoprene, PVC, SRPVC, TPE, or XL	
		Minimum average	Minimum at any point	Minimum average	Minimum at any point
Over ... mm	But not over ...mm	mm	mm	mm	mm
7.62	8.89	0.25[c]	0.20[c]	1.27	1.02
8.89	12.70	0.33	0.25	1.27	1.02
12.70	17.78	0.38	0.30	1.52	1.22
17.78	19.05	0.51	0.41	1.52	1.22
19.05	27.94	0.51	0.41	1.78	1.42
27.94	36.83	0.51	0.41	2.03	1.63
36.83	38.10	0.51	0.41	2.29	1.83
38.10	45.72	0.64	0.51	2.29	1.83
45.72	57.15	0.64	0.51	2.79	2.24

[a] A thicker jacket is required to enable some cables to comply with one or more tests. See 13.2.1.

[b] See 5.8 regarding the conductor diameter(s) to use in the calculation. The equivalent diameter of a flat assembly is to be calculated as 1.1284× $(TW)^{1/2}$, 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 8.2(c) as not having any intervening wrap or other protective covering shall not be thinner in average thickness than 0.33 mm and shall not be thinner at any point than 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.

13.2 Thicker jacket

13.2.1 A cable on which a jacket thicker than indicated in Table 13.1 or Table 13.2 is used to enable the cable to comply with any applicable flame or smoke-and-flame test or other test specified in this Standard shall be made with whatever greater thickness of jacket is intended 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. See the last sentence of 5.8 regarding the maximum total thickness of two overall cable jackets.

13.3 Cable temperature rating

13.3.1 For a cable in which the jacket and insulation are rated for 60°C (140°F), the temperature rating of the cable is to be 60°C (140°F).

13.3.2 For a cable in which the insulation is rated for 75 – 105°C (167 – 221°F), 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, and the temperature rating of the cable is to be the same as the temperature rating of the insulation in the cable.

13.3.3 For a cable in which the insulation is rated for 125 – 250°C (257 – 482°F), the relationship between the temperature ratings of the insulation and the overall cable jacket and any binder jacket is not specified and, with the exception stated in note b to Table 7.1 regarding strand diameter and coating, the temperature rating of the cable is to be that of whichever insulation or jacket in the cable has the lowest temperature rating.

14 Metal Covering (Armor)

14.1 General

14.1.1 Where used on a flat or round cable (see 1.4), armor shall consist of interlocked metal strip or a metal sheath. See Copper Sulphate Test of Zinc Coating on Steel Strip for and from Interlocked Steel Armor, Section 32; Tension Test of Interlocked Steel or Aluminum Armor, Section 34; and Flexibility Test of Cable Having Interlocked Armor or a Smooth or Corrugated Metal Sheath, Section 35. See 40.2 regarding the color of armor that is the outermost covering on a cable. Any armor used shall be as follows:

a) A smooth metal sheath shall comply with 14.1.3 and with Smooth Metal Sheath, Section 14.2.

b) A welded and corrugated metal sheath shall comply with 14.1.3, 14.1.4, and with Welded and Corrugated Metal Sheath, Section 14.3.

c) An extruded and corrugated metal sheath shall comply with 14.1.3, 14.1.4, and with Extruded and Corrugated Metal Sheath, Section 14.4.

d) Interlocked metal strip shall comply with 14.1.3 and with Interlocked Armor, Section 14.5.

14.1.2 A jacket or other covering is not required under any form of armor.

14.1.3 The metal sheath, or the strip forming the interlocked armor, shall be continuous throughout the entire length of the cable. A metal sheath shall not have flaws that affect its integrity– that is, a metal sheath shall not have any weld openings, cracks, splits, foreign inclusions, or similar flaws. Splicing of the strip from which interlocked armor is formed shall not include any cut or broken ends (see 14.5.3).

14.1.4 The number of convolutions per unit length of a welded or extruded corrugated metal sheath is not specified. The adequacy of the convolutions is to be judged on the basis of the performance of the finished cable in the tests specified or referenced 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. The sheath shall be tightly formed around the underlying cable. Smooth metal shields are covered in 8.2(b).

14.2.2 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.

Table 14.1
Thicknesses[a] of smooth aluminum sheath

Calculated[a] diameter of round assembly under sheath or Calculated[a] equivalent diameter of flat assembly under sheath		Minimum average	Minimum at any point
Over .... inches	But not over .... inches	Inch	Inch (0.90 × average)
0	0.400	0.035	0.032
0.400	0.740	0.045	0.041
0.740	1.050	0.055	0.050
1.050	1.300	0.065	0.059
1.300	1.550	0.075	0.068
1.550	1.800	0.085	0.077
Over 1.800		0.095	0.086
Over .... mm	But not over .... mm	mm	mm
0	10.16	0.89	0.81
10.16	18.80	1.14	1.04
18.80	26.67	1.40	1.27
26.67	33.20	1.65	1.50
33.02	39.37	1.90	1.73
39.37	45.72	2.16	1.96
Over 45.72		2.41	2.18

[a] See 5.8 regarding the conductor diameter(s) to use in the calculation. The equivalent diameter of a flat assembly is to be calculated as $1.1284 \times (TW)^{1/2}$, in which T is the thickness of the assembly and W is the width of the assembly.

14.2.3 Where a smooth or corrugated metal sheath does not comply with the requirements in this Standard and the cable manufacturer repairs the cable, the original sheath is to be stripped from the entire length of the cable and the cable is to 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 tightly formed around the underlying cable. Stripping and replacement of a noncomplying sheath are covered in 14.2.3. Corrugated metal shields are covered in 8.2(b).

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. Stripping and replacement of a noncomplying sheath are covered in 14.2.3.Corrugated metal shields are covered in 8.2(b).

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 14.2.2.

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 14.4.2.

14.5 Interlocked armor

14.5.1 Interlocked steel or aluminum strip shall comply with 14.1.3 and 14.5.2 – 14.5.10. Dimensions of the metal strip shall comply with 14.5.9. The strip shall be tightly formed around the underlying cable.

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 capable of diminishing 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 capable of damaging the underlying cable or any jacket over the armor. Splices shall not 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, which shall consist of the full width of the strip where practical. Where this is not practical, the tensile strength shall be determined 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.

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 inch or 3.3 mm in diameter. The zinc coating complies with this requirement when the strip is bent around the specified mandrel and the coating does not flake or fly off and none of it is removed from the strip by rubbing with the fingers.

14.5.7 Loosening or detachment during the adherence test and superficial (tiny) 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 on Steel Strip for and from Interlocked Steel Armor, Section 32.

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 0.51 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.

14.5.10 The color of the steel or aluminum strip is not specified. Typically, where there is no jacket over the armor, the strip face that is to be outermost on the cable is red.

Table 14.2
Dimensions of zinc-coated steel strip or aluminum strip for interlocked armor

Calculated[b] diameter of round assembly under armor or Calculated[b] equivalent diameter of flat assembly under armor		Maximum width[b] of unformed strip	Minimum thickness at any point of the formed strip removed from the finished cable	
			Steel	Aluminum
Over .... inches	But not over .... inches		mils	
0	0.500	500	17	22
0.500	1.000	750	17	22
1.000	1.500	875	17	22
1.500	2.000	875	22	27
Over 2.000		1000	22	27
Over .... mm	But not over .... mm		mm	
0	12.70	12.7	0.43	0.56
12.70	25.40	22.2	0.43	0.56
25.40	38.10	22.2	0.43	0.56
38.10	50.80	22.2	0.56	0.69
Over 50.80		25.4	0.56	0.69

[a] See 5.8 regarding the conductor diameter(s) to use in the calculation. The equivalent diameter of a flat assembly is to be calculated as 1.1284 × $(TW)^{1/2}$, in which T is the thickness of the assembly and W is the width of the assembly.

[b] Tolerances for the width of steel strip are not to exceed plus 10 mils and minus 5 mils or plus 0.2 mm and minus 0.1 mm. Tolerances for the width of aluminum strip are not to exceed plus and minus 10 mils or plus and minus 0.2 mm.

15 Jacket over Armor

15.1 A jacket is required over any armor that is on a cable intended for burial directly in the earth (see 1.4). A jacket is required over the armor on each cable intended for encasement in concrete, mortar, other masonry, plaster, or similar construction. A jacket is not required over armor on other cables (see 1.4). A jacket over armor shall comply with Overall Cable Jacket, Section 13. The same calculated (see 5.8) core dimension that is used in determining the thicknesses of an overall cable jacket that is not over armor is to be used in determining the thicknesses required for an over-armor jacket – that is, an over-armor jacket is not required to be thicker than a cable jacket that is not over armor. See 40.2 regarding the color of an overall jacket.

PERFORMANCE

16 Continuity Test of Conductors and Shields

16.1 Finished cable shall be tested for continuity of each conductor and for continuity of each shield. This continuity test is to be conducted before the voltage test is performed as described in Alternative Spark and Dielectric Voltage-Withstand Tests, Section 26. The continuity test 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 each individual shipping length is to be tested 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 cable jacket is applied, in which case, one shipping length from each master reel of the finished cable is also to be tested. For any conductor or any shield in the shipping length found not to be continuous, 100 percent of the finished cable on the master reel from which the test length was taken is to be tested.

16.2 For a cable that contains one or more shields, each conductor and shield taken separately is to be connected in series with a light-emitting diode (LED), lamp, buzzer, bell, or other indicator, and an a-c or d-c power supply of less than 30 V.

16.3 For a cable that does not contain any shielding, either the procedure in 16.2 or the eddy-current method in 16.4 and 16.5 is to be used.

16.4 For eddy-current testing, the equipment is to comply with each of the following:

a) The equipment is to apply current at one or several frequencies in the range of 1 – 125 kHz to a test coil for the purpose of inducing eddy currents in the conductors moving through the coil at production speed.

b) The equipment is to detect the variation in impedance of the test coil caused by each break in one or more of the conductors.

c) The equipment is to show a visual indication to the operator.

16.5 During eddy-current testing, the longitudinal axis of the cable is to be coincident with the electrical center of the test coil. The cable is to have little or no vibration as it passes through the test coil and is to clear the coil by a distance not greater than 1/2 inch or 13 mm. Variations in the speed of the cable through the test coil are to be limited to plus 50 percent and minus whatever percentage (50 percent maximum) keeps the signal amplitude from falling below the level at which a break is detectable. Separate calibration, balance, and adjustments for sensitivity, maximum signal-to-noise ratio, and maximum rejection of signals indicating gradual variations in diameter and other slow changes are to be made for each size, type of stranding, and conductor material. Calibration without any cable in the test coil is to be made at least daily to check whether the equipment is functioning. Variations in the temperature along the length of the cable being tested from the temperature at which the equipment was calibrated and adjusted for that size, type of stranding, and conductor material are to be gradual without hot or cold spots that cause false signals.

17 D-C Resistance Test of Conductors

17.1 Requirements

17.1.1 The direct-current resistance of any length of metal-coated or uncoated copper conductor in ohms based on 1000 conductor feet or in ohms based on a conductor kilometer shall not be higher than the maximum value indicated for the marked size of the conductor (see 5.5) in the applicable Table 17.1 (solid conductors) or Table 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 cable shall not exceed the single-conductor value in the applicable Table 17.1 or Table 17.2 multiplied by whichever of the following factors is appropriate:

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

Table 17.1
Maximum direct-current resistance of solid conductors

AWG size of conductor	Uncoated				Coated			
	20°C		25°C		20°C		25°C	
	Ohms per 1000 feet[a]	Ohms per kilometer	Ohms per 1000 feet[a]	Ohms per kilometer	Ohms per 1000 feet[b]	Ohms per kilometer	Ohms per 1000 feet[b]	Ohms per kilometer
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
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

[a] 1.02 × nominal.
[b] 1.06 × nominal.

Table 17.2
Maximum direct-current resistance of stranded conductors

AWG size of conductor	Uncoated				Coated			
	20°C		25°C		20°C		25°C	
	Ohms per 1000 feet[a]	Ohms per kilometer	Ohms per 1000 feet[a]	Ohms per kilometer	Ohms per 1000 feet[b]	Ohms per kilometer	Ohms per 1000 feet[b]	Ohms per kilometer
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

[a] 1.04 × nominal.
[b] 1.08 × nominal.

17.2 General method

17.2.1 The method is not specified. Measurements are to be made to an accuracy of 2 percent or better by means of a Kelvin-bridge ohmmeter or its equivalent (see 17.2.2 concerning measurement at other temperatures). Where the results of any measurement indicate noncompliance, the results of referee measurements made under the conditions outlined in Kelvin-Bridge Referee Method, Section 17.3, are to be taken as conclusive. Determination of the conductor diameter or area instead of its d-c resistance is described in 5.5 – 5.7.

17.2.2 The resistance of a conductor measured at a 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. Where the resistance measurements are made at a temperature higher the 20°C (68°F) and the resistance values read are lower than those specified in Table 17.1 or Table 17.2, the conductor complies without adjustment of the resistance values read.

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	27	80.6	0.992	0.973
1	33.8	1.102	1.081	28	82.4	0.989	0.970
2	35.6	1.098	1.076	29	84.2	0.985	0.966
3	37.4	1.093	1.072	30	86.0	0.981	0.962
4	39.2	1.089	1.067	31	87.8	0.977	0.958
5	41.0	1.084	1.063	32	89.6	0.974	0.955
6	42.8	1.079	1.059	33	91.4	0.970	0.951
7	44.6	1.075	1.054	34	93.2	0.967	0.948
8	46.4	1.070	1.050	35	95.0	0.963	0.944
9	48.2	1.066	1.045	36	96.8	0.959	0.941
10	50.0	1.061	1.041	37	98.6	0.956	0.937
11	51.8	1.057	1.037	38	100.4	0.952	0.934
12	53.6	1.053	1.033	39	102.2	0.949	0.930
13	55.4	1.048	1.028	40	104.0	0.945	0.927
14	57.2	1.044	1.024	41	105.8	0.942	0.924
15	59.0	1.040	1.020	42	107.6	0.938	0.921
16	60.8	1.036	1.016	43	109.4	0.935	0.917
17	62.6	1.032	1.012	44	111.2	0.931	0.914
18	64.4	1.028	1.008	45	113.0	0.928	0.911
19	66.2	1.024	1.004	46	114.8	0.925	0.908
20	68.0	1.020	1.000	47	116.6	0.922	0.905
21	69.8	1.016	0.996	48	118.4	0.918	0.901
22	71.6	1.012	0.992	49	120.2	0.915	0.898
23	73.4	1.008	0.989	50	122.0	0.912	0.895
24	75.2	1.004	0.985	51	123.8	0.909	0.892
25	77.0	1.000	0.981	52	125.6	0.906	0.889
26	78.8	0.996	0.977	53	127.4	0.902	0.885
54	129.2	0.899	0.822	72	161.6	0.846	0.830
55	131.0	0.896	0.879	73	163.4	0.844	0.828
56	132.8	0.893	0.876	74	165.2	0.841	0.825
57	134.6	0.890	0.873	75	167.0	0.838	0.822
58	136.4	0.887	0.870	76	168.8	0.835	0.819
59	138.2	0.884	0.867	77	170.6	0.833	0.817
60	140.0	0.881	0.864	78	172.4	0.830	0.814
61	141.8	0.878	0.861	79	174.2	0.828	0.812
62	143.6	0.875	0.858	80	176.0	0.825	0.809
63	145.4	0.872	0.856	81	177.8	0.822	0.807
64	147.2	0.869	0.853	82	179.6	0.820	0.804
65	149.0	0.866	0.850	83	181.4	0.817	0.802
66	150.8	0.863	0.847	84	183.2	0.815	0.799
67	152.6	0.860	0.844	85	185.0	0.812	0.797
68	154.4	0.858	0.842	86	186.8	0.810	0.794

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)
69	156.2	0.855	0.839	87	188.6	0.807	0.792
70	158.0	0.852	0.836	88	190.4	0.805	0.789
71	159.8	0.849	0.833	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°F). See 17.3.5 regarding temperature equilibrium.

17.3 Kelvin-bridge referee method

17.3.1 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 a 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 17.3.5 regarding temperature equilibrium.

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

17.3.3 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 unless the coil and lead ratios are balanced.

17.3.4 Each general-purpose Kelvin-bridge potential electrode shall contact the conductor specimen with a surface that is a sharp knife edge as specified in the first sentence of 17.3.7. The length of the conductor specimen between the knife edges is to be measured to the nearest 0.01 inch or 0.2 mm.

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

17.3.6 Because the bridge measuring the current raises the temperature of the specimen, the magnitude of the current is to be low and the time of its use is to be brief. Too much current, too much time, or both, are being used for a measurement where any change in resistance is detected by the galvanometer in two successive readings.

17.3.7 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. Where 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. Where 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. Where 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 the resistance of the specimen. Where 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 17.3.1 – 17.3.6 and the referee determination is to be repeated (two or four readings as indicated in this paragraph) using the same specimen or a new specimen.

18 Heat Shock Test

18.1 The overall PVC jacket in place on the finished cable, and each diameter of non-NEC PVC-insulated conductor removed from the finished cable, shall not show any cracks on the inside or outside surface of the PVC after being wound onto mandrels in the manner described in 540.1 and 540.2 of UL 1581 and then subjected to a temperature of 121.0 ±1.0°C (249.8 ±1.8°F) in an air oven for 60 min. A mandrel 0.062 inch or 1.6 mm in diameter is to be used for the insulated conductors regardless of their AWG size or their diameter. For nylon-jacketed conductors, the test is to be conducted with the nylon in place. Insulated conductors are to be wound onto the mandrel for six complete turns. The number of turns and the mandrel diameter to use for testing the jacket on the cable are specified in Table 18.1. Flat cable is to be wound flatwise onto the mandrel.

Table 18.1
Mandrel diameter and number of turns for heat shock test of jacket on cable

Calculated[a] diameter over cable jacket of round cable or Calculated[a] equivalent diameter[b] over cable jacket of flat cable				Mandrel diameter		Number of turns
Over ... inches	But not over ... inches	Over ... mm	But not over ... mm	inches	mm	
0	0.375	0	9.53	0.750	19.05	6
0.375	0.625	9.53	15.88	1.625	41.28	6
0.625	1.000	15.88	25.40	3.000	76.20	6
1.000	2.000	25.40	50.80	3 × calculated diameter	3 × calculated diameter	1/2 (U bend)
Over 2.000		Over 50.80		4 × calculated diameter	4 × calculated diameter	1/2 (U bend)

[a] See 5.8 regarding the conductor diameter(s) to use in the calculation.

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

19 Deformation Test

19.1 The thickness of the overall cable jacket and the thickness of the insulation on conductors other than NEC wires shall not decrease more than the percentage indicated in Table 19.1 when the overall cable jacket and the non-NEC insulated conductors are removed from the finished cable and subjected to the load indicated in Table 19.1 while being maintained at the temperature indicated in Table 19.1. The test is to be conducted and the measurements and calculation are to be made as described under Deformation Test, Section 560 of UL 1581. Each diameter of non-NEC insulated conductor used in the cable is to be tested. For nylon-jacketed conductors, the nylon is to be in place throughout the test and the measurements are to be made over the nylon.

Table 19.1
Specifications for the deformation test

Insulation or jacket material	Maximum percent decrease	Load[a] gf	Load[a] N	Oven temperature
CP, thermoplastic CPE, thermoset CPE, EPCV				
Insulation	30	500	4.90	121.0 ±1.0°C
Jacket	30	2000	19.61	(249.8 ±1.8°F)
ECTFE, ETFE, FEP				
Insulation	25	1000	9.81	121.0 ±1.0°C
Jacket	25	4000	39.23	(249.8 ±1.8°F)
PTFE, TFE				
Insulation	25	1000	9.81	121.0 ±1.0°C (249.8 ±1.8°F)
PVC				
Insulation	50	500	4.90	121.0 ±1.0°C
Jacket	50	2000	19.61	(249.8 ±1.8°F)
75°C PVC insulation under a nylon jacket	30[b]	500	4.90	121.0 ±1.0°C 249.8 ±1.8°F
90°C PVC insulation under a nylon jacket	25[b]	500	4.90	136.0 ±1.0°C (276.8 ±1.8°F)
TPE				
90 and 105°C	50	500	4.90	121.0 ±1.0°C
insulations				(249.8±1.8°F)
90 and 105°C	50	2000	19.61	121.0 ±1.0°C
jackets				(249.8 ±1.8°F)
XLPE, XLPVC, XLEVA, blends of these				
Insulation	30	500	4.90	121.0 ±1.0°C
Jacket	30	2000	19.61	(249.8 ±1.8°F)
NBR/PVC, neoprene				
Insulation	No test	–		–
Jacket	No test	–		–
Semirigid PVC, silicone rubber insulation	No test	–		–

[a] The specified load is not the weight to be added to each rod in the test apparatus. The specified load is the total of the weight added and the weight of the individual rod. Because the weight of the rod varies from one apparatus to another, specifying the exact weight to be added to a rod to achieve the specified load on a specimen is impractical in all cases except for an individual apparatus.

[b] Nylon in place, measurements over the nylon.

20 Cold Bend Test of the Insulation

20.1 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 on conductors other than NEC wires removed from the finished cable (before being conditioned) shall not crack on the inside or outside surface when specimens of each diameter of conditioned non-NEC insulated conductor are wound onto the applicable diameter of mandrel in the cold chamber as described in 20.2 – 20.4.

20.2 Round metal mandrels are to be used in this test. The diameter of the mandrel for each diameter (calculated) of non-NEC insulated conductor used in the cable is to be as indicated in Table 20.1. The mandrels are to be securely mounted in the chamber in a position that facilitates the winding.

20.3 The non-NEC insulated conductors are to be removed from a 24-inch or 610-mm length of the finished cable and are to be separated from one another and individually placed in the precooled cold chamber. The specimens and mandrels 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, onto the appropriate mandrel for the number of complete turns indicated in Table 20.1. Adjacent turns are to touch one another. The winding of each specimen is to be at a uniform rate of 4 – 6 turns per minute. The winding is to be completed in the cold chamber.

20.4 With a minimum of handling and while remaining in the coiled form, each specimen is to be slid from its mandrel, removed from the test chamber, and placed on a horizontal surface. The specimens are to rest in the coiled form 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. Circumferential depressions in the outer surface indicate cracks on the inside surface of an insulation other than a fluoropolymer. Circumferential depressions in a fluoropolymer surface are indicators of cracking or are yield marks (locally stronger points), so the inside fluoropolymer surface is to be examined visually. The examinations are to be made with normal or corrected vision without magnification.

Table 20.1
Mandrel diameter and number of turns for cold bend test of insulation

Calculated[a] diameter over the insulation				Diameter of mandrel		Number of complete turns of specimen on mandrel
Over ... inches	But not over ... inches	Over ... mm	But not over ... mm	Inches	mm	
0	0.125	0	3.18	0.250	6.35	6
0.125	0.250	3.18	6.35	0.500	12.70	6
0.250	0.375	6.35	9.52	0.750	19.05	6
0.375	0.500	9.52	12.70	1.000	25.40	6
0.500	0.625	12.70	15.88	1.250	31.80	6
0.625	0.750	15.88	19.05	1.500	38.10	1
0.750	0.875	19.05	22.22	1.750	44.45	1
0.875	1.000	22.22	25.40	2.000	50.80	1

[a] See 5.8 regarding the conductor diameter to use in the calculation.

21 Cold Bend Test of the Complete Cable

21.1 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 (−94.0°F), specimens of the complete cable shall not be damaged when the specimens are individually wound onto a round mandrel as described in 21.2 and 21.3. See 41.1 (j) and (k) regarding marking or not marking the cable with its low-temperature rating.

21.2 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 (−94.0°F). Tolerance of +3.0°C, −2.0°C (+5.4°F, −3.6°F) apply to each of these temperatures. 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 three full turns around a round metal mandrel of a diameter equal to 15 times the calculated overall cable diameter in the case of a round cable that is without armor and contains the specific metal sheath (shield) described in 8.3, 12 times the calculated overall cable diameter in the case of a round cable that is without armor and contains any other sheath (shield), 8 times the calculated overall cable diameter in the case of a round cable that is without armor and does not contain any sheath (shield) or, for all other cables, 15 times the calculated overall cable diameter in the case of a round cable, or 15 times the equivalent diameter of a flat cable. The equivalent diameter of a flat cable is to be calculated as $1.1284 \times (TW)^{1/2}$, in which T is the calculated thickness of the cable and W is the calculated width of the cable. A flat cable is to be wound flatwise onto the mandrel. There is not to be any more tension applied to a specimen than keeps 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 a uniform rate of 4 – 6 turns per minute, 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 is to be performed in the cold chamber.

21.3 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 complies where, for the first length tested, there are no cracks, splits, tears, or other openings in any part of the cable. Cracking on the inside surface of a jacket or of the insulation (on NEC wires and on conductors other than NEC wires) is detectable 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 indicators of cracking or are yield marks (locally stronger points), so the inside fluoropolymer surface is to be examined visually. A white appearance (stress whitening) of a PVDF or PVDF copolymer jacket after flexing is not cause for rejection. Where the first test length has any of the indicated faults, compliance is to be judged by the results obtained from the three remaining test lengths. The cable does not comply where any of the three test lengths have one or more faults. The examinations are to be made with normal or corrected vision without magnification.

22 Smoke and Flame Testing of NPLFP Cables

22.1 Type NPLFP cables shall comply with the flame-propagation 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 are tested in sets in the manner described in NFPA 262. 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 that is to be made. The test specimens that represent a given construction typically are the smallest and largest diameters to be produced in that construction.

23 Flame Testing of Riser Cables

23.1 Cables with the metal covering described in Metal Covering (Armor), Section 14, and without the jacket described in Jacket over Armor, Section 15, comply with the requirements in 23.2 and are not required to be tested.

23.2 Jacketed Type NPLFR cables shall comply with the limits stated in the Standard Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts, UL 1666 when specimens are tested in sets in the manner described in UL 1666. 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 (see specification of specimens in 23.3 and 23.4). Where the flame-propagation height and/or the temperature exceed the limits specified in UL 1666 and repeated in 1.12(b) for any set of cable specimens tested, compliance in tests of additional sets of specimens is required to qualify the full size range desired by the manufacturer. See 24.2.1 and 24.2.2 regarding shields and regarding construction changes that trigger repeat testing.

23.3 For cables with insulated conductors and coaxial and optical-fiber members that, when individually tested after removal from the finished cable, comply with the horizontal flame test described in Horizontal-Specimen Flame Test for Thermoplastic- and Thermoset-Insulated Wires and Cables, Section 1100 of UL 1581, the test specimens that represent a given cable construction for the riser flame test typically are the smallest diameter of the cable to be produced in that construction. The number of cable lengths in a set of specimens is to be determined as indicated in UL 1666.

23.4 For cables with insulated conductors and coaxial and optical-fiber members that, when individually tested after removal from the finished cable, do not comply with the horizontal flame test referred to in 23.3, the test specimens that represent a given cable construction for the riser flame test typically are the smallest and largest diameters of the cable to be produced in that construction. The number of cable lengths in a set of specimens is to be determined as indicated in UL 1666.

24 Alternative Vertical-Tray Flame Tests of General-Purpose Cables

24.1 Choice of test by the manufacturer

24.1.1 Cables with the metal covering described in Metal Covering (armor), Section 14, and without the jacket described in Jacket over Armor, Section 15, comply with the requirements in Sections 24.3 and 24.4 and are not required to be tested.

24.1.2 The manufacturer of Type NPLF cables is to specify either the test referenced in UL Test, Section 24.3, or the test referenced in FT4/IEEE 1202 Test, Section 24.4, for each construction of that manufacturer's jacketed cables. The same test is not required for all constructions. See 1.12(c).

24.2 Changes in construction

24.2.1 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.

24.2.2 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.

24.3 UL test

24.3.1 Jacketed Type NPLF cables shall not exhibit damage (as defined in UL 1685) that equals or exceeds a height of 8 ft, 0 inch or 244 cm when sets of cable specimens as described in 24.3.2 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 for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. 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 (see specification of specimens and evaluation of results in 24.3.2 and 24.3.3). See 24.2.1 and 24.2.2 regarding shields and regarding construction changes that trigger repeat testing.

24.3.2 For cables with insulated conductors and coaxial and optical-fiber members that, when individually tested after removal from the finished cable, comply with the horizontal flame test described in Horizontal-Specimen Flame Test for Thermoplastic- and Thermoset-Insulated Wires and Cables, Section 1100 of UL 1581, the test specimens that represent a given construction for the UL or FT4/IEEE 1202 tray flame test typically are a cable that is 0.500 inch or 12.7 mm in overall diameter. The number of cable lengths in a set of specimens is to be determined as indicated in UL 1685. Where the cable damage height equals or exceeds 8 ft, 0 inch or 244 cm measured upward from the bottom of the cable tray for any individual cable test length in the set of the cable specimens tested, compliance in tests of additional sets of specimens is required to qualify the full size range desired by the manufacturer.

24.3.3 For cables with insulated conductors and coaxial and optical-fiber members that, when individually tested after removal from the finished cable, do not comply with the horizontal flame test referred to in 24.3.2, the test specimens that represent a given construction for the UL or FT4/IEEE 1202 tray flame test typically are the smallest and largest diameters to be produced in the construction represented. The number of cable lengths in a set of specimens is to be determined as indicated in UL 1685. Where the cable damage height equals or exceeds 8 ft, 0 inch or 244 cm measured upward from the bottom of the cable tray for any individual cable test length in either set of cable specimens tested, compliance in tests of additional sets of specimens is required to qualify the full size range desired by the manufacturer.

24.4 FT4/IEEE 1202 test

24.4.1 Jacketed Type NPLF cables shall not exhibit damage (as defined in UL 1685) that equals or exceeds a height of 1.5 m or 4 ft, 11 inches when sets of specimens are tested as described under FT4/IEEE 1202 Type of Flame Exposure (smoke measurements are not applicable) in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. 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. See the specification of specimens in 24.3.2 and 24.3.3 and, for evaluation of results in each case, substitute the following sentence of this paragraph for the final sentence in 24.3.2 and in 24.3.3. Where the cable damage height equals or exceeds 1.5 m or 4 ft, 11 inches measured upward from the lower edge of the burner face for 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 24.2.1 and 24.2.2 regarding shields and regarding construction changes that trigger repeat testing. "FT4/IEEE 1202" or "FT4" is the applicable (not required) cable and tag marking – see Information on or in the Cable, Section 41, and Information on the Tag, Reel, or Carton, Section 42.

25 Sunlight-Resistance Test

25.1 Cable of any type on which there is an overall cable jacket on or through which the designation "sun res" or "sunlight resistant" indicated in 41.1(g) is legible qualifies for use in sunlight where 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 overall jacket is tested as described in Xenon-Arc Tests, Section 1200 of UL 1581, using 720 h of xenon-arc conditioning.

26 Alternative Spark and Dielectric Voltage-Withstand Tests

26.1 Choice of test by the manufacturer

26.1.1 The insulation on each insulated circuit and grounding conductor (on NEC wires and on conductors other than NEC wires) in the finished cable shall comply with either the spark test described in 26.2.1 or the dielectric voltage-withstand test described in 26.3.1 – 26.3.3. The cable manufacturer shall make the choice. Every insulated conductor shall be completely discharged at the conclusion of each test.

26.2 Spark test of insulated conductors before cable assembly

26.2.1 The spark-test alternative is to be either a d-c spark test at 10,500 V or an a-c rms spark test at a 48 – 62 Hz potential of 7500 V. The potential shall be sinusoidal or nearly so. The insulated circuit and grounding conductors (NEC wires and conductors other than NEC wires) are to be tested as single conductors before being shielded or assembled into a group or into the cable, or as twisted pairs after being paired and before further assembly. The test equipment and method are to be as described in Spark Test, Section 910 of UL 1581. One hundred percent of production shall be tested by the manufacturer at the factory. An insulated conductor does not comply where there are any faults in the spark testing of that conductor.

26.3 Dielectric voltage-withstand test between insulated conductors after cable assembly

26.3.1 The dielectric voltage-withstand test alternative is to be either a d-c potential of 2500 V applied for the time indicated in 26.3.2 or a 48 – 62 Hz potential of 1500 V applied for the time indicated in 26.3.2. The potential shall be sinusoidal or nearly so. The test potential is to be applied between each insulated circuit and grounding conductor (NEC wires and conductors other than NEC wires) taken separately and all of the other insulated conductors, any shields, any bare grounding conductor, and any metal covering connected together and to earth ground. The test equipment and method are to be as described in Dielectric Voltage-Withstand Tests for Power-Limited Circuit Cable and Cable for Power-Limited Fire-Alarm Circuits, Section 830 of UL 1581. The equipment is to apply the test potential automatically for each test. The test potential is to be applied manually for longer than the 15 or 60 s. In all cases, the full test potential is to be applied throughout the entire 15-s or longer test interval or throughout the entire 60-s or longer test interval.

26.3.2 For routine production testing, the test potential is to be applied for at least 15 s. Otherwise, the test potential is to be applied for at least 60 s.

26.3.3 The test 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 each individual shipping length is to be tested 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 any overall cable jacket is applied, in which case, one shipping length from each master reel of the finished cable is also to be tested. Where there is a dielectric breakdown of the insulation on any insulated conductor in the shipping length, 100 percent of the finished cable on the master reel from which the test 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 insulated circuit and grounding conductor other than an NEC wire in all finished cable shall be capable of exhibiting an insulation resistance at 60.0°F (15.6°C) of not less than 150 megohms based on 1000 conductor feet, or not less than 45.75 megohms based on a conductor kilometer, when the cable is tested as described in 27.2 – 27.7.

27.2 The measuring equipment and test procedure shall be applicable. They are not otherwise specified. A megohm bridge used for these measurements shall be of appropriate 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.

27.3 Individually insulated circuit and grounding conductors (any nylon or similar covering is to be in place) that are not NEC wires are to be immersed in tap water for at least 12 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 (the inside surface of a metal tank that 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.

27.4 Where at the time of immersion the temperature of any part of the coil 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 judged 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 to within 5.0°F (2.8°C) of the temperature of the insulation and conductor before the coil is immersed.

27.5 The water and the entire length of the immersed insulated conductor, or nylon-jacketed or similarly covered insulated conductor, 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. Where 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.

27.6 A test at 60.0°F (15.6°C) is to be made for a coil that shows results that do not comply when the water temperature is other than 60.0°F (15.6°C).

27.7 Where coils are connected together for the insulation-resistance test and results that comply are not obtained, the individual coils 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 60.0°F (15.6°C) from another room temperature

Temperature		M[a]				
		CP, EPCV, XLPE, XLPVC, and XLEVA	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

Table 27.1 Continued on Next Page

Table 27.1 Continued

Temperature		M[a]				
		CP, EPCV, XLPE, XLPVC, and XLEVA	PVC[b] and semirigid PVC[b]			
°F	°C		I	II	III	IV
57	13.9	0.91	0.73	0.78	0.80	0.84
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
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	39.0	20.3	14.6	7.68

[a] M = 1.00 for TPE, silicone rubber, ECTFE, ETFE, FEP, PTFE, and TFE.

[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, where 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 28.

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

28.1 Two specimens, conveniently of a 16 or 18 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 of interest. 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.

28.2 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 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.

28.3 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 taken as being at the temperature of the bath indicated on the bath thermometer.

28.4 Each of the two specimens is to be exposed (28.3 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.

28.5 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.

28.6 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 28.1, C heads the column of multiplying factors M that applies to the particular insulation.

Table 28.1
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

Table 28.1 Continued on Next Page

Table 28.1 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
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
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	23.3	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 28.1 – 28.6 and t is the temperature of the cable in degrees F.

29 Crushing Test of Cable Marked for Direct Burial

29.1 Finished cable that is marked as indicated in 41.1(f) to show that the cable is for direct burial in the earth shall withstand without rupture of the overall cable jacket and without rupture of the insulation on any insulated circuit or grounding conductor (on NEC wires and on conductors other than NEC wires), 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 is to be conducted and the results evaluated as described in 29.2 – 29.6.

29.2 The results of this test on a given construction are to be taken as representative of the performance of all other cables of the same construction containing either more insulated circuit and grounding conductors/optical-fiber members of the same size or the same or a larger number of insulated circuit and grounding conductors/optical-fiber members of a larger size. The performance of the cabled insulated circuit and grounding conductors and optical-fiber members in a round cable is to be taken as representative of the performance of those conductors and members in both round and flat cables.

29.3 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 inch 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.

29.4 The cable is to be tested in a continuous length of at least 36 inches or 914 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 on the test length with chalk or another innocuous means 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 inches or 230 mm down the length of the cable.

29.5 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 cable 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 29.1 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 of force indicated in 29.1 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 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.

29.6 The test length of the cable is to be advanced to and crushed at each of the successive marks for a total of three crushes. The overall cable jacket and the insulation on each insulated circuit and grounding conductor are to be examined at each of the three points at which the cable was crushed. The cable does not comply where the overall cable jacket or the insulation on any conductor is split, torn, cracked, or otherwise ruptured at any of the three points. Flattening of the jacket or the insulation, or both of these, is to be disregarded.

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

30.1 The mechanical water absorption (MWA) of the insulation on the insulated circuit and grounding conductors that are not NEC wires in a direct-burial cable shall not be more than 20.0 milligrams per square inch of exposed surface or shall not be more than 3.1 milligrams per square centimeter of exposed surface, when specimens of the insulated conductors are tested as described in 30.2 – 30.8.

Exception: This requirement does not apply to insulated conductors that comply with the requirements for Long Term Insulation Resistance Test in Water, Section 31.

30.2 The cable jacket and any metal or other covering(s) outside of the individual conductor insulation are to be removed, or specimens are to be selected before application of the overall cable jacket and other covering(s), leaving the insulation completely exposed. The insulated conductors and any optical-fiber members are to be removed from the cable assembly and the optical-fiber members and any conductors consisting of NEC wires are to be discarded. The surface of each finished, insulated circuit and grounding 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 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.

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

30.4 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 described in 30.3 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 specimens above the cover plate.

30.5 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 within 3 min after removal from the water, and this weight is to be designated as W_2.

30.6 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 promptly after removal from the desiccator. This weight is to be designated as W_3.

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

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

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

in which:

W_1 is the original weight of the specimen in milligrams,

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

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

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

30.8 The insulation on a circuit conductor or an insulated grounding conductor that is not an NEC wire is not for use in direct-burial cable where the MWA for any specimen of that insulation exceeds the limit specified in 30.1.

31 Long Term Insulation Resistance Test in Water

31.1 Insulated conductors, other than wet location NEC wires, intended for use in cable marked "wet location" shall comply with the requirements of the Long Term Insulation Resistance Test in the Standard for Thermoplastic Insulated Wires and Cables, UL 83, or the Standard for Thermoset Insulated Wire and Cable, UL 44.

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

32.1 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:

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 specified 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 specified 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 a specified copper sulphate solution.

32.2 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 is present is to be neutralized by the addition of 1 gram or so of cupric oxide (CuO) or 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.

32.3 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 to expose both edges and the inner surface of the formed strip to view and also to facilitate working cheesecloth between the turns onto the inner surface for the purpose of drying that surface during the test. To reduce the damage to the zinc coating, the strip is not to be straightened as it is unwound. The strip is to remain in the helical form with a diameter that is not larger than about three times the cable diameter. Three 6-inch or 150-mm (axial measurement) specimens are to be cut from the partially uncoiled armor. Additionally, three straight 6-inch or 150-mm specimens are to be cut from a sample length of the zinc-coated steel strip before forming.

32.4 With prudent attention to the risks to health and to the risk of fire presented by the solvent, the six specimens are to be cleaned with an organic solvent. Each specimen is to be examined for evidence of damage to the zinc coating, and only specimens that are not damaged are to be selected for use in the test. One specimen of the unformed strip and one specimen of the armor are to be tested.

32.5 The two selected specimens are to be rinsed in water, and all of their surfaces are to be dried with clean cheesecloth. Most of the water is to be removed in the drying operation (water slows the reaction between the zinc and the solution, thereby adversely affecting the test results). The surface of the zinc is to be dry and clean before a specimen is immersed in the solution of copper sulphate. The specimens are not to be touched by the hands or anything else capable of contaminating or damaging the surfaces.

32.6 A glass, polyethylene, or other chemically nonreactive beaker having a diameter near or equal twice the diameter measured over the specimen of partially uncoiled armor is to be filled with the solution of copper sulphate to a depth of not less than 3 inches or 76 mm. The temperature of the solution is to be maintained at 18.3 ±1.1°C (65.0 ±2.0°F).

32.7 One of the selected specimens is to be immersed in the solution and is to be supported on end in the center of the beaker with at least half of its axial length immersed. The specimen is to remain in the solution for 60 s, during which time it is not to be moved nor is the solution to be stirred or agitated.

32.8 At the end of the 60-s period, the specimen is to be removed from the beaker, rinsed immediately in running tap water, rubbed with clean cheesecloth (cheesecloth or a clean soft-bristle test-tube or bottle brush of applicable size is to be used for rubbing the interior surfaces of the specimen of partially uncoiled armor; only cheesecloth is to be used on the other surfaces of this specimen and on the unformed strip) until any loosely adhering deposits of copper are removed, and is then to be dried with clean cheesecloth. The turns of the specimen of partially uncoiled armor are not to be separated farther during this process. Again, the hands and other damaging and contaminating objects and substances are not to touch the surfaces that were immersed. The part of the specimen that was immersed is to be examined, evaluating each edge and broad surface separately and disregarding the portion of the specimen within 1/2 inch or 13 mm of its immersed end.

32.9 When the part of the specimen that was immersed has any deposit of bright, firmly adherent copper outside the 1/2-inch or 13-mm end portion, an estimate is to be made and recorded of the percentage of each edge and broad surface that is covered with copper.

32.10 Regardless of whether the first dip results in a bright, adherent deposit of copper, the immersion, washing, rubbing, drying, examining, estimating, and recording operations are to be repeated once using the same specimen and beaker of solution. After the second dip, the solution in the beaker is to be disposed of properly.

32.11 The remaining specimen is to be subjected to the 2-dip procedure described in 32.1– 32.10.

32.12 Neither the armor nor the unformed strip complies where there is any bright, adherent copper showing outside the 1/2-inch or 13-mm end portion of the immersed part of the specimen of unformed strip after the first or second dip. Even where the unformed strip complies, the armor does not comply where the specimen of partially uncoiled armor shows any bright, adherent copper after the first dip or more than 25 percent coverage after the second dip. Contamination is present where, after any dip, there is adherent copper that is dull or dark rather than being bright and shiny. In each such instance, the results are to be disregarded and the test is to be repeated on a new specimen.

33 Abrasion Resistance Test of Overall Jacket

33.1 The overall jacket on finished cable shall not wear through exposing the underlying construction in fewer than 70 complete cycles of abrasion against sharp steel edges. The test is to be conducted as described in 33.2 – 33.5.

33.2 Six straight untwisted 15-inch or 380-mm specimens are to be cut from a length of finished cable. The specimens are to be laid parallel to one another on a flat horizontal steel plate and are to be individually secured in place at their ends. The abrasion tool is to consist of a round solid steel weighted cylinder across one face of which three straight parallel teeth are machined symmetrically about a diameter (see Figure 33.1).The tool is to be supported above (not touching) the center of each specimen with its teeth perpendicular to the longitudinal axis of the specimen. The support is to minimize the lateral play of the tool at the ends of each stroke during the abrasion process.