UL 1655

STANDARD FOR SAFETY

Community-Antenna Television Cables

UL Standard for Safety for Community-Antenna Television Cables, UL 1655

Third Edition, Dated October 23, 2024

Summary of Topics

This new Third Edition of ANSI/UL 1655 dated October 23, 2024 incorporates editorial changes including renumbering and reformatting to align with current style.

The requirements are substantially in accordance with Proposal(s) on this subject dated August 2, 2024.

No Text on This Page

UL 1655

Standard for Community-Antenna Television Cables

First Edition – November, 1997
Second Edition – April, 2009

Third Edition

October 23, 2024

This ANSI/UL Standard for Safety consists of the Third Edition.

The most recent designation of ANSI/UL 1655 as an American National Standard (ANSI) occurred on October 23, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

MANUFACTURING AND PRODUCTION TESTS

PERFORMANCE

MARKINGS

INTRODUCTION

1 Scope

1.1 This Standard states the construction, test, and marking requirements covering the safety of single and multiple coaxial and coaxial/optical-fiber cables for the distribution of radio frequency signals such as employed in a community antenna television system, and for supplying low-energy power at a potential not exceeding 60 volts to equipment directly associated with the signal distribution. These are power-limited cables and are of the following types for installation and use as the CATV cables specified in Article 820 and other applicable parts of the National Electrical Code (NEC), NFPA 70. Electrically nonconductive material separates each optical-fiber member from the rest of the cable.

a) PLENUM CABLES – Type CATVP (coaxial) and Type CATVP-OF (coaxial/optical-fiber). These cables are for installation as specified in Section 800.179(A) of the National Electrical Code, NFPA 70 in a duct, plenum, or other space used to transport environmental air without the cable being enclosed in raceway in that space.

b) RISER CABLES – Type CATVR (coaxial) and Type CATVR-OF (coaxial/optical-fiber). These cables are for installation as specified in Section 800.179(B) of the National Electrical Code, NFPA 70 in vertical runs in a shaft or for vertical runs that penetrate more than one floor.

c) GENERAL-PURPOSE CABLES – Type CATV (coaxial) and Type CATV-OF (coaxial/optical-fiber). These cables are general-applications commercial cables for use as specified in Section 800.179(C) of the National Electrical Code, NFPA 70.

d) LIMITED-USE CABLES – Type CATVX (coaxial) and Type CATVX-OF (coaxial/optical-fiber). These are limited use cables as specified in Section 800.179(D) of the National Electrical Code, NFPA 70.

1.2 This Standard does not specify the impedance or other signal-carrying characteristics of these cables. This Standard does not cover tests for the signal-carrying performance of these cables.

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 the like 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. Some overall jackets incorporate a nonmetallic messenger. A metallic messenger may be joined to the cable jacket by an interconnecting web.

1.4 Cables of a CATV type do not have a voltage rating.

1.5 Cables of materials that qualify for temperatures above 60 °C (140 °F) are marked with a temperature rating of 75, 90, 105, 125, 150, 200 °C or 250 °C (167, 194, 221, 257, 302, 392 °F or 482 °F). Temperature marking is not required for cables that qualify for a temperature rating of 60 °C (140 °F).

1.6 Cables that contain one or more electromagnetic shields in addition to the outer conductors of the coaxial members (these shields are identified as "additional" in 9.1) are not required to be marked to indicate the presence of the additional shielding. A shielded cable that is marked has "shielded" on the tag and either on the overall cable jacket or legible through the jacket.

1.7 Cables that qualify for exposure to sunlight (720-hour sunlight-resistance test – see 27.1) have the designation "sun res" or "sunlight resistant" on the tag and either on the overall cable jacket or legible through the jacket.

1.8 Cables that qualify for burial directly in the earth (1000-pound crushing test – see 29.1) have the designation "dir bur", "direct burial", or "for direct burial" on the tag and either on the overall cable jacket or legible through the jacket.

1.9 Optical performance is not evaluated. Cables with optical fibers are to have a tag marking in accordance with 10.3 and 37.1(d). Where there are conductive parts in an optical-fiber member or in a group of such members, a tag marking [36.1(e)] indicates the presence of these parts.

1.10 These requirements do not cover antenna-rotator or other coaxial/electrical cables – that is, coaxial cables with additional conductors for electric-light, power, control, non-power-limited fire-alarm, Class 1, Class 2, or Class 3 circuits.

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

a) PLENUM CABLES – All Type CATVP and Type CATVP-OF cables are tested for smoke and flame characteristics as specified in Smoke and Flame Testing of Plenum Cables, Section 23, 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, NFPA 262. A cable that complies exhibits a maximum flame-propagation distance that is not greater than 5 ft, 0 in or 152 cm, a peak optical density of smoke produced of 0.50 or less, and an average optical density of smoke produced of 0.15 or less.

b) RISER CABLES – Jacketed Type CATVR and Type CATVR-OF cables that comply with the flame-propagation characteristics as specified in Flame Testing of Riser Cables, Section 24, which references the Standard for Test for Flame-Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts, UL 1666.

c) GENERAL-PURPOSE CABLES – Jacketed Type CATV and Type CATV-OF cables are to 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 26. The cable manufacturer is to choose one of the following tests:

1) The UL test referenced in 26.1.1 – 26.3.2. 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 or the Standard for Wire and Cable Test Methods, UL 2556.

2) The FT4/IEEE 1202 test referenced in 26.1.1 and 26.4.1. 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 or the Standard for Wire and Cable Test Methods, UL 2556. 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 36.1(h).

d) LIMITED-USE CABLES – All Type CATVX and Type CATVX-OF cables are subjected to the VW-1 flame test specified in VW-1 (Vertical-Specimen) Flame Test of Limited-Use Cables, Section 25, which references the test method described as the VW-1 (Vertical-Specimen) Flame Test in the Standard for Wire and Cable Test Methods, UL 2556. These cables are not marked "VW-1".

1.12 These requirements do not specify or test for the electrostatic/electromagnetic performance of a shield.

2 Units of Measurement

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

3 Referenced Publications

3.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

3.2 The following publications are referenced in this Standard:

ANSI Z136, *American National Standard for Safe Use of Lasers*

ASTM B566, *Standard Specification for Copper-Clad Aluminum Wire*

ASTM B869, *Standard Specification for Copper-Clad Steel Electrical Conductor for CATV Drop Wire*

ASTM D5423, *Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation*

ASTM D5474, *Standard Guide for Selection of Data Elements for Ground-Water Investigations*

ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

NFPA 70, *National Electrical Code*

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*

NFPA 262, *Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces*

UL 13, *Power-Limited Circuit Cables*

UL 1424, *Cables for Power-Limited Fire-Alarm Circuits*

UL 1581, *Electrical Wires, Cables, and Flexible Cords*

UL 1666, *Test for Flame-Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts*

UL 1685, *Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables*

UL 1690, *Data-Processing Cable*

UL 2556, *Wire and Cable Test Methods*

UL 444, *Communications Cables*

UL 758, *Appliance Wiring Material*

CONSTRUCTION

4 Materials

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

4.2 Cables of a CATV type shall comply in all respects with the applicable requirements for construction details, test performance, and markings.

5 Center Conductor of Coaxial Members

5.1 The center conductor of each coaxial member shall be round and of solid 30 – 1 AWG soft-annealed copper, of stranded 30 AWG – 500 kcmil soft-annealed copper, of solid 30 – 6 AWG medium-drawn or hard-drawn copper, of solid 30 – 6 AWG copper-clad steel, of solid 30 – 1 AWG copper-clad aluminum, or of a smooth or corrugated copper tube. A stranded conductor shall consist of round strands with a right- or left-hand direction of lay. Seven strands, concentric, is the stranding assumed in these requirements; however, individual strand diameter, the number of strands, and the stranding type are not specified. See Metal Coating of Center Conductor, Section 6.

5.2 The nominal diameters indicated in Table 5.1 for solid and stranded center conductors are to be used in calculating the dimensions needed for various parts of the cable when using Table 15.1, Table 15.2, Table 16.1, and Table 16.2. The length of lay of the wires (strands) of a stranded center conductor is not specified.

5.3 All solid, stranded, and tubular center conductors are to be identified as a particular AWG or circular-mil size in the marking on or in the cable and on the tag, reel, or carton. The size of a solid center conductor shall be verified either by determination of the d-c resistance or by determination of the diameter as described in 5.4. The size of a stranded or tubular center conductor shall be verified either by determination of the d-c resistance, as described in 5.5, or by determination of the cross-sectional area. Determination of the conductor size by measurement of the d-c resistance as described in D-C Resistance Test of Center Conductor, Section 21, is the referee method in all cases.

5.4 Where measured as the means of size verification (see 5.3), the diameter of a solid center 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 (0.01 mm), with each division of a width that facilitates estimation of each measurement to 0.0001 inch (0.001 mm). The maximum and minimum diameters at a given point on the solid conductor are each to be recorded to the nearest 0.0001 inch or 0.1 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.

5.5 Where measured as the means of size verification (see 5.3), the cross-sectional area of a stranded or tubular center 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 in UL 2556.

Table 5.1
Dimensions of Center Conductor of a Coaxial Member

Size of conductor	Diameter of solid conductor				Cross-sectional area of tubular or stranded conductor				Nominal diameter of conductor (7 strands)	
	Nominal See 5.2		Minimum See 5.4(b) mils are 0.99 x nominal except where note [a] applies		Nominal		Minimum cmil = 0.98 x nominal			
	mils	(mm)	mils	(mm	cmil	(mm^2)	cmil	(mm^2)	mils	(mm)
30 AWG	10.0	(0.254)	9.5[a]	(0.241)[a]	100	(0.0507)	98	(0.0497)	11.3	(0.287)
29	11.3	(0.287)	10.7[a]	(0.272)[a]	128	(0.0647)	125	(0.0633)	12.8	(0.325)
28	12.6	(0.320)	12.0[a]	(0.305)[a]	159	(0.0840)	156	(0.0790)	14.3	(0.363)
27	14.2	(0.361)	13.5[a]	(0.343)[a]	202	(0.102)	198	(0.100)	16.1	(0.409)
26	15.9	(0.404)	15.1[a]	(0.384)[a]	253	(0.128)	248	(0.126)	18.0	(0.457)
25	17.9	(0.455)	17.0[a]	(0.432)[a]	320	(0.162)	314	(0.159)	20.3	(0.516)
24	20.1	(0.511)	19.1[a]	(0.485)[a]	404	(0.205)	396	(0.201)	22.8	(0.579)
23	22.6	(0.574)	21.5[a]	(0.546)[a]	511	(0.259)	501	(0.254)	25.6	(0.650)
22	25.3	(0.643)	24.0[a]	(0.610)[a]	640	(0.324)	627	(0.318)	28.7	(0.729)
21	28.5	(0.724)	27.1[a]	(0.688)[a]	812	(0.412)	796	(0.404)	32.3	(0.820)
20	32.0	(0.813)	30.4[a]	(0.772)[a]	1020	(0.519)	1000	(0.509)	36.2	(0.919)
19	35.9	(0.912)	34.1[a]	(0.866)[a]	1290	(0.653)	1264	(0.641)	40.7	(1.03)
18	40.3	(1.02)	40.2	(1.016)	1620	(0.823)	1588	(0.807)	45.6	(1.16)
17	45.3	(1.15)	44.9	(1.140)	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	(1.81)	5180	(2.63)	5076	(2.58)	81.6	(2.07)
12	80.8	(2.05)	80	(2.03)	6530	(3.31)	6399	(3.24)	91.5	(2.32)
11	90.7	(2.30)	90	(2.28)	8230	(4.17)	8065	(4.09)	103	(2.62)
10	101.9	(2.588)	101	(2.56)	10380	(5.261)	10172	(5.16)	116	(2.95)
9	114.4	(2.906)	113	(2.88)	13090	(6.631)	12828	(6.50)	130	(3.30)
8	128.5	(3.264)	127	(3.23)	16510	(8.367)	16180	(8.20)	146	(3.71)
7	144.3	(3.665)	143	(3.63)	20820	(10.55)	20404	(10.34)	164	(4.17)
6	162.0	(4.115)	160	(4.07)	26240	(13.30)	25715	(13.03)	184	(4.67)
5	181.9	(4.620)	180	(4.57)	33090	(16.77)	32428	(16.43)	206	(5.23)
4 AWG	204.3	(5.189)	202	(5.14)	41740	(21.15)	40905	(20.73)	232	(5.89)
3	229.4	(5.827)	227	(5.77)	52620	(26.67)	51568	(26.14)	260	(6.60)
2	257.6	(6.543)	255	(6.48)	66360	(33.62)	65033	(32.95)	292	(7.42)
1	289.3	(7.348)	286	(7.27)	83690	(42.41)	82016	(41.56)	332	(8.43)
1/0	–	–	–	–	105600	(53.49)	103488	(52.42)	372	(9.45)
2/0	–	–	–	–	13310	(67.43)	130438	(66.08)	418	(10.62)
3/0	–	–	–	–	167800	(85.01)	164444	(83.31)	470	(11.94)
4/0	–	–	–	–	211600	(107.2)	207368	(105.1)	528	(13.41)

Table 5.1 Continued on Next Page

Table 5.1 Continued

Size of conductor	Diameter of solid conductor				Cross-sectional area of tubular or stranded conductor				Nominal diameter of stranded conductor (7 strands)	
	Nominal See 5.2		Minimum See 5.4(b) mils are 0.99 x nominal except where note [a] applies		Nominal		Minimum cmil = 0.98 x nominal			
	mils	(mm)	mils	(mm	cmil	(mm^2)	cmil	(mm^2)	mils	(mm)
250 kcmil	–	–	–	–	250 kcmil	(127)	245	(124.1)	575	(14.61)
300	–	–	–	–	300	(152)	294	(149.0)	630	(16.00)
350	–	–	–	–	350	(177)	343	(173.8)	681	(17.30)
400	–	–	–	–	400	(203)	392	(198.6)	728	(18.49)
450	–	–	–	–	450	(228)	441	(223.5)	772	(19.61)
500	–	–	–	–	500	(253)	490	(248.3)	813	(20.65)

[a] Minimum diameter (0.95 x nominal) of a reduced-diameter solid conductor. See corresponding resistance (1.1 x nominal) in Table 21.1.

5.6 Each center and outer conductor and each shield shall be continuous throughout the entire length of the finished cable as determined by the Continuity Test of Center and Outer Conductors and Shields, Section 20.

5.7 A joint in a solid center conductor or in one of the individual wires of a stranded center 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 (13 mm), there are no sharp points, and the distance between brazes or welds in a single conductor does not average less than 3000 feet (915 m) in any reel length of insulated single conductor. A joint made before insulation is applied to a center 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 %. 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.

5.8 Any section of a center conductor that includes a factory joint shall have a tensile strength that is not less than 85 % of the tensile strength of an adjacent section of the conductor not having a joint.

6 Metal Coating of Center Conductor

6.1 Where the insulation adjacent to the copper center conductor or copper cladding on the steel or aluminum center conductor is of a material that corrodes unprotected copper in the test described in Conductor Corrosion in UL 2556, the copper conductor or copper cladding 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 center conductor or the individual wires (strands) of a stranded center conductor on which a coating is not required for corrosion protection. The metal coating shall be on both the inside and outside of the copper tube when the metallic coating is used to increase the temperature rating of the conductor.

6.3 The maximum temperature rating of the cable is not specified relative to the small-diameter copper wires used in the outer conductor. The temperature rating of a cable in which the center conductor is of copper, copper tube, or copper-clad steel shall not exceed the temperature indicated in Table 6.1 for the diameter and coating of the solid conductor or individual strands (see 15.3.1 regarding application of Table 6.1). The temperature rating of a cable in which the center conductor is aluminum shall not exceed 90 °C (194 °F).

Table 6.1
Maximum Temperature Rating of Cable Relative to Diameter and Coating of solid Copper Center Conductor or of Copper Center-Conductor Strands

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

7 Insulation

7.1 Material and application

7.1.1 The center conductor of each coaxial member shall be insulated for its entire length. An air-gap dielectric shall be permitted. The insulation material is not specified. The insulation shall be solid or expanded (foamed) with or without a solid dielectric skin (a thin, solid, extruded layer that is or is not separable) applied over the solid or foamed insulation. A skin is not required to be of the same material as the insulation. An air-gap coaxial member shall consist of a solid spacer (thread) that has a nominally circular cross section and is applied to the center conductor helically in a continuous length (the length and direction of lay are not specified) with or without a solid insulating tube overall. Otherwise, the insulation shall be applied directly to the center 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.

7.1.2 Neither flexibility nor physical properties testing is specified for 60 °C (140 °F) insulation. Flexibility or physical properties testing in accordance with 7.1.3 – 7.1.5 is required for all insulations rated 75 °C (167 °F) or greater.

7.1.3 Specimens of solid single-layered insulations removed from finished insulated conductors shall comply with the values of unaged elongation and tensile strength shown in the applicable physical-properties table for the material referenced in Section 50 of UL 1581, and when tested in accordance with the test procedures in UL 2556. Specimens of solid single-layered insulations except PVDF rated 125 °C (257 °F) shall comply with the values of aged retention of elongation and tensile strength shown in the applicable physical-properties table for the material referenced in Section 50 of UL 1581, and when tested in accordance with the test procedures in UL 2556. PVDF rated 125 °C (257 °F), foamed, and multi-layered insulations shall comply with 7.1.4.

7.1.4 Solid or foamed 125 °C (257 °F) PVDF and PVDF copolymer insulations with or without a skin and other insulations with a skin shall comply with the flexibility test in 15.2 (conditioning per Table 50.185 of UL 1581) using specimens consisting of the insulated center conductor and wound onto a mandrel having a diameter equal to the diameter over the insulation (1 x OD). Solid or foamed 150 °C (302 °F) PVDF and PVDF copolymer insulations without a skin and all other solid insulations without a skin shall comply with the tensile strength and ultimate elongation requirements for unaged and aged specimens of the particular material in the applicable table of physical properties in Specific Materials, Section 50 of UL 1581. All specimens are to be prepared from samples taken from the finished cable.

7.1.5 Insulation that is of material generically different from any insulation material for which there is a table of physical properties in Specific Materials, Section 50 of UL 1581 (new material), or that is of material for which physical properties are tabulated in UL 1581 yet does not comply with the applicable short-term tests in the UL 1581 table, shall be of a material and in thicknesses and with a temperature rating appropriate for a CATV-series cable. The material shall be evaluated for the requested temperature rating as described in Long-Term Aging, in UL 2556. Investigation of the electrical, mechanical, and physical characteristics of the cable using either material shall show the material to be comparable in performance to the insulation materials in UL 2556 through tests such as crushing, impact, abrasion, deformation, heat shock, and dielectric voltage-withstand.

7.2 Thicknesses

7.2.1 General

7.2.1.1 The dimensions of the spacer (thread) portion of the material insulation in an air-gap coaxial member are not specified. The average thickness and the minimum thickness at any point of solid or foamed insulation on the center conductor of a coaxial member are not specified but the thicknesses used shall be measured. The thicknesses used shall be adequate to result in compliance with the tests specified or referenced in this Standard. The thicknesses of solid and foamed insulations (including any skin) are to be determined by means of measurements made as described in Thicknesses of Insulation on Flexible Cord and on Fixture Wire in UL 2556, with the following modifications for a stranded conductor that leaves one or more strand impressions in the insulation that are too small to accommodate the smaller pin referred to UL 2556. For this application, the pin is to be 0.0200 inch (0.508 mm in diameter:

a) The 0.003-inch (0.08-mm) thickness-reduction allowance in 250.5 of UL 1581 is to be applied only to insulation that is from a stranded center conductor that leaves the impressions described above in this paragraph and has an average thickness (including any skin) of at least 0.015 inch (0.38 mm).

b) Only an optical method as applicable from 7.2.1.2 and 7.2.1.3 is to be used for thickness measurements of insulation that is from a stranded center conductor that leaves the impressions described above in this paragraph and has an average thickness (including any skin) less than 0.015 inch (0.38 mm).

7.2.1.2 A simply manipulated optical device that is accurate to 0.001 inch (0.01 mm) is to be used for measuring the insulation, with each measurement recorded to the nearest 0.001 inch (0.01 mm).

7.2.1.3 The center conductor is to be removed from the insulation before measuring the thicknesses of the insulation as discussed in 7.2.1.1(b). A thin slice of the insulation plus any skin is then to be cut perpendicular to the longitudinal axis of the resulting hollow tube. Measurements are to be made of the maximum and minimum wall thicknesses of the slice. The recorded maximum and minimum thicknesses are to be added together and then divided by 2 without any rounding of the sum. The resulting average is to be rounded (see 7.2.2.1 – 7.2.5.1, which apply ASTM E29) to the same degree as stated in 7.2.1.2 for the recorded measurements. The average thickness so determined and the recorded minimum thickness are to be taken as the average and minimum-at-any-point thicknesses that are established for the construction as the result of the Crushing Resistance Test of Center-Conductor Insulation, Section 28.

7.2.2 Rounding to the nearest 0.0001 inch

7.2.2.1 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 Rounding to the nearest 0.001 inch

7.2.3.1 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).

7.2.4 Rounding to the nearest 0.001 mm

7.2.4.1 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).

7.2.5 Rounding to the nearest 0.01 mm

7.2.5.1 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).

8 Coaxial Members

8.1 Each coaxial member shall consist of a single central conductor covered in turn with solid or foamed insulation (with or without a skin) complying with 7.1.1 or of the air-gap construction complying with 7.1.1 and 7.2.1.1; a shield(s) (outer conductor) complying with Electromagnetic Shields, Section 9; and a jacket, which is required on a cable consisting of a single coaxial member, and is not required (see the last sentence of 5.7 regarding the maximum total thickness of two jackets on any member) on a coaxial member inside a multiple-member cable. The jacket on a coaxial member shall comply with Overall Cable Jacket, Section 15, where the jacket on the member constitutes the overall cable jacket.

9 Electromagnetic Shields

9.1 An electromagnetic shield is not required other than as the outer conductor of a coaxial member. Except that a reduction in metal-shield mass and/or coverage affects the performance of the cable in the applicable flame test (see 26.2.2), the construction is not specified for any shield ["additional" shield – see marking in 36.1(i)] that is applied over an individual coaxial member, over one or several groups of coaxial members with or without one or more optical-fiber members in any group, or over the entire cable assembly. The number of shields constituting an outer conductor is not specified. Material applied as insulation between shields shall be an insulation grade of one of the materials named or referenced in and meet the requirements of 15.3.1 (thickness not specified). Each shield shall be continuous throughout the entire length of the finished cable as determined by the continuity test described in Continuity Test of Center and Outer Conductors and Shields, Section 20.

9.2 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 an uninsulated metal-coated or uncoated (uncoated 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 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 9.2). 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 in a single coaxial cable, bonding of the coating to the insulation is not specified. Any inward-facing coating on a metal tape applied over more than one member is not to bond to the 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 16.1.1 (a), (b), or (c) as applicable.

c) A serving, wrap, or braid of aluminum wires or of metal-coated or uncoated (uncoated 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 (0.33 mm) and is thinner at any point than 0.010 inch (0.25 mm), a wrap or other protective covering is to be provided over the wire serving, wrap, or braid (see note c to Table 15.1). The construction of the protective covering is not specified. The covering is to 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).

9.3 The specific metal sheath to which reference is made in 22.2 (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 9.2(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 (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 members in the cable.

10 Optical-Fiber Members

10.1 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.

10.2 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 37.1(e).

10.3 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 ANSI Z136 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, 37.1 specifies a tag, reel, or carton marking.

11 Binders

11.1 Use of a binder is not specified over any group of coaxial members (with or without one or more optical-fiber members in the group), 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 9; or a core wrap as described in Core Wrap, Section 13. Except for thickness, which is not specified, a binder jacket shall comply with Overall Cable Jacket, Section 15. 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 of UL 2556. The material, construction, manner of application, and other details of a thread or tape binder are not specified.

12 Communications Conductor

12.1 A communications conductor shall consist of a single insulated copper conductor for use in voice communications during installation of the cable (conductor then abandoned). Surface marking of the communications conductor is not required. Identification of this conductor is not required in the cable and/or tag markings as indicated in 36.1(b).

13 Core Wrap

13.1 Enclosure of an assembly or group of 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 9, 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 11.

14 Assembly of a Multiple-Member Cable

14.1 A multiple-member cable is to be constructed flat or round. Fillers are not specified. The use of a communications conductor (see Communications Conductor, Section 12) is not specified. The coaxial and/or optical-fiber members 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 members into a group or other assembly is not specified. In a round cable consisting of 2, 3, or 4 members, the individual members shall be cabled or laid straight. In other cables, all members and groups of members 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 members are not required to be of the same dimensions or of the same materials. The mixture of center-conductor insulation, sizes, stranding, and metal and optical-fiber member materials and sizes is not specified in a cable with multiple members.

15 Overall Cable Jacket

15.1 General

15.1.1 An overall jacket is required on each unarmored single coaxial cable, on each unarmored multiple-member cable, and on each armored cable intended (see 17.1) for encasement in concrete, mortar, other masonry, plaster, or the like [see also 16.3.1, 16.4.1, and 16.5.1 – a cable jacket is not required under armor or any of the shields discussed in 9.2(b)]. The overall cable jacket shall be of one of the materials referenced in 15.3.1. 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). 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. 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 exceptions stated in Table 6.1 and 15.3.1 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. Incorporation of a nonmetallic messenger in the overall jacket is not specified. The thickness of the jacket is not specified in the area of an incorporated messenger. Elsewhere, the overall jacket shall be of the thicknesses indicated in Table 15.1 (fluoropolymer materials), in Table 15.2 (materials other than fluoropolymers), or in 15.4.1 (thicker jacket) when measured as described in Thicknesses of Jacket on Flexible Cord, Fixture Wire, and Elevator Cable in UL 2556. See Flexibility Test, 15.2; Physical Properties Tests, 15.3; and 15.3.1.

15.1.2 A jacket that is of material generically different from any jacket material referenced in 15.3.1 (new material), or that is of material referenced in 15.3.1 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 CATV cable type. The material shall be evaluated for the requested temperature rating as described in Long-Term Aging in UL 2556. Investigation of the electrical, mechanical, and physical characteristics of the cable using either material shall show the material to be comparable in performance to the jacket materials referenced in 15.3.1 through tests such as crushing, impact, abrasion, deformation, heat shock, and dielectric voltage-withstand.

15.2 Flexibility test

15.2.1 PVDF jackets and PVDF co-polymer jackets conditioned in place on coaxial and optical-fiber members, conditioned in place as binder jackets on a group or on an assembly, and conditioned in place as the overall jacket on the finished cable shall not show any cracks on the inside or outside jacket surface after the specimens are wound onto a mandrel of the 2x diameter indicated in 15.2.2. See 7.1.4 regarding flexibility testing of 125 °C (257 °F) PVDF and PVDF copolymer insulations using a mandrel diameter equal to the diameter over the insulation. A white appearance (stress whitening) of the insulation or jacket after flexing is not cause for rejection.

15.2.2 The specimens, with the jackets in place, are to be conditioned in a circulating-air oven that is a Type II oven complying with ASTM D5423 and ASTM D5474 and is maintained at the temperature and for the length of time indicated for the material in the UL 1581 table of physical properties referenced in 15.3.1 of this wire Standard (UL 1655). The conditioning is to be followed by 16 – 96 h of rest in still air at room temperature before the specimens are wound onto a mandrel. The conditioned specimens are to be wound at room temperature for six complete turns (adjacent turns touching) onto a circular mandrel having a diameter twice that of the overall cable jacket, binder jacket, coaxial-member jacket, or optical-fiber-member jacket. Each specimen is to be unwound before being examined. Circumferential depressions in the fluoropolymer surface are indicators of cracking or are yield marks (locally stronger points), so the jacket is to be removed and its inside surface examined visually. The examinations are to be made with normal or corrected vision without magnification.

15.3 Physical properties test

15.3.1 Specimens prepared from samples of jackets of materials other than 125 °C (257 °F) PVDF or PVDF co-polymer shall have values of tensile strength and ultimate elongation that comply with the applicable table of physical properties in Section 50 of UL 1581. 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 15.3.2. The limit for the cable temperature rating is 150 °C (302 °F) (see 15.1) where an insulation or jacketing material having a temperature rating higher than 150 °C (302 °F) is used in a cable having a solid copper center conductor or copper center-conductor strands that are smaller in diameter than 0.015 inch (0.38 mm) and are uncoated or are coated with a tin or tin/lead alloy. The indicated rating higher than 150 °C (302 °F) applies where, regardless of diameter, the solid conductor, tube, or strands are coated with silver [200 °C (392 °F)] or nickel [250 °C (482 °F)]. See 6.3 and 6.1.

15.3.2 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 UL 2556, with the following modifications:

a) Buffing as described in 440.3 of UL 1581 is to be used to remove wire-braid impressions and other unevenness from jackets thinner than 0.018 inch average and 0.014 inch minimum at any point or thinner than 0.46 mm average and 0.36 mm minimum at any point.

b) For jackets from cables having an overall diameter not greater than 0.200 inch (5.1 mm), tubular or die-cut specimens are to be tested. Tubular specimens are not to be prepared from jackets of larger cables.

15.4 Jacket

15.4.1 A cable on which a jacket thicker than indicated in Table 15.1 or Table 15.2 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 % of the average thickness of the heavier jacket. See the last sentence of 5.7 regarding the maximum total thickness of two overall cable jackets.

15.4.2 A jacket of thickness other than indicated in Table 15.1 or Table 15.2 is acceptable if, upon evaluation, it has been found to comply with the requirements of this standard. Evaluation of thinner jackets may include but not be limited to crush, impact and abrasion tests.

Table 15.1
Thicknesses[a] of Nonintegral Fluoropolymer Cable Jacket

Calculated[b] diameter of round assembly under jacket or Calculated[b] equivalent diameter of flat assembly under jacket		Minimum average thickness of jacket	Minimum thickness at any point of jacket
Over ... inches	But not over ... inches	Inch	Inch (0.80 x average)
0	0.250	0.008[c]	0.006[c]
0.250	0.350	0.010[c]	0.008[c]
0.350	0.500	0.013	0.010
0.500	0.700	0.015	0.012

Table 15.1 Continued on Next Page

Table 15.1 Continued

Calculated[b] diameter of round assembly under jacket or Calculated[b] equivalent diameter of flat assembly under jacket		Minimum average thickness of jacket	Minimum thickness at any point of jacket
0.700	1.500	0.020	0.016
Over ... mm	**But not over ... mm**	**mm**	**mm**
0	6.35	0.20[c]	0.15[c]
6.35	8.89	0.25[c]	0.20[c]
8.89	12.70	0.33	0.25
12.70	17.78	0.38	0.30
17.78	38.10	0.51	0.41

[a] A thicker jacket is required to enable some cables to comply with one or more tests. See 15.4.1.

[b] See 5.2 regarding the conductor diameter(s) to use in the calculation. The equivalent diameter of a flat assembly is to be calculated as 1.1284 x $(TW)^{1/2}$, in which *T* is the thickness of the assembly and *W* is the width of the assembly.

[c] A jacket that is applied directly over the wire serving, wrap, or braid mentioned in 9.2(c) (no intervening wrap or other protective covering) shall not be thinner in average thickness than 0.013 inch (0.33 mm) and shall not be thinner at any point than 0.010 inch (0.25 mm).

Table 15.2
Thicknesses[a] of Nonintegral Cable Jacket of Other Than Fluoropolymer Materials

Calculated[b] diameter of round assembly under jacket or Calculated[b] equivalent diameter of flat assembly under jacket		Jacket whose tensile strength is less than 2500 lbf/in^2 or 17.21 MN/m^2 or 1724 N/cm^2 or 1.76 kgf/mm^2				Jacket whose tensile strength is at least 2500 lbf/in^2 or 17.21 MN/m^2 or 1724 N/cm^2 or 1.76 kgf/mm^2	
		PVC		Other material			
		Minimum average thickness of jacket	Minimum thickness at any point of jacket	Minimum average thickness of jacket	Minimum thickness at any point of jacket	Minimum average thickness of jacket	Minimum thickness at any point of jacket
Over .... inches	**But not over .... inches**	**inch**	**inch (0.80 x average)**	**inch**	**inch (0.80 x average)**	**inch**	**inch (0.80 x average)**
0	0.350	0.023	0.018	0.030	0.024	0.013	0.010
0.350	0.400	0.027	0.022	0.030	0.024	0.018	0.014
0.400	0.700	0.032	0.026	0.030	0.024	0.018	0.014
0.700	1.000	0.045	0.036	0.045	0.036	0.030	0.024
1.000	1.500	0.045	0.036	0.060	0.048	0.030	0.024
1.500	1.800	0.060	0.048	0.075	0.060	0.045	0.036
Over .... mm	**But not over .... mm**	**mm**	**mm**	**mm**	**mm**	**mm**	**mm**
0	8.89	0.58	0.46	0.76	0.61	0.33	0.25
8.89	10.16	0.69	0.56	0.76	0.61	0.46	0.36
10.16	17.78	0.81	0.66	0.76	0.61	0.46	0.36
17.78	25.40	1.14	0.91	1.14	0.91	0.76	0.61
25.40	38.10	1.14	0.91	1.52	1.22	0.76	0.61
38.10	45.72	1.52	1.22	1.90	1.52	1.14	0.91

[a] A thicker jacket is required to enable some cables to comply with one or more tests. See 15.4.1.

[b] See 5.2 regarding the conductor diameter(s) to use in the calculation. The equivalent diameter of a flat assembly is to be calculated as 1.1284 x $(TW)^{1/2}$, in which *T* is the thickness of the assembly and *W* is the width of the assembly.

16 Metal Covering (Armor)

16.1 General

16.1.1 Where used on a flat or round cable, 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 30; Tension Test of Interlocked Steel or Aluminum Armor, Section 31; and Flexibility Test of Cable Having Interlocked Armor or a Smooth or Corrugated Metal Sheath, Section 32. Any armor used shall be as follows:

a) A smooth metal sheath shall comply with 16.1.3 and with Smooth Metal Sheath, 16.2.

b) A welded and corrugated metal sheath shall comply with 16.1.3, 16.1.4, and with Welded and Corrugated Metal Sheath, 16.3.

c) An extruded and corrugated metal sheath shall comply with 16.1.3, 16.1.4, and with Extruded and Corrugated Metal Sheath, 16.4.

d) Interlocked metal armor shall comply with 16.1.3 and with Interlocked Armor, 16.5.

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

16.1.3 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 the like. Splicing of the strip from which interlocked armor is formed shall not include any cut or broken ends (see 16.5.3).

16.1.4 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.

16.2 Smooth metal sheath

16.2.1 A smooth metal sheath shall be of an aluminum-base alloy having a copper content of 0.40 % or less. The sheath shall be tightly formed around the underlying cable. Smooth metal shields are covered in 9.2(b).

16.2.2 The average thickness and the minimum thickness at any point of the smooth sheath shall not be less than indicated in Table 16.1. 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 (0.01 mm). The spindle shall be round.

16.2.3 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.

Table 16.1
Thicknesses[a] of Smooth Aluminum Sheath

Calculated[b] diameter of round assembly under sheath or Calculated[b] equivalent diameter of flat assembly under sheath		Minimum average	Minimum at any point
Over ... inches	**But not over ... inches**	**Inch**	**Inch (0.90 x 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	33.02	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] Lesser thicknesses are to be based on compliance of the sheath with the performance requirements in the requirements for metal-clad cables (UL 1569).

[b] See 5.2 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.

16.3 Welded and corrugated metal sheath

16.3.1 A welded and corrugated metal sheath shall be of an aluminum-base alloy having a copper content of 0.40 % or less of bronze or of electrolytic copper. The sheath shall be tightly formed around the underlying cable and shall be welded and corrugated. Stripping and replacement of a noncomplying sheath are covered in 16.2.3. Corrugated metal shields are covered in 9.2(b).

16.3.2 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 indicated in Table 16.3. 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 (5.1 mm) in diameter, with flat surfaces on each.

16.4 Extruded and corrugated metal sheath

16.4.1 An extruded and corrugated metal sheath shall be of an aluminum-base alloy having a copper content of 0.40 % or less. The sheath shall be tightly formed around the underlying cable. Stripping and replacement of a noncomplying sheath are covered in 16.2.3. Corrugated metal shields are covered in 9.2(b).

16.4.2 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 indicated in Table 16.3 when determined as indicated in 16.2.2.

16.5 Interlocked armor

16.5.1 Interlocked steel or aluminum strip shall comply with 16.1.3 and 16.5.2 – 16.5.8. Dimensions of the metal strip shall comply with 16.5.9. Interlocked metal shields are covered in 9.2(b). The strip shall be tightly formed around the underlying cable.

16.5.2 The strip shall be made of steel or of an aluminum-base alloy with a copper content of 0.40 % 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.

16.5.3 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 materially increase the width or thickness of the strip nor shall they lessen the mechanical strength of the strip or adversely affect the formed armor.

16.5.4 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.

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

16.5.6 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 (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.

16.5.7 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.

16.5.8 Unformed and formed zinc-coated steel strip shall comply with the Copper Sulphate Test on Steel Strip for and from Interlocked Steel Armor, Section 30.

16.5.9 The width of unformed aluminum strip or of unformed zinc-coated steel strip shall not be greater than indicated in Table 16.2. The minimum thickness at any point of the formed metal strip removed from the finished cable shall not be less than indicated in Table 16.2 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 (5.1 mm) in diameter, with flat surfaces on each.

Table 16.2
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	19.0	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 5.2 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.

[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.

Table 16.3
Minimum Thickness at any Point of Unformed Metal Tape from which Corrugated Sheath is Welded or Extruded

Metal	Calculated diameter under sheath		Thickness of unformed metal tape	
	inches	mm	mils	mm
Aluminum	0 – 2.180	0 – 55	22	0.56
	Over 2.180 but not over 3.190	Over 55 but not over 81	29	0.74
	Over 3.190 but not over 4.200	Over 81 but not over 107	34	0.87
Bronze or electrolytic copper	0 – 2.365	0 – 60	17	0.43
	Over 2.365 but not over 3.545	Over 60 but not over 90	21	0.53
	Over 3.545 but not over 4.200	Over 90 but not over 107	25	0.64

[a] The insulation thickness used in calculating the diameter is to be the specified average insulation thickness where an average is specified and is to be the specified minimum thickness at any point of the insulation where an average thickness is not specified.

[b] Thicknesses that are less than indicated in this table may be accepted based on performance of the sheath under the requirements for metal-clad cables in UL 1569.

17 Jacket over Armor

17.1 A jacket is required over any armor on a cable intended for burial directly in the earth. A jacket is required over the armor on each cable intended for encasement in concrete, mortar, other masonry, plaster, or the like. A jacket is not required over armor on other cables. A jacket over armor shall comply with Overall Cable Jacket, Section 15. The same calculated (see 5.2) 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.

18 Metallic Messenger

18.1 A metallic messenger may be joined to the outermost jacket by the means of a web. The jacket thickness over the messenger and between the messenger and the cable core is not specified provided that the required jacket thickness over the conductors is not reduced.

MANUFACTURING AND PRODUCTION TESTS

19 Production Line Testing (Spark and Dielectric)

19.1 Alternative spark and dielectric voltage-withstand tests of all coaxial members

19.1.1 Choice of test by the manufacturer

19.1.1.1 The insulation in each coaxial member of all cable types shall comply with either the spark test described in 19.1.2.1 or the dielectric voltage-withstand test described in 19.1.3.1 and 19.1.3.2. The cable manufacturer shall make the choice and shall test 100 % of production at the cable factory. Every coaxial member shall be completely discharged at the conclusion of each test.

19.1.2 Spark test of members before cable assembly

19.1.2.1 The spark-test alternative is to be either a d-c spark test at 2500 V or an a-c rms spark test at a 48 – 62 Hz near-sinusoidal potential of 1750 V. Each coaxial member is to be tested after it is insulated and before the outer conductor is applied. The test equipment and method are to be as described in Spark Test, in UL 2556. A coaxial member does not comply where there are any faults.

19.1.3 Dielectric voltage-withstand test of members after cable assembly

19.1.3.1 The dielectric voltage-withstand test alternative is to be either a d-c potential of 2500 V applied for at least 2 seconds or a 48 – 62 Hz near-sinusoidal potential of 1500 V applied for at least 2 seconds. The insulation in each coaxial member in every length of cable produced shall withstand the test potential without breakdown when the potential is applied between each center conductor taken separately and all other center conductors, outer conductors, any shields, 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, in UL 2556. The equipment is to apply the test potential automatically for each 2-second test. The test potential is to be applied manually for longer than 2 seconds. In all cases, the full test potential is to be applied throughout the entire 2-seconds or longer test interval.

19.1.3.2 The test is to be conducted in one of the following ways on 100 % 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. Where there is a dielectric breakdown of the insulation in any coaxial member in the shipping length, 100 % of the finished cable on the master reel from which the test length was taken is to be tested.

PERFORMANCE

20 Continuity Test of Center and Outer Conductors and Shields

20.1 Finished cable shall be tested for continuity of the center and outer conductors in each coaxial member and for continuity of each shield. This continuity test shall be conducted before the voltage test is performed as described in Alternative Spark and Dielectric Voltage-Withstand Tests of All Coaxial Members, Section 19.1. The continuity test is to be conducted in one of the following ways on 100 % 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 center or outer conductor or any shield that the shipping length found not to be continuous, 100 % of the finished cable on the master reel from which the test length was taken is to be tested.

20.2 To determine whether or not the finished cable complies with the continuity requirement in 5.6 or 9.1, each center conductor, outer 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.

21 D-C Resistance Test of Center Conductors

21.1 Requirements

21.1.1 The direct-current resistance of any length of metal-coated or uncoated copper, copper-clad steel, and copper-clad aluminum center 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 5.3) in the applicable Table 21.1 (solid coated copper, uncoated copper, and copper-clad aluminum conductors), Table 21.2 (solid copper-clad steel conductors), or Table 21.3 (stranded coated and uncoated copper conductors) when measured at or adjusted to a temperature of 20 °C (68 °F) or 25 °C (77 °F). The direct current resistance shall be measured as described in UL 2556. The direct-current resistance of each center conductor in a finished cable with multiple coaxial members shall not exceed the single-conductor value in the applicable Table 21.1, Table 21.2, or Table 21.3 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 21.1
Maximum Direct-Current Resistance of Solid Center Conductors of Copper-Clad Aluminum and Coated and Uncoated Copper

AWG size of conductor	20 °C						25 °C					
	Copper-clad aluminum		Uncoated copper		Coated copper		Copper-clad aluminum		Uncoated copper		Coated copper	
	Ohms per 1000 ft[d]	(Ohms per km)	Ohms per 1000 ft[a]	(Ohms per km)	Ohms per 1000 ft[b]	(Ohms per km)	Ohms per 1000 ft[e]	(Ohms per km)	Ohms per 1000 ft[a]	(Ohms per km)	Ohms per 1000 ft[b]	(Ohms per km)
30	–	–	114[c]	(374)[c]	119[c]	(390)[c]	–	–	117[c]	(384)[c]	121[c]	(397)[c]
29	–	–	89.3[c]	(293)[c]	92.9[c]	(305)[c]	–	–	91.1[c]	(299)[c]	94.7[c]	(311)[c]
28	–	–	71.8[c]	(236)[c]	74.7[c]	(245)[c]	–	–	73.3[c]	(240)[c]	76.2[c]	(250)[c]
27	–	–	56.5[c]	(185)[c]	58.8[c]	(193)[c]	–	–	57.6[c]	(189)[c]	59.9[c]	(197)[c]
26	–	–	45.1[c]	(148)[c]	46.9[c]	(154)[c]	–	–	46.0[c]	(151)[c]	47.8[c]	(157)[c]
25	–	–	35.6[c]	(117)[c]	37.0[c]	(121)[c]	–	–	36.3[c]	(119)[c]	37.7[c]	(124)[c]
24	–	–	28.6[c]	(93.8)[c]	31.5[c]	(103)[c]	–	–	29.2[c]	(95.8)[c]	32.1	(105)[c]
23	–	–	22.3[c]	(73.2)[c]	23.2[c]	(76.1)[c]	–	–	22.7	(74.5)	23.7[c]	(77.8)[c]
22	–	–	18.0[c]	(59.1)[c]	19.8[c]	(65.0)[c]	–	–	18.4[c]	(60.4)[c]	20.2[c]	(66.3)[c]
21	–	–	14.1[c]	(46.3)[c]	14.7[c]	(48.2)[c]	–	–	14.4[c]	(47.2)[c]	15.0[c]	(49.2)[c]
20	–	–	11.1[c]	(36.4)[c]	11.6[c]	(38.1)[c]	–	–	11.3[c]	(37.1)[c]	11.8[c]	(38.7)[c]
19	–	–	8.86[c]	(29.1)[c]	9.21[c]	(30.2)[c]	–	–	9.04[c]	(29.7)[c]	9.39[c]	(30.8)[c]
18	–	–	6.52	(21.4)	6.78	(22.2)	–	–	6.64	(21.8)	6.91	(22.7)
17	–	–	5.15	(16.9)	5.36	(17.6)	–	–	5.25	(17.2)	5.46	(17.9)
16	–	–	4.10	(13.5)	4.26	(14.0)	–	–	4.18	(13.7)	4.35	(14.3)
15	–	–	3.24	(10.6)	3.37	(11.1)	–	–	3.30	(10.8)	3.43	(11.3)
14	–	–	2.57	(8.45)	2.68	(8.78)	–	–	2.62	(8.61)	2.72	(8.96)
13	–	–	2.04	(6.69)	2.12	(6.96)	–	–	2.08	(6.82)	2.16	(7.09)
12	2.65	(8.71)	1.62	(5.31)	1.68	(5.53)	2.71	(8.89)	1.65	(5.42)	1.71	(5.64)
11	2.11	(6.92)	1.29	(4.22)	1.34	(4.37)	2.15	(7.06)	1.32	(4.30)	1.37	(4.48)
10	1.670	(5.479)	1.019	(3.343)	1.06	(3.48)	1.703	(5.590)	1.038	(3.408)	1.08	(3.55)
9	1.325	(4.347)	0.8084	(2.652)	0.8319	(2.730)	1.352	(4.435)	0.8242	(2.704)	0.8483	(2.784)
8	1.051	(3.446)	0.6407	(2.102)	0.6594	(2.163)	1.071	(3.515)	0.6532	(2.143)	0.6724	(2.206)
7	0.8328	(2.733)	0.5081	(1.667)	0.5229	(1.716)	0.8497	(2.788)	0.5181	(1.699)	0.5332	(1.749)
6	0.6609	(2.168)	0.4031	(1.323)	0.4148	(1.361)	0.6741	(2.211)	0.4110	(1.348)	0.4230	(1.388)

Table 21.1 Continued on Next Page

Table 21.1 Continued

AWG size of conductor	20 °C						25 °C					
	Copper-clad aluminum		Uncoated copper		Coated copper		Copper-clad aluminum		Uncoated copper		Coated copper	
	Ohms per 1000 ft[d]	(Ohms per km)	Ohms per 1000 ft[a]	(Ohms per km)	Ohms per 1000 ft[b]	(Ohms per km)	Ohms per 1000 ft[e]	(Ohms per km)	Ohms per 1000 ft[a]	(Ohms per km)	Ohms per 1000 ft[b]	(Ohms per km)
5	0.5242	(1.720)	0.3197	(1.049)	0.3291	(1.079)	0.5361	(1.754)	0.3260	(1.070)	0.3356	(1.101)
4	0.4155	(1.363)	0.2535	(0.8315)	0.2608	(0.8559)	0.4239	(1.390)	0.2585	(0.8478)	0.2660	(0.8727)
3	0.3296	(1.081)	0.2010	(0.6595)	0.2069	(0.6788)	0.3362	(1.103)	0.2050	(0.6725)	0.2109	(0.6922)
2	0.2613	(0.8574)	0.1594	(0.5231)	0.1641	(0.5384)	0.2666	(0.8747)	0.1626	(0.5333)	0.1673	(0.5489)
1	0.2073	(0.6798)	0.1264	(0.4146)	0.1300	(0.4268)	0.2113	(0.6935)	0.1289	(0.4228)	0.1326	(0.4352)

[a] 1.02 x nominal except where note [c] applies.

[b] 1.06 x nominal except where note [c] applies.

[c] Maximum resistance (1.1 x nominal) for this size of a reduced-diameter solid conductor. See corresponding diameter (0.95 x nominal) in Table 5.1.

[d] 1.02 x nominal.

[e] 1.06 x nominal.

Table 21.2
Maximum Direct-Current Resistance of Solid Hard-Drawn 21-Percent-Conductivity Copper-Clad-Steel Center Conductors

AWG size of conductor	20 °C		25 °C	
	Ohms per 1000 feet[a]	(Ohms per kilometer)	Ohms per 1000 feet[a]	(Ohms per kilometer)
30	493.900	(1620.485)	493.919	(1620.482)
29	385.859	(1266.003)	387.878	(1272.628)
28	310.629	(1019.174)	310.648	(1019.236)
27	244.505	(802.221)	244.524	(802.283)
26	195.217	(640.507)	195.236	(640.569)
25	154.344	(506.403)	154.363	(506.465)
24	122.252	(401.109)	122.271	(401.171)
23	96.654	(317.122)	96.673	(317.184)
22	77.172	(253.201)	77.191	(253.264)
21	60.825	(199.567)	60.844	(199.629)
20	48.232	(158.249)	48.251	(158.312)
19	38.316	(125.715)	38.339	(125.790)
18	30.412	(99.782)	30.431	(99.844)
17	24.096	(79.059)	24.115	(79.121)
16	19.143	(62.808)	19.162	(62.871)
15	15.150	(49.707)	15.169	(49.769)
14	12.022	(39.444)	12.041	(39.506)
13	9.527	(31.258)	9.546	(31.320)
12	7.656	(25.119)	7.484	(24.555)
11	6.004	(19.699)	6.023	(19.761)
10	4.756	(15.604)	4.775	(15.667)
9	3.774	(12.382)	3.793	(12.445)
8	2.991	(9.813)	3.010	(9.876)
7	2.372	(7.783)	2.391	(7.845)
6	1.882	(6.175)	1.901	(6.237)

[a] The values in these columns are based on information in ASTM B566. The method of calculation is now described in Section 7 "Resistance" of ASTM B869.

Table 21.3
Maximum Direct-Current Resistance of Coated and Uncoated Stranded Copper Center Conductors

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)
30 AWG	108	(354)	110	(361)	112	(367)	114	(374)
29	84.3	(277)	86.0	(282)	87.7	(288)	89.4	(293)
28	67.9	(223)	69.3	(227)	70.7	(232)	72.0	(236)
27	53.4	(175)	54.5	(179)	55.6	(182)	56.6	(186)

Table 21.3 Continued on Next Page

Table 21.3 Continued

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)
26	42.7	(140)	43.6	(143)	44.4	(145)	45.2	(148)
25	33.7	(111)	34.4	(113)	35.0	(115)	35.7	(117)
24	26.7	(87.6)	27.2	(89.2)	27.7	(90.9)	28.4	(93.2)
23	21.1	(69.2)	21.5	(70.5)	21.9	(71.9)	22.3	(73.2)
22	16.9	(55.4)	17.2	(56.4)	17.5	(57.4)	17.9	(58.7)
21	13.3	(43.6)	13.6	(44.6)	13.9	(45.6)	14.1	(46.3)
20	10.5	(34.4)	10.7	(33.1)	10.9	(35.8)	11.1	(36.4)
19	8.39	(27.5)	8.66	(28.4)	8.71	(28.8)	8.87	(29.1)
18	6.66	(21.9)	6.79	(22.3)	6.92	(22.7)	7.04	(23.1)
17	5.29	(17.4)	5.40	(17.7)	5.47	(17.9)	5.57	(18.3)
16	4.19	(13.7)	4.27	(14.0)	4.35	(14.3)	4.44	(14.6)
15	3.30	(10.8)	3.37	(11.1)	3.44	(11.3)	3.50	(11.5)
14	2.62	(8.60)	2.67	(8.76)	2.73	(8.96)	2.77	(9.09)
13	2.08	(6.82)	2.12	(6.96)	2.16	(7.09)	2.20	(7.22)
12	1.65	(5.41)	1.68	(5.51)	1.71	(5.61)	1.74	(5.71)
11	1.32	(4.33)	1.35	(4.43)	1.37	(4.49)	1.40	(4.59)
10	1.039	(3.409)	1.060	(3.476)	1.080	(3.546)	1.102	(3.615)
9	0.8245	(2.705)	0.8407	(2.758)	0.8574	(2.813)	0.8742	(2.868)
8	0.6535	(2.144)	0.6643	(2.186)	0.6795	(2.230)	0.6929	(2.274)
7	0.5182	(1.700)	0.5284	(1.734)	0.5389	(1.768)	0.5495	(1.802)
6	0.4112	(1.328)	0.4192	(1.375)	0.4276	(1.403)	0.4359	(1.430)
5	0.3261	(1.070)	0.3325	(1.091)	0.3392	(1.113)	0.3458	(1.134)
4	0.2585	(0.8481)	0.2636	(0.8649)	0.2689	(0.8820)	0.2742	(0.8993)
3	0.2050	(0.6727)	0.2091	(0.6860)	0.2132	(0.6996)	0.2175	(0.7133)
2	0.1626	(0.5335)	0.1659	(0.5440)	0.1691	(0.5548)	0.1724	(0.5657)
1	0.1289	(0.4230)	0.1315	(0.4313)	0.1340	(0.4398)	0.1367	(0.4485)
1/0	0.1022	(0.3354)	0.1042	(0.3419)	0.1063	(0.3487)	0.1084	(0.3556)
2/0	0.08108	(0.2660)	0.08267	(0.2712)	0.08432	(0.2766)	0.08598	(0.2820)
3/0	0.06431	(0.2110)	0.06558	(0.2151)	0.06688	(0.2194)	0.06820	(0.2238)
4/0	0.05099	(0.1673)	0.05200	(0.1705)	0.05248	(0.1722)	0.05352	(0.1755)
250 kcmil	0.04316	(0.1416)	0.04401	(0.1444)	0.04488	(0.1473)	0.04577	(0.1501)
300	0.03597	(0.1180)	0.03667	(0.1204)	0.03740	(0.1227)	0.03814	(0.1252)
350	0.03082	(0.1011)	0.03144	(0.1031)	0.03206	(0.1052)	0.03270	(0.1072)
400	0.02698	(0.08851)	0.02751	(0.09024)	0.02776	(0.09109)	0.02831	(0.09288)
450	0.02398	(0.07867)	0.02445	(0.08021)	0.02467	(0.08097)	0.02516	(0.08256)
500	0.02158	(0.07080)	0.02200	(0.07220)	0.02222	(0.07287)	0.02264	(0.07431)

[a] 1.04 x nominal

[b] 1.08 x nominal

22 Cold Bend Test of the Complete Cable

22.1 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 22.2 and 22.3. See 36.1 (j) and (k) regarding marking or not marking the cable with its low-temperature rating.

22.2 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). Tolerances 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 cable diameter in the case of a round cable that is without armor and contains the specific metal sheath (shield) described in 9.2 or, for all other cables, equal to 12 times the calculated diameter of a round cable or 12 times the equivalent diameter of a flat cable. The equivalent diameter of a flat cable is to be calculated as 1.1284 × $(TW)^{1/2}$, 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 seconds per turn, and the time taken to remove a specimen from the cold chamber and complete the winding is not to exceed 30 seconds. As an alternative, the test is to be performed in the cold chamber.

22.3 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 hours 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 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 flouropolymer surface is to be examined visually. Where the first test length has any of these 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.

23 Smoke and Flame Testing of Plenum Cables

23.1 Type CATVP and CATVP-OF cables shall comply with the flame-propagation and smoke-density limits stated in 1.11 when specimens are tested in sets in accordance with 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. Where the flame-propagation distance and/or the optical densities exceed the limits specified in NFPA 262 and repeated in 1.11(a) 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 26.2.1 and 26.2.2 regarding shields and regarding construction changes that trigger repeat testing.

24 Flame Testing of Riser Cables

24.1 Cables with the metal covering described in Metal Covering (Armor), Section 16, and without the jacket described in Jacket over Armor, Section 17, comply with the requirements in 24.1 and are not required to be tested.

24.2 Jacketed Type CATVR and CATVR-OF cables shall comply with the limits stated in 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. The test specimens that represent a given construction typically, are the physically smallest and largest diameters to be produced in that construction. Where the flame-propagation distance and/or the temperature exceed the limits specified in UL 1666 and repeated in 1.11(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 26.2.1 and 26.2.2 regarding shields and regarding construction changes that trigger repeat testing.

25 VW-1 (Vertical-Specimen) Flame Test of Limited-Use Cables

25.1 Type CATVX and CATVX-OF cables shall not convey flame vertically along their length or to combustible materials in their vicinity when specimens are tested vertically as described in VW-1 (Vertical-Specimen) Flame Test, UL 2556 [see 1.11(d)]. 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. For round cable, the test specimens that represent a given construction typically are the smallest and largest diameters to be produced in that construction. For flat cable, the test specimens that represent a given construction typically are selected from the widths to be produced in that construction. Where one or more of the three reasons for noncompliance occur as stated in UL 2556 for any cable specimen tested, compliance in tests of additional specimens is required to qualify the full size range desired by the manufacturer. See 26.2.1 and 26.2.2 regarding shields and regarding construction changes that trigger repeat testing. These cables are not marked "VW-1".

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

26.1 Choice of test by the manufacturer

26.1.1 Cables with the metal covering described in Metal Covering (Armor), Section 16, and without the jacket described in Jacket over Armor, Section 17, comply with the requirements in 26.3 and 26.4 and are not required to be tested.

26.1.2 The manufacturer of Type CATV and CATV-OF cables shall specify either the test described in UL Test, 26.3, or the test described in FT4/IEEE 1202 Test, 26.4, for each construction of that manufacturer's cables. The same test is not required for all constructions. See 1.11(c).

26.2 Changes in construction

26.2.1 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.

26.2.2 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.

26.3 UL test

26.3.1 Type CATV and CATV-OF cables shall not exhibit char (as defined in UL 1685) that equals or exceeds a height of 8 feet, 0 inches (244 cm) when sets of cable specimens as described in 26.3.2 are separately installed in a vertical ladder type of cable tray and are subjected to 20 minutes of flame as described under UL Flame Exposure (smoke measurements are not applicable) in UL 1685 or UL 2556. 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 26.3.2). See 26.2.1 and 26.2.2 regarding shields and regarding construction changes that trigger repeat testing.

26.3.2 For any construction of a round or flat cable containing a total of 50 or fewer members, the test specimens typically are two sets each of the smallest and largest diameters of finished cable that the manufacturer intends to produce in the construction represented. Where the round or flat cable contains a total of more than 50 members, the test specimens typically are two sets each of the smallest, largest, and one or more mid-range diameters. The number of cable lengths in a set of specimens is to be determined as indicated in UL 1685. In any case, a tested size does not comply where damage to the insulation and/or the overall cable jacket reaches the upper end of any individual cable test length in any set of specimens tested.

26.4 FT4/IEEE 1202 test

26.4.1 Type CATV and CATV-OF cables shall not exhibit char (as defined in UL 1685) that equals or exceeds a height of 1.5 m (4 feet, 11 inches) when sets of specimens are tested as described under FT4/IEEE 1202 Type of Flame Exposure (smoke measurements are not applicable) in UL 1685 or UL 2556. 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 26.3.2 and, for evaluation of results, substitute the following sentence of this paragraph for the final sentence of 26.3.2. Where the cable damage height equals or exceeds 1.5 m (4 feet, 11 inches) measured upward from the lower edge of the burner face for any individual cable in any set of specimens tested, compliance of additional sets of specimens is required to qualify the full size range desired by the manufacturer. See 26.2.1 and 26.2.2 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 36, and Information on the Tag, Reel, or Carton, Section 37.

27 Sunlight-Resistance Test

27.1 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 36.1(f) 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, described in UL 2556, using 720 hours of xenon-arc conditioning.

28 Crushing Resistance Test of Center-Conductor Insulation

28.1 An average of at least 300 lbf or 1334 N or 136 kgf shall be required for crushing solid or foamed insulation in a coaxial member taken from finished cable to the point that the center conductor contacts the earth-grounded metal of the testing machine or, for air-gap insulation, for contact to be made between the inner and outer conductors. The test is to be made on a coaxial member as described in 28.3 – 28.5, with the results qualifying both solid, stranded, or tubular center conductors having the same form of insulation (solid, foamed, or air gap) of the same material in the same thicknesses. See 28.2.

28.2 Solid insulation that is at least 0.006 inch (0.15 mm) in average thickness (including any skin) and of a material having a tensile strength (unaged specimens) of at least 2000 lbf/in^2 or 13.79 MN/m^2 or 1379 N/cm^2 or 1.41 kgf/mm^2 has a crushing strength that complies without this test. Foamed insulation of the following or greater thickness has a crushing strength that complies without this test:

a) 0.007 inch (0.18 mm) in average thickness, including a skin of at least 0.002 in or 0.05 mm.

b) 0.010 inch (0.25 mm) in average thickness without any skin.

28.3 The coaxial members are to be removed from a length of the finished cable and one member in which the center conductor is solid is to be selected and its outer conductor and any jacket are to be removed without damaging the solid or foamed insulation or any skin over the insulation. The insulated center conductor that remains is to be straightened with the fingers. Any jacket is to be removed from air-gap cable without removing the outer conductor. Five specimens 7 inches (180 mm) long are to be cut from the straight insulated conductor. Each specimen is to be tested separately by being crushed twice between 2-inches-wide (50-mm-wide), flat, horizontal steel plates in a compression machine whose jaws close at the rate of 0.20 ±0.02 in/min (5.0 ±0.5 mm/min). The edges of the plates are not to be sharp. The length of a specimen is to be parallel to the 2-inch (50-mm) dimension of the plates, 1 inch (25 mm) of the specimen is to extend outside the plates at one end of the specimen, and 4 inches (100 mm) of the specimen is to extend outside the plates at the other end of the specimen.

28.4 The plates are to be connected together, to the metal of the testing machine, and to earth ground. The specimens, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 24.0 ±8.0 °C (75.2 ±14.4 °F) throughout the test. The machine is to be started and the specimen is to be subjected to the increasing force of the plates moving toward one another until a short circuit occurs [as indicated by a low-voltage (less than 30 V) indicator such as a buzzer, lamp, or LED] between the conductor in the specimen and one or both of the earth-grounded plates. The maximum force exerted on the specimen before the short circuit occurs is to be recorded as the crushing force for that end of the specimen.

28.5 After the short circuit occurs, the machine is to be reversed and the plates separated. The specimen is to be turned end for end, rotated 90°, reinserted (from the end opposite the one originally inserted) between the plates as described in 28.3, and crushed as described in 28.4. The two crushing forces are to be averaged for each specimen. The average of all ten of the crushing forces obtained for the five specimens is to be used as the value to compare with the requirement.

29 Crushing Test of Cable Marked for Direct Burial

29.1 Finished cable (any cable other than Type CATVX or Type CATVX-OF is eligible) that is marked as indicated in 36.1(e) 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 in any coaxial member, 1000 lbf or 4448 N or 454 kgf applied for 60 seconds 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 coaxial members of the same size or the same or a larger number of coaxial members of a larger size. The performance of the cabled coaxial members in a round cable is to be taken as representative of the performance of those coaxial 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 (10 ±1 mm/min). Each plate is to be 2 inches (50 mm) wide. A solid steel rod 3/4 inch (19 mm) in diameter and of a length equal to at least 6 inches (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 (915 mm), with the cable being crushed at three points along that length. The points at which the cable is to be crushed are to be measured and marked with chalk or another innocuous means on the test length before the test is begun. The first mark is to be placed 9 inches (230 mm) from one end of the test length and the two remaining marks are to be made at succeeding intervals of 9 inches (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 uppersteel 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 (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 seconds 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 (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 in each coaxial member 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 in any of the coaxial members 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 Copper Sulphate Test of Zinc Coating on Steel Strip for and from Interlocked Steel Armor

30.1 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 second 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 second immersion in a specified solution of copper sulphate, and

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

30.2 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.