UL 2250

STANDARD FOR SAFETY

Instrumentation Tray Cable

UL Standard for Safety for Instrumentation Tray Cable, UL 2250

Third Edition, Dated March 30, 2017

SUMMARY OF TOPICS

This revision of ANSI/UL 2250 dated June 12, 2025 includes ITC-ER References to the National Electrical Code (NEC); 1.1 and 43.1(g)

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

The revised requirements are substantially in accordance with Proposal(s) on this subject dated April 25, 2025.

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UL 2250

Standard for Instrumentation Tray Cable

First Edition – December, 1996
Second Edition – April, 2006

Third Edition

March 30, 2017

This ANSI/UL Standard for Safety consists of the Third Edition including revisions through June 12, 2025.

The most recent designation of ANSI/UL 2250 as an American National Standard (ANSI) occurred on June 12, 2025. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover Type ITC instrumentation control cables consisting of two or more current-carrying copper or thermocouple alloy conductors with or without either or both:

a) Grounding conductor(s), bare or insulated, and

b) One or more optical-fiber members, all under an overall jacket.

These electrical and composite electrical/optical-fiber cables are intended for use (optical and electrical functions associated in the case of a hybrid cable) on circuits rated 150 V or less and 5 A or less in accordance with Article 335 and other applicable parts of the National Electrical Code (NEC).

1.2 These cables are rated 300 V but are not so marked. Cables for direct-burial are so marked. Jacketed Type ITC cables comply with one of the following 70,000 Btu/h (20.5 kW) vertical-tray flame tests:

a) The UL test referenced in 35.2.1 – 35.2.2 of these requirements. 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.

b) The FT4/IEEE 1202 test referenced in 35.3.1 of these requirements. This paragraph applies the test method described as the FT4/IEEE 1202 Type of Flame Exposure (smoke measurements are not applicable) in UL 1685.

c) For limited-smoke cable, either the UL test or the FT4/IEEE 1202 test referenced in 35.4.1 and 35.4.2 of these requirements. These paragraphs apply the test methods described in UL 1685 with smoke measurements included.

1.3 A cable that contains one or more electromagnetic shields may be surface marked or have a marker tape to indicate that it is "shielded". A cable that contains one or more optical-fiber members has "-OF" supplementing the type letters and is limited (see 14.3) to carrying optical energy that has been ruled not hazardous to the human body.

1.4 All Type ITC cables qualify for exposure to sunlight (a 720-hour sunlight-resistance test is required – see 29.1). A marking is not required; however, where used, the marking consists of "sun res" or "sunlight resistant" on the tag and either on the overall cable jacket or legible through the jacket [see 42.1(i)].

1.5 These cables may have a metal sheath or armor over the required non/metallic jacket.

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

1.7 The overall jacket on Type ITC cable is a "gas/vaportight continuous sheath" in the sense discussed in Sections 501.15 (D) and 501.15 (E) of the National Electrical Code, ANSI/NFPA 70, (see 16.1.1).

1.8 Cables that are surface marked "-ER" are for use as exposed runs of not more than 50 ft (15.2 m) between a cable tray and equipment where the cables are supported and secured every 6 ft (1.8 m).

2 Units of Measurement

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

3 References

3.1 Wherever the designation "UL 1581" is used in this Standard, reference is to be made to the designated part(s) of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

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 Instrumentation tray cable shall comply in all respects with the applicable requirements for construction details, test performance, and markings.

5 Conductors

5.1 The conductors shall be of soft-annealed copper or thermocouple alloy. Soft-annealed copper shall comply with ASTM B3. A metal coating that is provided on soft-annealed copper, in compliance with Section 8 shall be of tin complying with ASTM B33, of a tin/lead alloy complying with ASTM B189, of nickel complying with ASTM B355, of silver complying with ASTM B298 or of another metal or alloy (evaluation required). Thermocouple alloys are not specified.

5.2 Each conductor shall be continuous throughout the entire length of the finished cable – see test in 19.1 and 19.2.

6 Size, Temper, and Assembly

6.1 Conductors shall be solid or stranded 22 – 12 AWG copper or solid size 22 – 12 AWG thermocouple alloy. The sizes of thermocouple-extension wire are nominal and are intended only for use in the cable marking that is described in 42.1(g). The conductor in a thermocouple-extension wire is not required to comply with a diameter or resistance value.

7 Conductor Diameter and Cross-Sectional Area

7.1 The diameter of a solid conductor shall not be smaller than indicated in Table 20.1 of UL 1581 when determined as described in 200.1 and 200.2 of UL 1581. The cross-sectional area of a stranded conductor shall not be smaller than indicated in the 0.98X nominal column Table 20.1 of UL 1581 when determined as required in 7.2.

7.2 The cross-sectional area of a stranded conductor is to be determined either:

a) As the sum of the areas of its component strands, or

b) By the weight method outlined in 210.1 – 210.4 of UL 1581.

8 Metal Coating

8.1 If the insulation adjacent to a conductor is of a material that corrodes unprotected copper in the test in 500.1 of UL 1581, and if a protective separator is not provided, the solid conductor and each of the individual strands of a stranded conductor shall be separately covered with a metal or alloy coating complying with 5.1 as applicable to the finished wire type.

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

8.3 The maximum temperature rating of the cable is not specified relative to the diameter of copper wires used in the serving, wrap, or braid shielding described in 15.5.2(b). Otherwise, copper strands and solid copper conductors shall not be used in a cable with a temperature rating higher than indicated in Table 8.1.

Table 8.1
Maximum temperature rating of cable relative to diameter and coating of solid copper conductor or of copper conductor strands

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

9 Separator

9.1 A separator is acceptable between the conductor and the insulation of a solid or stranded wire or cable, but is not required. A separator shall be insulating but shall not be considered to be part of the required insulation.

9.2 A separator used between a conductor and insulation shall be colored or shall be opaque to make the separator clearly distinguishable from the conductor once the insulation is removed. The color shall be other than green or green and yellow and may be solid, striped, or in some other pattern.

10 Joints

10.1 A joint in a solid conductor or in one of the individual wires of a stranded conductor shall be made in a workmanlike manner, shall be essentially smooth, and shall not have any sharp projections. A joint in a stranded conductor is to be made by separately joining each individual wire, or is to be made by machine brazing or welding of the conductor as a whole provided that the resulting solid section of the stranded conductor is not longer than 1/2 in or 13 mm, there are no sharp points, and the distance between brazes or welds in a single conductor does not average less than 3000 ft or 915 m in any reel length of insulated single conductor. A joint made before insulation is applied to a conductor shall not increase the diameter of the solid conductor or individual wire (strand). The insulation applied to joints after insulating shall be equivalent to that removed and shall comply with the requirements in this Standard.

11 Resistance

11.1 The direct-current resistance of any length of conductor shall not be higher than the maximum acceptable (nominal x 1.02) indicated in the applicable one of the eleven Tables 30.1 – 30.5, 30.6, 30.6A, and 30.7 – 30.10 of UL 1581 at 20°C (68°F) or at 25°C (77°F) or in Table 11.1or Table 11.2 of this Standard when measured as described in 220.1 – 220.9 of UL 1581.

Table 11.1
Maximum direct-current resistance of solid copper conductors

AWG size of conductor	Uncoated				Coated			
	20°C		25°C		20°C		25°C	
	Ω/1000 feet	Ω/km	Ω/1000 feet	Ω/km	Ω/1000 feet	Ω/km	Ω/1000 feet	Ω/km
22	16.5	54.1	16.8	55.1	17.2	56.4	17.5	57.4
21	13.1	43.0	13.3	43.6	13.6	44.6	13.8	45.3
20	10.3	33.8	10.5	34.5	10.7	35.1	10.9	35.8
19	8.21	26.9	8.37	27.4	8.54	28.0	8.70	28.5
18	6.52	21.4	6.65	21.8	6.78	22.2	6.91	22.7
17	5.15	16.9	5.25	17.2	5.36	17.6	5.47	17.9
16	4.10	13.5	4.18	13.7	4.26	14.0	4.35	14.3
15	3.24	10.6	3.30	10.8	3.37	11.1	3.43	11.3
14	2.57	8.45	2.62	8.61	2.68	8.78	2.72	8.96
13	2.04	6.69	2.08	6.82	2.12	6.96	2.16	7.09
12	1.62	5.31	1.65	5.42	1.68	5.53	1.71	5.64

Table 11.2
Maximum direct-current resistance of stranded copper conductors

AWG size of conductors	Uncoated				Coated			
	20°C		25°C		20°C		25°C	
	Ω/1000 feet	Ω/km	Ω/1000 feet	Ω/km	Ω/1000 feet	Ω/km	Ω/1000 feet	Ω/km
22	16.9	55.4	17.2	56.4	17.5	57.4	17.9	58.7
21	13.3	43.6	13.6	44.6	13.9	45.6	14.1	46.3
20	10.5	34.4	10.7	33.1	10.9	35.8	11.1	36.4
19	8.39	27.5	8.66	28.4	8.71	28.6	8.87	29.1
18	6.66	21.9	6.79	22.3	6.92	22.7	7.0	23.1
17	5.29	17.4	5.40	17.7	5.47	17.9	5.59	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	1.17	5.61	1.74	5.71

12 Stranding

12.1 A stranded wire or cable shall have a minimum of seven strands. The length of lay of the strands shall be a maximum of 20 times the diameter of the conductor for 19 – 12 AWG conductors and shall be a maximum of 25 times the diameter of the conductor for 22 – 20 AWG conductors. The direction of the lay shall be left-hand.

12.2 The individual wires used in making up a stranded conductor are usually drawn to a specified mil diameter which may or may not be the diameter of any AWG or other standard gauge number. The individual wires of a concentric-lay-stranded conductor are not necessarily all of the same diameter.

13 Insulation

13.1 Material and application

13.1.1 Each conductor shall be insulated for its entire length with one or more of the insulation materials indicated in Table 13.1, Table 13.2, or referenced in note a to Table 13.1. The insulation shall be solid. In any case, a solid dielectric skin (a thin, solid, extruded layer that may or may not be separable) of the same or other material from Table 13.1 may be applied over the solid insulation. The insulation shall be applied directly to the conductor, shall have a circular cross section, and shall fit tightly to the conductor but shall not adhere excessively. 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.

13.1.2 Either of the following materials that the manufacturer wishes to use as insulation or a jacket shall be evaluated for the requested temperature rating as described in Long-Term Aging, Section 481 of UL 1581:

a) Material generically different from any insulation or jacket material that is named in Table 13.1 or Table 16.1 (new material).

b) Material that is named in Table 13.1, Table 13.2, or Table 16.1 yet does not comply with the short-term tests specified for the material.

The temperature rating of materials (a) and (b) shall be the temperature rating for the cable determined as specified in 16.1.2. The thicknesses of insulation and/or jacket using materials (a) and/or (b) shall be as required for the cable. Investigation of the electrical, mechanical, and physical characteristics of the cable using material (a) and/or (b) shall show the material(s) to be comparable in performance to an insulation or jacket material named in Table 13.1 or Table 16.1 for the required temperature rating. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage-withstand.

Table 13.1
Index to insulations

Material(s)[a]	Temperature rating of Insulation	Applicable table of physical properties in UL 1581 (see 13.2)
CP	90°C (194°F) 75°C (167°F)	50.1 50.1
ECTFE ETFE	150°C (302°F)	50.63
FEP	200°C (392°F)[b]	50.70
HDFRPE LDFRPE	75°C (167°F)	50.133
HDPE	75°C (167°F)	50.136
LDPE	75°C (167°F)	50.136
PFA MFA	200°C (392°F)[b] 250°C (482°F)[b]	50.137 50.137

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Table 13.1 Continued

Material(s)[a]	Temperature rating of Insulation	Applicable table of physical properties in UL 1581 (see 13.2)
Polypropylene:	75°C (167°F)	50.139
PP, FRPP	60°C (140°F)	50.139
PTFE TFE	250°C (482°F)[b]	50.219
PVC	105°C (221°F)	50.182
	90°C (194°F)	50.182
	75°C (167°F)	50.182
	60°C (140°F)	50.182
SRPVC (semirigid PVC)	105°C (221°F)	50.183
	90°C (194°F)	50.183
	75°C (167°F)	50.183
	60°C (140°F)	50.183
PVDF and PVDF copolymer	150°C (302°F)	50.185
	125°C (257°F)	50.185
Silicone rubber	200°C (392°F)	50.210
	150°C (302°F)	50.210
TPE	105°C (221°F)	50.223
	90°C (194°F)	50.224
XL:		
XLPE	105°C (221°F)	50.245
XLPVC	90°C (194°F)	50.237
XLEVA	75°C (167°F)	50.241
blends of these		
XLPO	105°C (221°F)	50.233

[a] See 13.1.2 for the long-term evaluation of an insulation material not named in the first column or not complying with the short-term tests referenced in the last column.

[b] 150°C (302°F) is the limit for the cable temperature rating (see 8.3) where conductor strands are used that are smaller in diameter than 0.015 in or 0.38 mm and are uncoated or are coated with tin or a tin/lead alloy. The indicated rating higher than 150°C (302°F) applies where, regardless of diameter, the strands are coated with silver [200°C (392°F)] or nickel [250°C (482°F)].

Table 13.2
Physical properties 200°C (392°F) and 150°C (302°F) silicone insulation[a] suitable for use without a braid or covering

Temperature rating of insulation	Condition of specimens at time of measurement	Minimum ultimate elongation (1-in or 25-mm bench marks)	Minimum tensile strength
150°C (302°F) or 200°C (392°F)	Unaged	250 percent (2.5 in or 62.5 mm)	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2

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Table 13.2 Continued

Temperature rating of insulation	Condition of specimens at time of measurement	Minimum ultimate elongation (1-in or 25-mm bench marks)	Minimum tensile strength
150°C (302°F)	Aged in a full-draft circulating-air oven for 60 d at 158.0 ±1.0°C (316.4 ±1.8°F)	150 percent (1.5 in or 37.5 mm) or 25 percent of the result with unaged specimens	850 lbf/in^2 or 5.86 MPa (MN/m^2) or 586 N/cm^2 or 0.598 kgf/mm^2 or 60 percent of the result with unaged specimens
200°C (392°F)	Aged in a full-draft circulating-air oven for 60 d at 210 ±1.0°C (410.0 ±1.8°F)	100 percent (1 in or 25 mm) or 25 percent of the result with unaged specimens	600 lbf/in^2 or 4.14 MPa (MN/m^2) or 414 N/cm^2 or 0.422 kgf/mm^2 or 60 percent of the result with unaged specimens

[a] Silicone rubber designates a thermoset compound whose characteristic constituent is poly-organo-siloxane.

13.2 Properties

13.2.1 The following jackets and insulations in place on the conductor shall not show any cracks on either the inside or outside surface after specimens are tested in accordance with 20.2.1:

a) All solid insulations with a skin that cannot be removed without damage to the insulation.

b) Aged specimens of PVDF and PVDF copolymer jackets and solid insulations. As indicated in note a to Table 50.185 of UL 1581, unaged specimens of these jackets and insulations are to be tested for tensile strength and elongation.

13.2.2 PHYSICAL PROPERTIES TESTS – Specimens prepared from samples of insulations for which the flexibility test is not indicated shall have values of tensile strength and ultimate elongation that comply with the applicable table of physical properties referenced in Table 13.1. 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 13.2.3.

13.2.3 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 of Insulation and Jacket" in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581, with the modification that ECTFE and ETFE insulations with band-marking inks may have the ink removed before specimens are aged.

13.3 Thicknesses

13.3.1 The average thickness and the minimum thickness at any point of insulation (including any skin) in a coaxial member, and on every other conductor, before and after separation and in nonintegral flat cable, shall not be less than indicated in Table 13.3. The thicknesses of 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, Section 250 of UL 1581, with the following modifications for stranded conductors that leave one or more strand impressions in the insulation that are too small to accommodate the smaller pin referred to in 250.11 of UL 1581, which is to be 0.0200 in (20.0 mils) or 0.508 mm in diameter:

a) The 0.003-in (3-mil) or 0.08-mm thickness-reduction allowance mentioned in 250.5 of UL 1581 is to be applied only to insulation that is from a stranded conductor as mentioned above and has an average thickness (including any skin) of at least 0.015 in or 0.38 mm.

b) Only an optical method as applicable from 13.3.2 and 13.3.3 is to be used for thickness measurements of insulation that is from a stranded conductor as mentioned above and has an average thickness (including any skin) less than 0.015 in or 0.38 mm.

Table 13.3
Minimum thickness of insulation

AWG size of conductors	PVC, CP, TPE, XL, XLPO, PE[a], PP, FRPP, and silicone rubber		ECTFE, ETFE, FEP, MFA, PFA, PTFE, TFE, PVDF, PVDF copolymer, and SRPVC		PVC with nylon jacket		
					PVC		Nylon
	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point	Minimum thickness at any point
	mils						
22 – 20	12	11	9	8	9	8	2
19 – 15	15	13	9	8	9	8	2
14 – 12	20	18	12	11	12	11	2
	mm						
22 – 20	0.30	0.28	0.23	0.20	0.23	0.20	0.05
19 – 15	0.38	0.33	0.23	0.20	0.23	0.20	0.05
14 – 12	0.51	0.46	0.30	0.28	0.30	0.28	0.05

[a] Includes HDPE, LDPE, HDFRPE, and LDFRPE.

13.3.2 Thickness measurements of a nylon or similar covering or of insulation having an average thickness or minimum thickness at any point of not more than 0.0060 in or 0.152 mm (including any skin) are to be made by means of a micrometer microscope or other optical instrument that is calibrated to read directly to at least 0.0001 in (0.1 mil) or 0.001 mm. Each of these measurements is to be recorded to the nearest 0.0001 in or 0.001 mm. Otherwise, under 13.3.1(b), a simply manipulated optical device that is accurate to 0.001 in (1 mil) or 0.01 mm may be used for insulation, with each measurement recorded to the nearest 0.001 in or 0.01 mm.

13.3.3 For 13.3.1(b), the conductor and any covering over the insulation or skin are to be removed from the finished insulated conductor, wire, or member. A thin slice of the insulation plus any skin is then to be cut perpendicular to the longitudinal axis of the resulting hollow tube. Measurements are to be taken of the maximum and minimum wall thicknesses of the slice. The recorded maximum and minimum thicknesses are to be added together and divided by 2 without any rounding off of the sum but with the resulting average rounded off (see 13.3.4 – 13.3.7) to the same degree as stated in 13.3.2 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 to be compared with the applicable Table 13.3.

13.3.4 ROUNDING OFF to the NEAREST 0.0001 in – A figure in the fourth decimal place is to remain unchanged if the figure in the fifth decimal place is:

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

b) 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 if the figure in the fifth decimal place is:

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

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

13.3.5 ROUNDING OFF to the NEAREST 0.001 in – A figure in the third decimal place is to remain unchanged if the figure in the fourth decimal place is:

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

b) 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 if the figure in the fourth decimal place is:

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

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

13.3.6 ROUNDING OFF to the NEAREST 0.001 mm – A figure in the third decimal place is to remain unchanged if the figure in the fourth decimal place is:

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

b) 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 if the figure in the fourth decimal place is:

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

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

13.3.7 ROUNDING OFF to the NEAREST 0.01 mm – A figure in the second decimal place is to remain unchanged if the figure in the third decimal place is:

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

b) 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 if the figure in the third decimal place is:

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

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

13.4 Individual covering

13.4.1 Silicone insulation that complies with the requirements in Table 13.1 shall have a braid covering or a covering of nylon. A covering is not required over a silicone insulation that conforms to the requirements in Table 13.2.

13.4.2 The thicknesses at any point of a required or optional nylon or similar covering shall not be less than 0.002 in or 0.05 mm when measured as described in Thicknesses of Jacket on Flexible Cord, Fixture Wire, and Elevator Cable, Section 280, of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

14 Optical-Fiber Member(s)

14.1 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.

14.2 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 such part is of metal or other electrically conductive material, its presence shall be indicated by a marking as detailed in 43.1(e).

14.3 The energy that an optical-fiber cable carries in some laser systems presents a potential risk of eye, or other injury to people. Consequently, where optical-fiber cables are installed in a laser system, the recommendations of the ANSI Z136 laser system safety standards should be applied. To help protect optical-fiber cable installers, users, service personnel, and anyone who handles the optical-fiber cable component of the system after installation, 43.1 specifies a tag, reel, or carton marking.

15 Assembly

15.1 Optical-fiber member(s)

15.1.1 Optical-fiber member(s) alone shall not constitute a cable. One or more optical-fiber members may be included in a cable. Optical-fiber members may be grouped with or without electrical conductors. Optical-fiber members in a cable shall be cabled alone or as a group with the same direction and with the same length of lay as the electrical conductors. In the performance of the cable, each optical-fiber member is to be considered as a filler. A group of optical-fiber members without any electrical conductor(s) in it may include one or more non-current-carrying metal parts (earth-grounded or interrupted when the hybrid cable is installed) such as a metal strength element or a metal vapor barrier. The construction of these parts is not specified. Each such part shall be physically and electrically isolated from any bare grounding conductor in the cable.

15.2 Circuit and grounding conductors

15.2.1 All of the circuit conductors and insulated grounding conductors shall have the same voltage rating. Insulated conductors with different temperature ratings may be mixed in a given cable if the cable is rated for the lowest temperature rating of any of the constituent insulated conductors.

15.2.2 Two or more insulated conductors shall be assembled in a cable. Sizes may be mixed. A cable may contain precabled groups of conductors as described in 15.2.4.

15.2.3 In a cable, the conductors, and any grounding conductor, bare or insulated, may be cabled (round cable – see 15.2.4) or laid parallel (flat cable).

15.2.4 The conductors in a round cable shall be cabled with a length of lay that is uniform throughout the length of the cable and is not greater than indicated in Table 15.1. Grouping of the circuit conductors into pairs, triads, quads, and other precabled subassemblies is not required but is acceptable if the length of lay of the conductors in each group and of the groups in the overall assembly comply with this paragraph and with Table 15.1. The direction of lay may be changed at intervals throughout the length of the cable. The intervals need not be uniform. In a cable in which the lay is reversed:

a) Each area in which the lay is right- or left-hand for several (typically 10) complete twists (full 360° cycles) shall have the insulated conductors or precabled groups of insulated conductors cabled with a length of lay that is not greater than indicated in Table 15.1, and

b) The length of each lay-transition zone (oscillated section) between these areas of right- and left-hand lay shall not exceed 1.8 times the maximum length of lay indicated in Table 15.1.

If the direction of lay is not reversed in a cable containing layers of conductors or groups, the direction of lay of successive layers is not specified.

Table 15.1
Length of lay of insulated conductors and precabled groups[a]

Number of insulated conductors in cable	Maximum acceptable length of lay
2	30 times conductor diameter[b]
3	35 times conductor diameter[b]
4	40 times conductor diameter[b]
5 or more	15 times the calculated diameter of the overall assembly but, in a multiple-layer cable, the length of lay of the conductors in each of the inner layers of the cable is not specified (governed by the construction of the cabling machine)

[a] The length of lay of each conductor in a group shall comply with the tabulated value as if the group were a cable. Likewise, the length of lay of each group in a cable shall comply with the tabulated value as if each group was a conductor.

[b] "Conductor diameter" is the calculated diameter of the largest individual finished insulated conductor in the cable.

15.2.5 A single insulated conductor, added for use in voice communications during installation of the cable (conductor then abandoned), may be surface marked as a communications conductor. The conductor shall comply with the requirements in UL 2250 for insulated copper circuit conductor and is not required to be included in the cable surface marking.

15.2.6 For cables manufactured with a dual PLTC/ITC rating, a single insulated conductor, added for use in voice communications during installation of the cable (conductor then abandoned), may be surface marked as a communications conductor. The conductor shall comply with the requirements in the Standard for Power-Limited Circuit Cables, UL 13, Table 7.3, for insulated copper circuit conductors, and is not required to be included in the cable surface marking.

15.3 Fillers

15.3.1 Fillers may be provided in a cable to make the finished cable firm at all points. Fillers may be provided in a cable to make the finished cable round. In a round cable, fillers shall be cabled with the conductors or, if applicable to the construction, may be in the center of the cable. Fillers may be integral with or separate from any binder jacket or the overall cable jacket. If fillers are integral with a jacket, they and the jacket shall be readily separable from the underlying cable assembly. Fillers shall be of nonconductive nonmetallic material.

15.4 Binders

15.4.1 The entire cable assembly, or any group of conductors (with or without one or more optical-fiber members included in the group), or several such groups within the cable may be enclosed in a binder consisting of a shield (see 15.5.1 – 15.5.3) or of a braid, tape, or other unspecified means. An individual group or several groups may be enclosed in a thin binder jacket that is of the same material and temperature rating as the overall cable jacket.

15.5 Shield

15.5.1 A shield is not required but is acceptable over an individual insulated conductor, over one or several groups of conductors with or without one or more optical-fiber members in each group, or over the entire cable assembly. Several shields may be used in a given cable.

15.5.2 A shield shall consist of one of the following:

a) A polyester and metal laminated shield tape with or without a bare copper drain wire in electrical contact with the metal part of the tape. The drain wire shall be metal-coated if the tape metal is aluminum; otherwise, the drain wire may be metal-coated or uncoated. The drain wire may be under or over the tape.

b) A wrap or braid of metal-coated or uncoated copper wires.

c) A metal-coated or uncoated copper tape.

d) An evaluated equivalent of any of the above.

15.5.3 The details of the construction of a shield and the manner of its application are not specified but are to be judged on the basis of the performance of the finished cable in the tests described in this standard. There are no requirements for the electromagnetic performance of a shield.

16 Overall Jacket

16.1 Material and application

16.1.1 A jacket of one of the materials indicated in Table 16.1 shall be extruded directly over the flat or round assembly of conductors and any optical-fiber members, fillers, binders, and the like. The assembly shall be completely covered and well centered in the jacket. The jacket shall not have any defects (bubbles, open spots, rips, tears, cuts, or foreign material) that are visible with normal or corrected vision without magnification. The absence of the defects mentioned in the previous sentence is evidence of the integrity of an overall jacket– that is, the overall jacket constitutes the gas/vaportight continuous sheath mentioned in 1.7. The overall jacket shall be sunlight-resistant as determined by test (see 29.1). A sunlight-resistance marking is not required; where used, this marking shall comply with 42.1(i).

Table 16.1
Overall jacket

Material(s)[a]	Temperature rating of jacket	Applicable table of physical properties in UL 1581
CP	90°C (194°F)	50.1
	75°C (167°F)	50.1
Thermoplastic CPE	90°C (194°F)	50.28
Thermoset CPE	90°C (194°F)	50.29
	75°C (167°F)	50.30
ECTFE ETFE	150°C (302°F)	50.63
FEP	200°C (392°F)	50.70
NBR/PVC	90°C (194°F)	50.83
	75°C (167°F)	50.80
Neoprene	90°C (194°F)	50.124
	75°C (167°F)	50.123
PFA	200°C (392°F)	50.137
MFA	250°C (482°F)	50.137
PTFE TFE	250°C (482°F)	50.219
PVC	105°C (221°F)	50.182
	90°C (194°F)	50.182
	75°C (167°F)	50.182
	60°C (140°F)	50.182
PVDF and	150°C (302°F)	50.185
PVDF copolymer	125°C (257°F)	50.185
Silicone rubber	200°C (392°F)	50.210
	150°C (302°F)	50.210
TPE	105°C (221°F)	50.223
	90°C (194°F)	50.224
XL:		
XLPE	105°C (221°F)	50.245
XLPVC	90°C (194°F)	50.237
XLEVA	75°C (167°F)	50.241
blends of these		
XLPO	105°C (221°F)	50.233
[a] See 13.1.2 for the long-term evaluation of a jacket material not named in the first column or not complying with the short-term tests referenced in the last column.		

16.1.2 Cables on which a jacket thicker than indicated in Table 16.2 and Table 16.3 is necessary to enable the cable to comply with any applicable flame or other test described or referenced in these requirements shall be made with whatever greater thicknesses of jacket may be needed for this purpose. In this case, the minimum thickness at any point of the heavier jacket shall not be less than 80 percent of the average thickness of the heavier jacket.

a) For a cable in which the insulation is rated for 60 – 105°C (140 – 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. The temperature rating of the cable is the same as the temperature rating of the insulation.

b) 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 cable jacket is not specified but the temperature rating of the cable is that of whichever insulation or jacket in the cable has the lowest temperature rating.

16.2 Properties

16.2.1 Specimens prepared from samples of the overall jacket taken from the finished cable shall exhibit properties that comply with the applicable table referenced in Table 16.1 when tested as indicated in 16.2.2.

16.2.2 The methods of preparation of samples, of selection and conditioning of specimens, and of making the measurements and calculations for permanent set, ultimate elongation, and tensile strength shall be as indicated under the heading "Physical Properties Tests of Insulation and Jacket" in the Reference Standard for Electrical Wires, Cables, and Flexible Cords (UL 1581), except that cables with an overall diameter not greater than 0.200 in or 5.1 mm may have their jackets tested as tubular specimens rather than as a die-cut specimens.

16.3 Thicknesses

16.3.1 The average thickness and the minimum thickness at any point of the overall jacket shall not be less than indicated in Table 16.2 – Table 16.3 when measured as described in 13.3.2 and 13.3.3.

Table 16.2
Thicknesses[a,c] of non-fluoropolymer jacket

Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket		Minimum average thickness		Minimum thickness at any point	
in	mm	in	mm	in	mm
0 – 0.200	0 – 5.08	0.035	0.89	0.028	0.71
Over 0.200 but not over 0.300	Over 5.08 but not over 7.62	0.040	1.02	0.032	0.81
Over 0.300 but not over 0.500	Over 7.62 but not over 12.70	0.050	1.27	0.040	1.02
Over 0.500 but not over 0.750	Over 12.70 but not over 19.05	0.060	1.52	0.048	1.22
Over 0.750 but not over 1.100	Over 19.05 but not over 27.94	0.070	1.78	0.056	1.42
Over 1.100 but not over 1.450	Over 27.94 but not over 36.83	0.080	2.03	0.064	1.63
Over 1.450 but not over 1.800	Over 36.83 but not over 45.72	0.090	2.29	0.072	1.83

[a] A thicker jacket is required to enable some cables to comply with one or more tests. See 16.1.2.

Table 16.2 Continued on Next Page

Table 16.2 Continued

Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket		Minimum average thickness		Minimum thickness at any point	
in	mm	in	mm	in	mm

[b] The equivalent diameter of a flat assembly is to be calculated as

$$1.1284 \times (TW)^{1/2},$$

in which:

T is the length of the minor axis and

W is the length of the major axis.

[c] A jacket of thickness other than indicated in this table 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 16.3
Thickness[a,c] of fluoropolymer jacket

Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket		Minimum average thickness		Minimum thickness at any point	
in	mm	mils	mm	mils	mm
0 – 0.700	0 – 17.78	20	0.51	16	0.41
Over 0.700 but not over 1.000	Over 17.78 but not over 25.40	30	0.76	24	0.61
Over 1.000 but not over 1.500	Over 25.40 but not over 38.10	45	1.14	36	0.91
Over 1.500 but not over 2.500	Over 38.10 but not over 63.50	60	1.52	48	1.22

[a] A thicker jacket may be required to enable the cable to comply with one or more tests. See 16.1.2.

[b] The equivalent diameter of a flat assembly is to be calculated as

$$1.1284 \times (TW)^{1/2},$$

in which:

T is the length of the minor axis and

W is the length of the major axis.

[c] A jacket of thickness other than indicated in this table 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.

17 Metal Covering

17.1 General

17.1.1 Interlocked metal armor, or a continuous metal sheath is acceptable over the jacket on any cable. See tests in Crushing Test for Cable Marked for Direct Burial, Section 30, Tension Test of Interlocked Steel or Aluminum Armor, Section 37, and Flexibility Test for Cable Having Interlocked Armor or a Smooth or Corrugated Metal Sheath, Section 38. Any metal covering that is provided shall be as follows:

a) A smooth metal sheath shall comply with 17.1.2 and 17.2.1 – 17.2.3.

b) A welded and corrugated metal sheath shall comply with 17.1.2, 17.1.3, 17.3.1, and 17.3.2.

c) An extruded and corrugated metal sheath shall comply with 17.1.2, 17.1.3, 17.4.1, and 17.4.2.

d) Interlocked metal armor shall comply with 17.1.2 and 17.5.1 – 17.5.9.

e) Wire armor or a metal braid applied over a jacket that complies with Cable Jacket, Section 16.

17.1.2 The sheath, or the strip forming the interlocked armor, shall be continuous throughout the length of the cable. A sheath shall not have flaws that affect its integrity – that is, a sheath shall not have any weld openings, cracks, splits, foreign inclusions, or the like. The strip from which interlocked armor is formed may be spliced (see 17.5.4) but there shall not be any cut or broken ends.

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

17.2 Smooth metal sheath

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

17.2.2 The average thickness and the minimum thickness at any point of the smooth sheath shall not be less than indicated in Table 17.1. 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 in or 0.01 mm. The spindle shall be round.

Table 17.1
Thicknesses[a] of smooth aluminum sheath

Calculated diameter under aluminum See 5.1		Mils		mm	
in	mm	Minimum acceptable average thickness	Minimum acceptable thickness at any point	Minimum acceptable average thickness	Minimum acceptable thickness at any point
0 – 0.400	0 – 10.16	35	32	0.89	0.81
Over 0.400 but not over 0.740	Over 10.16 but not over 18.80	45	41	1.14	1.04
Over 0.740 but not over 1.050	Over 18.80 but not over 26.67	55	50	1.40	1.27
Over 1.050 but not over 1.300	Over 26.67 but not over 33.02	65	59	1.65	1.50
Over 1.300 but not over 1.550	Over 33.02 but not over 39.37	75	68	1.90	1.96
Over 1.550 but not over 1.800	Over 39.27 but not over 45.72	85	77	2.16	1.96
Over 1.800	Over 45.72	95	86	2.41	2.18

[a] Thicknesses that are less than indicated in this table may be accepted based on performance of the sheath under the requirements in the Standard for Metal-Clad Cables, UL 1569.

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

17.3 Welded and corrugated metal sheath

17.3.1 A welded and corrugated metal sheath shall be of an aluminum-base alloy having a copper content of 0.40 percent or less, a stainless steel alloy having a chromium content of not less than 16 percent, a copper alloy or a bronze alloy. The sheath shall be tightly formed around the underlying cable and shall be welded and corrugated. See 17.2.3.

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

17.3.3 In the case of stainless steel sheathed cables, any outer jacket compound and any cable jacket, binder, separator or insulation material coming in direct contact with the stainless steel armor shall not contain chlorine.

17.4 Extruded and corrugated metal sheath

17.4.1 An extruded and corrugated metal sheath shall be of an aluminum-base alloy having a copper content of 0.40 percent or less. The sheath shall be tightly formed around the underlying cable. See 17.2.3.

17.4.2 The minimum thickness at any point of the unformed metal tape from which the extruded and corrugated sheath is made shall not be less than 0.022 in or 0.56 mm when determined as indicated in the second sentence of 17.4.1.

17.5 Interlocked armor

17.5.1 Armor shall consist of interlocked zinc-coated steel or aluminum strip and shall comply with 17.1.2 and 17.5.2 – 17.5.9.

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

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

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

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

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

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

17.5.8 Unformed and formed zinc-coated steel strip shall comply with the copper sulphate test described in Copper Sulphate Test of Zinc Coating on Steel Strip for and from Interlocked Steel Armor, Section 36 for the zinc coating.

17.5.9 The width of unformed aluminum strip or of unformed zinc-coated steel strip shall not be greater than indicated in Table 17.2. The minimum thickness at any point of the formed metal strip removed from the finished cable shall not be less than indicated in Table 17.2 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 in or 5.1 mm in diameter, with flat surfaces on each.

Table 17.2
Dimensions of metal strip for interlocked armor

Calculated diameter under armor		Maximum acceptable width of unformed strip[a,b]		Minimum acceptable thickness at any point of the formed strip removed from the finished cable[b]			
				Steel		Aluminum	
in	mm	mils	mm	mils	mm	mils	mm
0 – 0.500	0 – 12.7	500	12.7	17	0.43	22	0.55
Over 0.500 but not over 1.000	Over 12.7 but not over 25.4	750	19.0	17	0.43	22	0.56
Over 1.000 but not over 1.500	Over 25.4 but not over 38.1	875	22.2	17	0.43	22	0.56
Over 1.500 but not over 2.000	Over 38.1 but not over 50.8	875	22.2	22	0.56	27	0.69
Over 2.000	Over 50.8	1000	25.4	22	0.56	27	0.69

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

[b] When the performance of the armor complies with the Standard for Metal-Clad Cables, UL 1569, dimensions of the armor may differ from those shown in this table.

18 Jacket over Metal Covering

18.1 A jacket is required over a metal covering that is on any cable intended for direct burial. A jacket is not required over a metal covering on other cable. Any jacket over a metal covering shall comply with Overall Jacket, Section 16. The thicknesses shall be in accordance with Table 16.3 and Table 18.1. The same calculated core diameter that is used in determining the thickness of the required cable jacket, in Table 16.2 and Table 16.3, is to be used in determining the thickness required for an over-metal jacket - that is, an over-metal jacket need not be thicker than a cable jacket that is not over a metal covering.

Table 18.1
Thicknesses of non-fluoropolymer jacket materials over armor

Calculated diameter of round assembly or equivalent diameter of flat assembly under jacket		Minimum average thickness		Minimum thickness at any point	
in	mm	in	mm	in	mm
0 – 0.200	0 – 5.08	0.035	0.89	0.028	0.76
Over 0.200 but not over 0.425	Over 5.08 but not over 10.80	0.040	1.02	0.032	0.81
Over 0.425 but not over 1.500	Over 10.80 but not over 38.10	0.050	1.27	0.035	0.89
Over 1.500 but not over 2.250	Over 38.10 but not over 57.15	0.060	1.52	0.042	1.07
Over 2.250 but not over 3.000	Over 57.15 but not over 76.20	0.075	1.90	0.052	1.32
Over 3.000	Over 76.20	0.085	2.16	0.060	1.52

PERFORMANCE

19 Continuity Test of Conductors

19.1 The cable shall be tested for continuity of each conductor. The continuity testing is to be conducted in one of the following ways on 100 percent of production by the cable manufacturer at the cable factory:

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

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

19.2 To determine whether or not the finished cable complies with the requirement in 5.2 or in 32.10 for cable marked “-ER”, each conductor taken separately is to be connected in series with a light-emitting diode (LED), lamp, buzzer, bell, or other indicator, and an appropriate low-voltage a-c or d-c power supply.

20 Heat Shock and Flexibility Tests

20.1 Heat shock

20.1.1 The insulation and any jacket of PVC, semirigid PVC, or TPE shall not develop any cracks either on the inside or outside surface when the specimens described in 20.1.2 are tested as described in 20.1.3.

20.1.2 Specimens of each of the following are to be prepared from the finished cable:

a) Insulation representative of each conductor, wire, and coaxial member in the cable. In the case of a non-air-gap coaxial member, the member is to be tested as a whole after removal of the outer conductor and any overall jacket.

b) Integral insulation and jacket on flat cable.

c) Each individual jacket, binder jacket, cable jacket, and jacket over a metal covering in the cable (this includes the jackets on coaxial and optical-fiber members).

20.1.3 Each specimen is to be tightly wound for the number of turns indicated in Table 20.1 around a circular metal mandrel of the diameter indicated in Table 20.1. Adjacent turns are to touch one another, and each end of each specimen is to be held in place by a clamp or other secure means. The specimen/mandrel assemblies are to be suspended in a full-draft circulating-air oven for 60 min at the temperature indicated in Table 20.2. No specimen is to touch anything other than the mandrel on which it is wound. At the end of the hour of heating, each specimen/mandrel assembly is to be removed from the oven and examined for cracks on the inside and outside surfaces immediately and again after cooling to room temperature in still air. Cracking on the inside surface is detectable as circumferential depressions in the outer surface of a specimen of material other than a fluoropolymer. Circumferential depressions in a fluoropolymer surface are indicators of cracking or are yield marks (locally stronger points), so the inside fluoropolymer surface is to be examined visually. The examinations are to be made with normal or corrected vision without magnification.

Table 20.1
Heat-shock mandrel diameters and number of turns

Specimen	Calculated diameter over round specimen or calculated length of minor axis of ribbon or flat cable		Diameter of mandrel		Number of complete turns of specimen on mandrel
	in	mm	in	mm	
Nonintegral insulation	Any	Any	0.062	1.6	6
Integral insulation and Jacket	Any	Any	0.062	1.6	1
Central conductor and insulation from any coaxial member	Any	Any	2 times specimen diameter		6
Jacket other than over a metal covering	0 – 0.375	0 – 9.5	0.750	19.0	6
	Over 0.375 but not over 0.625	Over 9.5 but not over 15.9	1.625	41.3	6
	Over 0.625 but not over 1.000	Over 15.9 but not over 25.4	3.000	76.2	1
	Over 1.000 but not over 2.000	Over 25.4 but not over 50.8	3 times specimen diameter		1/2 (U bend)

Table 20.1 Continued on Next Page

Table 20.1 Continued

Specimen	Calculated diameter over round specimen or calculated length of minor axis of ribbon or flat cable		Diameter of mandrel		Number of complete turns of specimen on mandrel
	in	mm	in	mm	
	Over 2.000	Over 50.8	4 times specimen diameter		1/2 (U bend)
Jacket over a metal covering	Any	Any	5 times cable diameter		1/2 (U bend)

Table 20.2
Air temperature for heat-shock test

Material	Temperature rating of wire, °C (°F)	Air oven temperature, ±1.0°C (±1.8°F)
PE (polyethylene)	60 (140), 75 (167), and 80 (176)	100.0 (212.0)
TPE (thermoplastic elastomer	90 (194) and 105 (221)	150.0 (302.0)
PVC	60 (140), 75 (167), and 90 (194)	121.0 (249.8)
PVC	105 (221)	136.0 (276.8)

20.2 Flexibility test

20.2.1 The specimens that are to be aged are to be placed in a full-draft circulating-air oven for the length of time and at the temperature indicated for the jacket material, or for the insulation material adjacent to the conductor, in the applicable physical-properties table referenced in Table 13.1. The aging 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 aged 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 diameter over the overall jacket, binder jacket, coaxial member jacket, or optical-fiber member jacket, or over the insulation (including any skin). Each specimen is to be unwound before being examined. Cracking on the inside surface is detectable as circumferential depressions in the outer surface of a specimen of material other than a fluoropolymer. Circumferential depressions in a fluoropolymer surface are yield marks (locally stronger points) rather than indicators of cracking, so the inside fluorpolymer surface is to be examined visually. The examinations are to be made with normal or corrected vision without magnification. A white appearance (stress whitening) of a PVDF or PVDF copolymer insulation or jacket after flexing is not cause for rejection.

21 Deformation Test

21.1 The insulation and any separable jacket shall not decrease more in thickness than the percentage indicated in Table 21.1 under the load indicated in Table 21.1 while being maintained at the temperature indicated in Table 21.1. The test is to be conducted as described in Deformation Test, Section 560 of UL 1581, using test specimens described in 21.2 – 21.4.

Table 21.1
Load, temperature, and decrease in thickness for deformation test

Material	Sample	AWG size of conductor	Load		Test temperature	Maximum acceptable decrease in thickness in percent
			gf	N		
FEP	Nonintegral insulation	30 – 21 20 – 12	500 800	4.90 7.85	121.0 ±1.0°C (249.8 ±1.8°F)	25 25
	Any separable jacket	–	4000[a]	39.23[a]	121.0 ±1.0°C (249.8±1.8°F)	25
HDFRPE, LDFRPE, LDPE, or HDPE	Nonintegral insulation	30 – 21 20 – 12	250 400	2.45 3.92	100.0 ±1.0°C (212.0 ±1.8°F)	50 50
PVC or semirigid PVC	Nonintegral insulation or intergral insulation and jacket	30 – 21 20 – 12 10 – 7 6 – 1 1/0 – 4/0	250 400 500 1600 2000	2.45 3.93 4.90 9.80 19.61	121.0 ±1.0°C (249.08±1.8°F)	50 50 50 50 50
	Any separable jacket	–	2000[a]	19.61[a]	121.0 ±1.0°C (249.8 ±1.8°F)	50
TPE	Nonintegral insulation	30 – 21 20 – 12	250 400	2.45 3.92	150.0 ±1.0°C (302.0 ±1.8°F)	50 50
	Any separable jacket	–	2000[a]	19.61[a]	150.0 ±1.0°C (302.0 ±1.8°F)	50
XLPO or XL	Nonintegral insulation or integral insulation and jacket	30 – 21 20 – 12	250 400	2.45 3.92	121.0 ±1.0°C (249.8 ±1.8°F)	50 50
	Any separable jacket	–	2000[a]	19.61[a]	121.0 ±1.0°C (249.8 ±1.8°F)	50

[a] A jacket is to be tested in tubular form if it is too small in diameter to yield flat specimens having a width equal to or exceeding the diameter of the presser foot. In this case, a solid steel rod having a diameter that is neither too loose nor tight in the jacket is to be inserted into the jacket. Using the nominal diameter in Table 20.1 in UL 1581, the diameter of the rod is to be converted to the equivalent AWG size and that size is to be used to determine the load from Table 21.1. A solid conductor may be used inserted of the steel rod.

21.2 The test is to be conducted using specimens prepared from samples of each of the following taken from the finished cable:

a) Insulation representative of each conductor, wire, and non-air-gap coaxial member in the cable. Specimens are to have solid conductors.

b) Integral insulation and jacket from flat cable.

c) Each individual jacket, binder jacket, cable jacket, and jacket over a metal covering in the cable (this includes the jackets on coaxial and optical-fiber members).

21.3 For any jacket that does not need to be tested in tubular form (see note a to Table 21.1), a rectangular specimen 1 in long and 9/16 in wide or 25 mm long and 14 mm wide is to be sliced and then buffed, or planed, split or skived to a uniform thickness of not more than 0.050 ±0.010 in or 1.27 ±0.25 mm, with both surfaces smooth.

21.4 The insulated conductors of a flat, parallel cable with integral insulation and jacket are to be separated. The insulation thickness T_1 of an insulated conductor from integral cable or of an individually insulated conductor or wire or of the center conductor of a non-air-gap coaxial member (any jacket is to be removed) or of a jacket that is to be tested in tubular form as described in note a to Table 21.1 is to be determined by the difference method from measurements made on a 1-in or 25-mm length of the insulated conductor from the finished cable.

22 Cold Bend Test of Insulation

22.1 After being conditioned for 4 h in circulating air that is precooled to and maintained at a temperature of -20.0°C, +3.0°C, -2.0°C (-4.0°F, +5.4°F, -3.6°F), the insulation on specimens removed from the finished cable (before being conditioned) shall not crack on the inside or outside surface when the specimens are individually wound onto a round mandrel in the cold chamber as described in 22.2 – 22.4.

22.2 A circular metal mandrel is to be used in this test. The diameter of the mandrel is to be as indicated in Table 22.1. The single mandrel is to be securely mounted in the chamber in a position that facilitates the winding.

Table 22.1
Cold bend mandrel diameter

Calculated diameter over round specimen or calculated length of minor axis of ribbon or flat cable		Diameter of mandrel	
in	mm	in	mm
0 – 0.045	0 – 1.14	0.125	3.18
Over 0.045 but not over 0.062	Over 1.14 but not over 1.58	0.188	4.78
Over 0.062 but not over 0.083	Over 1.58 but not over 2.11	0.250	6.35
Over 0.083 but not over 0.104	Over 2.11 but not over 2.64	0.313	7.95
Over 0.104 but not over 0.125	Over 2.64 but not over 3.18	0.375	9.53
Over 0.125 but not over 0.146	Over 3.18 but not over 3.71	0.438	11.1
Over 0.146 but not over 0.167	Over 3.71 but not over 4.24	0.500	12.7
Over 0.167 but not over 0.188	Over 4.24 but not over 4.78	0.563	14.3
Over 0.188 but not over 0.208	Over 4.78 but not over 5.28	0.625	15.9
Over 0.208 but not over 0.229	Over 5.28 but not over 5.82	0.688	17.5
Over 0.229 but not over 0.250	Over 5.82 but not over 6.35	0.750	19.1
Over 0.250 but not over 0.271	Over 6.35 but not over 6.88	0.813	20.7
Over 0.271 but not over 0.292	Over 6.88 but not over 7.42	0.875	22.2
Over 0.292 but not over 0.333	Over 7.42 but not over 8.46	1.000	25.4

22.3 The insulated conductors, wires, and any other coaxial members are to be removed from a 24-in or 610-mm length of other finished cable and are to be separated from one another and individually placed as round specimens in the precooled cold chamber. Any jacket and the shield(s) are to be removed from coaxial members before these members are placed in the cold chamber. The specimens and mandrel are to be conditioned for 4 h in circulating air that is precooled to and maintained at a temperature of -20.0°C, +3.0°C, −2.0°C (−4.0°F, +5.4°F, −3.6°F). At the end of the fourth hour, the specimens are to be wound individually, and in quick succession, for 6 full turns onto the mandrel, with adjacent turns touching (1 complete turn is to be used for flat cable). The winding of each specimen is to be at an approximately uniform rate of 5 seconds per turn. The winding is to be done in the cold chamber.

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

23 Cold Bend Test of Complete Cable

23.1 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), -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 23.2 and 23.3. See 42.1 (k) and (l) regarding marking or not marking the cable with its low-temperature rating.

23.2 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 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), -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 3 full turns around a circular wooden mandrel of a diameter equal to 8 times the calculated diameter or length of minor axis of the outside of a cable that does not contain any shield, 15 times the cable diameter or length of minor axis of the outside of a cable that contains the specific metal sheath described in 15.5.2, or equal to 12 times the calculated diameter or length of minor axis of the outside of a cable that contains one or more shields (coaxial members are included here if they are not covered under x 15). There is not to be any more tension applied to a specimen than is necessary to keep the surface of the specimen in contact with the mandrel. Adjacent turns are to touch one another. The winding of each specimen is to be conducted at an approximately uniform rate of 5 s per turn, and the time taken to remove a specimen from the cold chamber and complete the winding is not to exceed 30 s. As an alternative, the test may be performed in the cold chamber using wood or metal mandrels.

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

24 Spark Test after Insulating

24.1 The insulation on each conductor, wire, and coaxial member for and in every length of cable shall comply with a spark test. One hundred percent of production shall be tested by the manufacturer at the factory. No faults are acceptable.

24.2 The spark test indicated in 24.1 is to be at the voltage shown in Table 24.1 on each conductor, wire, and coaxial member after it is insulated and before any subsequent operation. The test equipment and method are to be as described in Method, Section 900, of UL 1581.

Table 24.1
Test potentials

Thickness of insulation	Voltage-withstand test potential in volts[a]	Spark potential in volts
15 mils or 0.38 mm or less	1500 ac or 2500 dc	3000 ac
30 mils or 0.76 mm or less	1500 ac or 2500 dc	5000 ac

[a] For routine production dielectric voltage-withstand testing, the time of application of the test potential may be 15 s instead of 1 min.

25 Dielectric Voltage-Withstand Test

25.1 The insulation on each conductor, wire, and coaxial member in every length of finished cable shall withstand without breakdown a 48 – 62 Hz essentially sinusoidal rms or dc test potential as shown in Table 24.1 applied for 1 min. In the case of a coaxial member or a single, shielded, insulated conductor, the test potential shall be applied between the conductor and the shield, with the shield connected to earth ground. In all other cases, the test potential shall be applied between each conductor taken separately and all other conductors and any shield(s) and/or metal covering connected together and to earth ground. The test equipment and method are to be as described in Dielectric Voltage-Withstand Tests for Power-Limited Circuit Cable and Power-Limited Fire-Protective-Signaling Circuit Cables, Section 830 of UL 1581.

26 Insulation Resistance Test at 60.0°F (15.6°C)

26.1 The insulation on each conductor, wire, and coaxial member in a Type ITC cable shall exhibit an insulation resistance at 60.0°F (15.6°C) of not less than 100 megohms based on 1000 conductor feet, or not less than 30.5 megohms based on a conductor kilometer, when the cable is tested as described in 26.2– 26.8.

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

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

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

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

a) The insulation and the conductor or wire are to be considered to be at the same temperature as the water in which they are immersed whenever the same d-c resistance of the conductor is obtained in each of three successive measurements made at intervals of 30 min by means of a

Kelvin-bridge ohmmeter that presents readings accurate to 2 percent or less of the value indicated by the meter.

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

26.6 The water and the entire length of the immersed insulated conductor are to be at any one temperature in the range of 40.0 – 95.0°F (4.4 – 35.0°C) at the time that the insulation resistance is measured. If their temperature at this time is other than 60.0°F (15.6°C), the resulting insulation resistance is to be multiplied by the applicable factor M indicated in Table 26.1.

Table 26.1
Multiplying factor M[a] for adjusting insulation resistance to 60.0°F (15.6°C) from another room temperature

Temperature		M[a]				
		CP, XL, and XLPO	PVC[b] and semirigid PVC[b]			
°F	°C		I	II	III	IV
40	4.4	0.53	0.12	0.17	0.21	0.31
41	5.0	0.55	0.13	0.19	0.23	0.33
42	5.6	0.57	0.15	0.21	0.25	0.35
43	6.1	0.59	0.16	0.22	0.27	0.37
44	6.7	0.60	0.18	0.25	0.29	0.39
45	7.2	0.62	0.20	0.27	0.31	0.42
46	7.8	0.64	0.23	0.29	0.34	0.44
47	8.3	0.66	0.2	0.32	0.36	0.47
48	8.9	0.68	0.28	0.35	0.39	0.49
49	9.4	0.70	0.31	0.38	0.43	0.53
50	10.0	0.73	0.35	0.42	0.46	0.56
51	10.6	0.76	0.39	0.46	0.50	0.59
52	11.1	0.78	0.43	0.50	0.54	0.63
53	11.7	0.80	0.48	0.55	0.58	0.67
54	12.2	0.83	0.54	0.60	0.63	0.70
55	12.8	0.86	0.60	0.65	0.68	0.75
56	13.3	0.88	0.66	0.71	0.74	0.79
57	13.9	0.91	0.73	0.78	0.80	0.84
58	14.4	0.94	0.82	0.85	0.86	0.90
59	15.0	0.97	0.90	0.92	0.93	0.95
60	15.6	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.11	1.09	1.08	1.06
62	16.7	1.07	1.24	1.19	1.17	1.13
63	17.2	1.10	1.38	1.30	1.26	1.19
64	17.8	1.13	1.53	1.41	1.36	1.26
65	18.3	1.17	1.70	1.54	1.47	1.34
66	18.9	1.20	1.88	1.69	1.59	1.42

Table 26.1 Continued on Next Page

Table 26.1 Continued

Temperature		Ma				
		CP, XL, and XLPO	PVCb and semirigid PVCb			
°F	°C		I	II	III	IV
67	19.4	1.24	2.09	1.84	1.72	1.51
68	20.0	1.28	2.31	1.99	1.85	1.60
69	20.6	1.32	2.57	2.18	2.00	1.69
70	21.1	1.36	2.85	2.38	2.17	1.79
71	21.7	1.40	3.17	2.59	2.34	1.90
72	22.2	1.45	3.52	2.82	2.53	2.02
73	22.8	1.50	3.90	3.08	2.72	2.14
74	23.3	1.55	4.31	3.35	2.94	2.27
75	23.9	1.59	4.78	3.65	3.18	2.40
76	24.4	1.64	5.30	3.98	3.43	2.54
77	25.0	1.69	5.88	4.34	3.70	2.70
78	25.6	1.75	6.51	4.73	4.00	2.86
79	26.1	1.80	7.27	5.16	4.33	3.03
80	26.7	1.86	8.07	5.61	4.67	3.21
81	27.2	1.90	8.98	6.12	5.04	3.40
82	27.8	1.97	9.92	6.69	5.45	3.60
83	28.3	2.02	11.0	7.28	5.89	3.82
84	28.9	2.10	12.2	7.92	6.35	4.05
85	29.4	2.23	13.5	8.67	6.84	4.30
86	30.0	2.30	14.9	9.31	7.30	4.53
87	30.6	2.30	16.6	10.1	7.93	4.81
88	31.1	2.37	18.5	11.0	8.50	5.09
89	31.7	2.43	20.6	12.0	9.23	5.40
90	32.2	2.53	23.0	13.1	9.95	5.72
91	32.8	2.60	25.3	14.3	10.7	6.08
92	33.3	2.68	28.2	15.6	11.6	6.44
93	33.9	2.76	31.2	17.0	12.5	6.83
94	34.4	2.86	35.0	18.5	13.5	7.24
95	35.0	2.94	39.0	20.3	14.6	7.68

a M=1.00 for silicone rubber, ECTFE, ETFE, FEP, FRPE, HDPE, LDPE, MFA, PFA, PP, FRPP, PVDF, PVDF-copolymer, PTFE, and TFE. M is to be determined individually for each TPE compound by means of the method described in Test Procedure for Determining the Multiplying-Factor Column for Adjusting Insulation Resistance, Section 27.

b Normally, one of the four columns I, II, III, or IV in this table is to be assigned to each PVC and semirigid PVC compound used. However, where a PVC compound or semirigid PVC compound does not fit into any of the four patterns (columns in this table), applicable values of M are to be determined by means of the method described in Test Procedure for Determining the Multiplying-Factor Column for Adjusting Insulation Resistance, Section 27.

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

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

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

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

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

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

27.4 Each of the two specimens is to be exposed (27.3 applies) to successive water temperatures of 50.0, 61.0, 72.0, 82.0, and 95.0°F (10.0, 16.1, 22.2, 27.8, and 35.0°C) and returning, 82.0, 72.0, 61.0, and 50.0°F (27.8, 22.2, 16.1, and 10.0°C). Insulation-resistance readings are to be taken at each temperature after equilibrium is established.

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

27.6 The resistivity coefficient C for a 1.0°F (0.55°C) change in temperature is to be calculated to two decimal places by dividing the insulation resistance at 60.0°F (15.6°C) read from the graph by the insulation resistance at 61.0°F (16.1°C). In Table 27.1, C heads the column of multiplying factors M that applies to the particular insulation.

Table 27.1
Multiplying factor M[a] for adjusting insulation resistance to 60.0°F (15.6°C)

Temperature		Resistivity coefficient C for 1.0°F (0.55°C)									
°F	°C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
40	4.4	0.55	0.46	0.38	0.31	0.26	0.22	0.18	0.15	0.12	0.10
41	5.0	0.48	0.40	0.33	0.28	0.28	0.23	0.19	0.16	0.14	0.12
42	5.6	0.59	0.49	0.42	0.35	0.30	0.25	0.21	0.18	0.15	0.13
43	6.1	0.60	0.51	0.44	0.37	0.32	0.27	0.23	0.20	0.17	0.15
44	6.7	0.62	0.53	0.46	0.39	0.34	0.29	0.25	0.22	0.19	0.16
45	7.2	0.64	0.56	0.48	0.42	0.36	0.32	0.28	0.24	0.21	0.18
46	7.8	0.66	0.58	0.50	0.44	0.39	0.34	0.30	0.26	0.23	0.20
47	8.3	0.68	0.60	0.53	0.47	0.42	0.37	0.33	0.29	0.26	0.23
48	8.9	0.70	0.62	0.56	0.50	0.44	0.40	0.36	0.32	0.29	0.26
49	9.4	0.72	0.65	0.59	0.53	0.48	0.42	0.39	0.35	0.32	0.29

Table 27.1 Continued on Next Page

Table 27.1 Continued

Temperature		Resistivity coefficient C for 1.0°F (0.55°C)									
°F	°C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
50	10.0	0.74	0.68	0.61	0.56	0.51	0.46	0.42	0.39	0.35	0.32
51	10.6	0.77	0.70	0.64	0.59	0.54	0.50	0.46	0.42	0.39	0.36
52	11.1	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.43	0.40
53	11.7	0.81	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45
54	12.2	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.54	0.51
55	12.8	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.59	0.57
56	13.3	0.89	0.86	0.82	0.79	0.76	0.74	0.71	0.68	0.66	0.64
57	13.9	0.92	0.89	0.86	0.84	0.82	0.79	0.77	0.75	0.73	0.71
58	14.4	0.94	0.93	0.91	0.89	0.87	0.86	0.84	0.83	0.81	0.80
59	15.0	0.97	0.95	0.94	0.95	0.94	0.93	0.92	0.91	0.90	0.89
60	15.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
62	16.7	1.06	1.08	1.10	1.12	1.14	1.17	1.19	1.21	1.23	1.25
63	17.2	1.09	1.12	1.06	1.19	1.23	1.26	1.30	1.33	1.37	1.40
64	17.8	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.46	1.52	1.57
65	18.3	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.61	1.69	1.76
66	18.9	1.19	1.27	1.34	1.42	1.50	1.59	1.68	1.77	1.87	1.97
67	19.4	1.23	1.32	1.41	1.50	1.61	1.71	1.83	1.95	2.08	2.21
68	20.0	1.27	1.37	1.48	1.59	1.72	1.85	1.99	2.14	2.20	2.48
69	20.6	1.30	1.42	1.55	1.9	1.84	2.00	2.17	2.36	2.56	2.77
70	21.1	1.34	1.48	1.63	1.79	1.97	2.16	2.37	2.59	2.84	3.11
71	21.7	1.38	1.54	1.71	1.90	2.10	2.33	2.58	2.85	3.15	3.48
72	22.2	1.43	1.60	1.80	2.01	2.25	2.52	2.81	3.14	3.50	3.90
73	22.8	1.47	1.67	1.89	2.13	2.41	2.72	3.07	3.45	.88	4.36
74	23.3	1.51	1.73	1.98	2.26	2.58	2.94	3.34	3.80	4.31	4.89
75	23.9	1.56	1.80	2.08	2.40	2.76	3.17	3.64	4.18	4.78	5.47
76	24.4	1.60	1.87	2.18	2.54	2.95	3.43	3.97	4.59	5.31	6.13
77	25.0	1.65	1.95	2.29	2.69	3.16	3.70	4.33	5.05	5.90	6.87
78	25.6	1.70	2.03	2.41	2.85	3.38	4.00	4.72	5.56	6.54	7.69
79	26.1	1.75	2.11	2.53	3.03	3.62	4.32	5.14	6.12	7.26	8.61
80	26.7	1.81	2.19	2.65	3.21	3.87	4.66	5.60	6.73	8.06	9.65
81	27.2	1.86	2.28	2.79	3.40	4.14	5.03	6.11	7.40	8.95	10.8
82	27.8	1.92	2.37	2.93	3.60	4.43	5.44	6.66	8.14	9.93	12.1
83	28.3	1.97	2.46	3.07	3.82	4.74	5.87	7.26	8.95	11.0	13.6
84	28.9	2.03	2.56	3.23	4.05	5.07	6.34	7.91	9.85	12.2	15.2
85	29.4	2.09	2.67	3.39	4.29	5.43	6.85	8.62	10.8	13.6	17.0

[a] Calculated from the formula $M=C^{t-60}$ in which C is determined as described in 27.1 – 27.6 and t is the temperature of the cable in degrees F.

28 Long Term Insulation-Resistance Test in Water

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

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

a) (Inch-pound):

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

in which:

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

D is the diameter over the insulation in inches; and

d is the diameter of the metal conductor in inches;

b) (SI)

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

in which:

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

D is the diameter over the insulation in mm; and

d is the diameter of the metal conductor in mm.

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

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

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

29 Sunlight Resistance Test

29.1 The cable is 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 finished cable is conditioned and tested as described in Xenon-Arc Tests, Section 1200 of UL 1581, using 720 h of xenon-arc exposure.

30 Crushing Test for Cable Marked for Direct Burial

30.1 Finished cable that is marked to indicate that the cable is for direct burial shall withstand without rupture of the:

a) Outermost cable covering, and

b) Insulation on any conductor, 1000 lbf or 4448 N or 454 kgf applied for 60 s by a flat horizontal steel plate that crushes the cable at the point at which the cable is laid over a steel rod.

The test shall be conducted and the results evaluated as described in 30.2 – 30.6.

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

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

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

30.5 The cable at the first mark is to be placed and held on the steel rod, with the longitudinal axis of the cable horizontal, perpendicular to the longitudinal axis of the rod, and in the vertical plane that laterally bisects the upper and lower plates and the rod. Flat parallel cable with integral insulation and jacket is to be tested flatwise. The upper steel plate is to be made snug against the cable. In a test using a dead weight or weights, weight exerting the force indicated in 30.1 is to be placed gently on the upper plate. In a test using a compression machine, the upper plate is to be moved downward at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min thereby increasing the force on the cable until the level indicated in 30.1 is reached. That level of force is to be held constant for 60 s and is then to be reduced to zero by removing the dead weight(s) or, in the compression machine, by raising the upper steel plate at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min until the cable is free.

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

31 Water Absorption Test of Insulation in Direct-Burial Cable

31.1 Conductors for use in Direct-Burial Cables shall meet the requirements of 31.2 or 31.3 or the Long Time Insulation Resistance in Water requirements for Type TW wires in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83.

31.2 The mechanical water absorption (MWA) of the insulation on the conductors in a direct-burial cable shall not be more than 20.0 milligrams mass per square inch of exposed surface or shall not be more than 3.1 milligrams mass per square centimeter of exposed surface, when specimens of the insulated conductors are tested as described in Test, Section 1040 of UL 1581. The water temperature is 82.0 ±1°C.

31.3 The capacitance and relative permittivity of the insulation on a conductor in a direct burial cable shall be determined using the method described in Test, Section 1020 of UL 1581 for 60°C conductors. The relative permittivity determined after a 24 h immersion shall not be more than 10.0. The capacitance after 14 days shall not be more than 10.0 percent higher than after one day and 5.0 percent higher than after 7 days.

32 Impact Test for Type ITC Cable Marked "-ER"

32.1 Type ITC cable marked "-ER" as indicated in 42.1 and 43.1 [NEC 727.4 (6)] shall be capable of withstanding without contact between circuit conductors, and without contact between a circuit conductor and any shield, the energy of a free-falling, flat-faced weight that impacts the cable at the point at which the cable is laid over a steel rod. The test shall be conducted and the results evaluated as described in 32.2 – 32.10. Flat cable shall be capable of withstanding the impact when tested with the broad and narrow faces laid over the rod (flatwise and edgewise using separate specimens).

32.2 The result of this test, conducted on a finished cable containing three circuit conductors that are of identical size, are to be taken as representative of the performance of all other cables of the same construction containing either more conductors of the same size or the same or a larger number of conductors of a larger size. The performance of a two conductor cable is to be tested on a finished cable containing two circuit conductors that are of identical size and shall be taken as representative of the performance of all other cables of the same construction containing the same or a larger number of conductors of the same or of a larger size. The performance of the cabled conductors in a round cable is to be taken as representative of the performance of those conductors in both round and flat cables.

32.3 A solid rectangular block of steel 4-3/4 in or 121 mm long by 3 in or 76 mm wide by 5 in or 127 mm high, with its upper face (4-3/4 by 3 in or 121 by 76 mm) horizontal, is to be secured to a concrete floor, the building framework, or another solid support. A solid steel rod 3/4 in or 19 mm in diameter and 4-3/4 in or 121 mm long is to be bolted or otherwise secured to the upper face of the stationary block with the longitudinal axis of the rod in the same vertical plane as the longitudinal axis of the stationary block.

32.4 An impact weight of 10 lb or 4.54 kg is to be used and shall consist of a solid rectangular block of steel with its lower face (the face that strikes the cable) 2 in or 51 mm wide and 6 in or 152 mm long. The edges of the lower face are to be rounded to a radius of 1/16 in or 1.5 mm.

32.5 The impact weight is to be supported with its lower face horizontal and with the longitudinal axis of its lower face in the same vertical plane as the longitudinal axes of the rod and the upper face of the stationary block. A vertical line through the centers of gravity of the impact weight, the rod, and the stationary block is to be coincident with a vertical line through the dimensional center of the lower face of the impact weight and the dimensional center of the upper face of the stationary block. A set of rails or other vertical guides is to constrain the impact weight and keep its lower face horizontal while the weight is falling and after it has struck the cable. The rails or other guides are not to interfere with the free fall of the impact weight. A means is to be provided at the top of the guides for releasing the impact weight to fall freely from any chosen height and strike the cable. The weight is to be kept from striking the cable more than once during each drop.

32.6 The test samples of the cable, the apparatus and the surrounding air are to be a thermal equilibrium with one another at a temperature of 23.0 ±5.0°C (73.4 ±9.0°F) throughout the test.

32.7 Round cable is to be tested in a single continuous length of at least 11 ft or 3.35 m with ten strikes being made on that length. Two such lengths are to be tested in the case of a flat cable, with ten strikes being made flatwise (broad faces of cable contacting the impact weight and the rod) on one length and ten strikes being made edgewise (narrow faces of cable contacting the impact weight and the rod) on the other length. The points at which the cable is to be struck are to be measured and marked with chalk or by another innocuous means on the test length before the test is begun. The first mark is to be placed 12 in or 305 mm from one end of the test length and the nine remaining marks are to be made at succeeding intervals of 12 in or 305 mm down the length of the cable.

32.8 The insulated circuit conductors in the length of cable being tested are to be connected in series with a 3-W 120-V neon lamp to one of the energized conductors of a 208-V 48 – 62 Hz 4-wire grounded-wye a-c circuit. Any bare or insulated grounding conductor in the test length of the cable is to be connected to any shield, to all parts of the impact apparatus, to earth ground, and to the grounded supply wire.

32.9 The impact weight is to be secured several cable diameters above the steel rod and 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 containing the coincident vertical lines mentioned in 32.5. The position of the 10 lb or 4.54 kg impact weight is to be adjusted to place the lower face of the weight 1.5 ft or 45.7 cm above the upper surface of the cable (this height results in an impact energy of 15 ft-lbf or 20.3 J or 207 kgf-cm). The impact weight is to be released from this height, is to fall freely in the guides, is to strike the cable once, and is then immediately to be raised up to and secured at the initial height. Note is to be taken and recorded of whether either or both of the neon lamps light during the impact indicating a momentary or other contact between the circuit conductors or between one or both of the circuit conductors and any grounding conductor or shield.

32.10 The test sample of the cable is to be advanced to and impacted at each of the successive marks for a total of ten strikes. After each strike, continuity of the circuit conductors is to be checked (see Continuity Test of Conductors, Section 19). When any lamp lights this is considered a failure and the impacted cable section containing the short should be removed from the cable before continuing with the impact test. If more than two of the ten impact points on any test length causes a lamp to light, the cable does not meet the impact-test requirement. Additionally, any failure of the continuity test is considered a failure of the impact test requirement.

33 Crushing Test for Type ITC Cable Marked "-ER"

33.1 Type ITC cable marked "-ER" as indicated in 42.1 and 43.1 [NEC 727.4 (6)] shall be capable of withstanding without contact between circuit conductors, and without contact between a circuit conductor and any shield and all grounding conductors connected together, the force of a flat horizontal steel plate that crushes the cable at the point at which the cable is laid over a steel rod.

33.2 The results of this test, conducted on a finished cable containing three circuit conductors that are of identical size, are to be taken as representative of the performance of all other cables of the same construction containing either more conductors of the same size or the same or a larger number of conductors of a larger size. The performance of a two conductor cable is to be tested on a finished cable containing two circuit conductors that are of identical size and shall be taken as representative of the performance of all other cables of the same construction containing the same or a larger number of conductors of the same or of a larger size. The performance of the cabled conductors in a round cable is to be taken as representative of the performance of those conductors in both round and flat cables.

33.3 The cable is to be crushed between flat, horizontal steel plates in a compression machine whose jaws close at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min. Each plate is to be 2 in or 50 mm wide. A solid steel rod 3/4 in or 19 mm in diameter and of the same length as the plates 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.

33.4 The test samples of the cable, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 23.0 ±5.0°C (73.3 ±9.0°F) throughout the test.

33.5 Round cable is to be tested in a continuous length of at least 100 in or 2.55 m with the cable being crushed at ten points along that length. Two such lengths are to be tested in the case of a flat cable, with the cable being crushed flatwise (broad faces of cable contacting the flat plate and the rod) at ten points on one length and edgewise (narrow faces of cable contacting the flat plate and the rod) at ten points on the other 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 in or 230 mm from one end of the test length and the nine remaining marks are to be made at succeeding intervals of 9 in or 230 mm down the length of the cable.

33.6 Each of the insulated circuit conductors in the length of cable being tested is to be connected in series with a buzzer or other low-voltage indicator and its supply circuit, one leg of which is to be earth-grounded. All grounding conductors in the test length of the cable are to be connected to any shield, to all metal parts of the crushing apparatus, to earth ground, and to the grounded supply wire.

33.7 The upper steel plate in the compression machine is to be raised several cable diameters above the steel rod and 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 plates and the rod. The upper steel plate is to be moved down until it is snug against the cable. The downward motion of the plate is then to be continued at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min increasing the force on the cable until one or more of the indicators signal that contact has occurred between the circuit conductors or between one or more of the circuit conductors and any grounding conductor. The force indicated by the dial on the compression machine at the moment of contact is to be recorded.

33.8 The length of cable being tested is to be advanced to and crushed at each of the successive marks for a total of ten crushes. When the average of the ten crushing trials is less than 1000 lbf or 4448 N or 454 kgf the cable does not comply with the crush-test requirement.

34 Changes in Construction

34.1 In regard to the tests referenced in Vertical-Tray Flame Tests on Cables, Section 35, a construction is changed (and therefore the full number of burns specified in the chosen 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.

34.2 For a cable that contains a metal or metallized 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.

35 Vertical-Tray Flame Tests on Cables

35.1 General

35.1.1 The cable manufacturer is to specify either the UL test referenced in 35.2.1 and 35.2.2, the FT4/IEEE 1202 test referenced in 35.3.1, or (for limited-smoke cable) the test referenced in 35.4.1 and 35.4.2. A test is required for each construction of cable. The same test is not required for all constructions. See 1.2. Cables with the metal covering described in Metal Covering, Section 17, and without the jacket described in Jacket over Metal Covering, Section 18, comply with the requirements in 35.2, 35.3, and 35.4 and are not required to be tested.

35.2 UL test

35.2.1 Type ITC cable of a given construction shall not exhibit damage (as defined in UL 1685) that equals or exceeds a height of 8 ft, 0 in or 244 cm when sets of cable specimens as described in 35.2.2 are separately installed in a vertical ladder type of cable tray and are subjected to 20 min of flame as described under UL Flame Exposure (smoke measurements are not applicable) in the Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. The test specimens shall be of the complete, finished cable. The test specimens shall be representative of the entire size range that the manufacturer intends to produce in each construction made (see specification of specimens and evaluation of results in 35.2.2). See 34.1 and 34.2 regarding shields and regarding construction changes that trigger repeat testing.

35.2.2 The test specimens for the UL or FT4/IEEE 1202 tray flame test typically are the smallest and largest diameters [equivalent diameter for a cable that is not round is calculated as $1.1284 \times (TW)^{1/2}$, in which T is the length of the minor axis of the cable and W is the length of the major axis of the cable] cable that the manufacturer intends to produce in each construction made. The number of cable lengths in a set of specimens is to be determined as indicated in UL 1685. Where the cable damage height equals or exceeds 8ft. 0 in or 244 cm measured upward from the bottom of the cable tray on any individual cable test length in either set of cable specimens tested, compliance in tests of additional sets of specimens is required to qualify the full size range desired by the manufacturer.

35.3 FT4/IEEE 1202 test

35.3.1 Finished cable shall not exhibit damage (as defined in UL 1685) that equals or exceeds a height of 1.5 m or 4 ft 11 in when sets of specimens are tested as described under FT4/IEEE 1202 Type of Flame Exposure (smoke measurements are not applicable) in the Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. 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 35.2.2 and, for evaluation of results in each case, substitute the following sentence of this paragraph for the final sentence in 35.2.2. Where the cable damage height equals or exceeds 1.5 m or 4 ft 11 in measured upward from the lower edge of the burner face on any individual cable in any set of specimens tested, compliance in tests of additional sets of specimens is required to qualify the full size range desired by the manufacturer. See 34.1 and 34.2 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 42, and Information on the Tag, Reel, or Carton, Section 43.