



UL 13

STANDARD FOR SAFETY

Power-Limited Circuit Cables

UL Standard for Safety for Power-Limited Circuit Cables, UL 13

Fourth Edition, Dated March 18, 2015

SUMMARY OF TOPICS

This revision of ANSI/UL 13 dated March 18, 2022 includes copper-clad aluminum as a conductor option in Class 2 circuit, and thermostat cable for 18 AWG HVAC applications; [Table 5.1](#), [Table 5.2](#), [5.6](#), [Table 20.1](#), and [47.6](#).

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated October 8, 2021 and November 22, 2021.

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MARCH 18, 2015
(Title Page Reprinted: March 18, 2022)



ANSI/UL 13-2022

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UL 13

Standard for Power-Limited Circuit Cables

First Edition – November, 1990
Second Edition – February, 1996
Third Edition – July, 2007

Fourth Edition

March 18, 2015

This ANSI/UL Standard for Safety consists of the Fourth Edition including revisions through March 18, 2022.

The most recent designation of ANSI/UL 13 as an American National Standard (ANSI) occurred on March 18, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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INTRODUCTION

1 Scope

1.1 These requirements cover 60 – 250°C (140 – 482°F) single- and multiple-conductor power-limited circuit cables for use as fixed wiring within buildings (some are also marked for direct burial) principally for Class 3 and Class 2 circuits as described in Article 725 and other applicable parts of the National Electrical Code (NEC). Cables covered by these requirements are:

- a) Types CL3P and CL2P (plenum cables),
- b) Types CL3R and CL2R (riser cables),
- c) Types CL3 and CL2 (commercial cables for other than plenum, riser, or tray uses),
- d) Types CL3X and CL2X (cables for limited use), and
- e) Type PLTC (cable for non-plenum and non-riser Class 3 and Class 2 circuits in general and in trays).

1.2 Cables for Class 3 circuits are rated for 300 volts but are not so marked. Cables for Class 2 circuits do not have a voltage rating. See [47.1\(h\)](#).

1.3 A cable that contains one or more electromagnetic shields may be surface marked or have a marker tape to indicate that it is "shielded". A cable that contains one or more optical-fiber members has "-OF" supplementing the type letters and is marked in accordance with [48.1\(d\)](#). A cable may consist of or contain one or more coaxial members.

1.4 The overall jacket on a cable that has "sun res" or "sunlight resistant" in a surface marking or on a marker tape complies with a 720-h sunlight-resistance test. The overall jacket on all Type PLTC cable is required to comply with this 720-h test, so Type PLTC cable may be marked "sun res" or "sunlight resistant" but is not required to be so marked.

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

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

a) TYPE CL3P and CL2P CABLES – Cables that are intended for installation in accordance with section 725.82 (A) of the National Electrical Code, ANSI/NFPA 70, in a duct, plenum, or other space used to transport environmental air without the cables being enclosed in a raceway in that space are to be tested for smoke and flame characteristics in accordance with the National Fire Protection Association Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces, ANSI/NFPA 262. A cable that complies exhibits a maximum flame-propagation distance that is not greater than 5 ft, 0 in or 152 cm, a peak optical density of smoke produced of 0.50 or less (32 percent light transmission), and an average optical density of smoke produced of 0.15 or less.

b) TYPE CL3R and CL2R CABLES – Cables that are intended for use in vertical runs in a shaft, or for installations in which the cables penetrate more than one floor, as specified in Section 725.82 (B) of the National Electrical Code, ANSI/NFPA 70, are to be tested for flame-propagation characteristics in accordance with the Standard for Test for Flame-Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts, UL 1666. A cable that complies has a flame-propagation height less than 12 ft, 0 in or 366 cm and temperatures are 850.0°F (454.4°C) or less at a height of 12 ft, 0 in or 366 cm.

c) TYPE CL3 and CL2 CABLES – Type CL3 and CL2 general-use cables comply with a 70,000 Btu/h (20.5 kW) vertical-tray flame test. The cable manufacturer chooses one of the following tests:

1) THE UL TEST REFERENCED IN [28.2.1](#) – This paragraph applies 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, to cable that is surface marked or designated by a marker tape as "CL3" or "CL2". For compliance, this test damages less than 8 feet (244 cm) of cable.

2) THE FT4/IEEE 1202 TEST REFERENCED IN [28.3.1](#) – This paragraph applies the test method described as the FT4/IEEE 1202 Type of Flame Exposure (smoke measurements are not applicable) in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. This test differs from the UL test in loading (more cables are used, with small cables bundled, and the spacing between cables is limited), burner angle, and failure criterion. For compliance, this test damages less than 150 cm (59 in) of cable. A cable that complies either is not marked or it bears the designation "FT4/IEEE 1202" or "FT4" legible on or through the outer surface or on a marker tape [see marking in [47.1\(i\)](#)].

d) TYPE CL3X and CL2X CABLES – Type CL3X and CL2X cables comply with the VW-1 vertical-specimen flame test. The cable is not marked "VW-1".

e) TYPE PLTC CABLE – Type PLTC tray cable complies with a 70,000 Btu/h (20.5 kW) vertical-tray flame test. The cable manufacturer chooses the test in (c)(1) or (c)(2). This test is applied to cable that is surface marked or designated by a marker tape as "PLTC".

1.7 The overall jacket on Type PLTC cable is a "gas/vapor-tight continuous sheath" in the sense discussed in sections 501.15 (D) and 501.15 (E) of the National Electrical Code, ANSI/NFPA 70. Cables that are surface marked "-ER" are for use as exposed runs between a cable tray and utilization equipment where the cables are continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channel.

1.8 With certain exceptions, as noted in [1.9](#), Type CL3X and CL2X cables are required by the NEC to be used with protection such as raceway. The Type CL3 and CL2 and other cables covered in these requirements that are not required by the NEC to be used in raceway are capable of use without the physical protection of raceway but may be pulled into conduit or installed in other raceway.

1.9 Type CL3X and CL2X cables are limited by the NEC to use in unconcealed spaces in which the exposed length of cable does not exceed 10 ft or 3.05 m, and in raceway. These NEC limitations do not apply to Type CL3X and CL2X cables that are smaller in diameter than 0.25 in or 6.35 mm and are used in a one-, two-, or multi-family dwelling.

1.10 These requirements do not cover cables that contain conductors for electric-light, power, or Class 1 circuits. These requirements do not cover optical-fiber cables that do not contain any electrical conductors. These requirements do not cover communication cables (see the Standard for Communications Cables, UL 444) or cables for power-limited fire-alarm circuits (see the Standard for Cables for Power-Limited Fire-Alarm Circuits, UL 1424). These requirements do not cover vault-lacing cable, which is for use in concrete as part of a theft-alarm system.

1.11 These requirements do not cover the optical or other performance of any optical-fiber member or group of such members. See [8.3](#).

2 Units of Measurement

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

3 References and Terms

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

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

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

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

CONSTRUCTION

4 Materials

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

4.2 Power-limited circuit cable shall comply in all respects with the applicable requirements for construction details, test performance, and markings.

5 Conductors

5.1 Conductors shall comply in size (see [5.2](#)) and material with [Table 5.1](#). The nominal diameters of solid and stranded conductors which are 30 - 6 AWG conductor size, that are indicated in [Table 5.2](#) and Table 20.1 in UL 1581 when conductor size is smaller than 30 AWG, are to be used in calculating the dimensions required for various parts of the cable when using [Table 13.1](#), [Table 13.2](#), [Table 13.3](#), [Table 14.1](#), [Table 14.2](#), [Table 15.1](#), and [Table 21.1](#). The length of lay of the wires (strands) of a bunch-stranded conductor shall not exceed 20 times the calculated diameter over the assembled conductor for 19 – 6 AWG conductors and shall not exceed 30 times the calculated diameter over the assembled conductor for 30 – 20 AWG conductors. For a bunch-stranded member of a rope-lay conductor, the length of lay of the individual strands within the bunch shall not be more than 30 times the outside diameter of the member. The length of lay of the member in the outer layer of a rope-lay conductor shall be 8 – 16 times the outside diameter of that layer.

Table 5.1
Conductors

Cable types	AWG sizes of thermocouple-extension wire ^a	AWG sizes of soft-annealed copper conductors ^b	AWG sizes of solid or stranded copper-clad steel conductors	AWG sizes of solid or stranded silver plated steel conductors	AWG sizes of solid copper-clad aluminum conductors
CL3P, CL3R, CL3, CL3X	24 – 12	24 ^c , 23 – 12, 11 ^f , 10 ^f	28 ^{c, f} , (27 – 10) ^f	None	None
CL2P, CL2R, CL2, CL2X	24 – 12	30 ^{c, d} , (29 – 25) ^d , 24 – 12, (11 – 6) ^e	28 ^{c, e} , (27 – 6) ^e	30 ^{c, d, e} , (29 – 25) ^d , (24 – 12) ^e	16 ^g
PLTC	22 – 12	22 – 12	None	None	None

^a The sizes of thermocouple-extension wire are nominal and are intended only for use in the cable marking that is specified in [47.1](#) (b)(5) or (b)(6). The conductor in a thermocouple-extension wire is not required to comply with a diameter or resistance value.

^b A copper conductor shall be round and shall be solid or stranded. A stranded conductor shall consist of round strands with a right- or left-hand direction of lay. Seven strands, concentric, is the stranding assumed in these requirements, however, individual strand diameter, any mix or different strand diameters, the number of strands, and the stranding type are not specified. A solid copper conductor and the individual wires (strands) of a stranded copper conductor shall comply with ASTM B 3. See [6.1 – 6.4](#) (metal coating) and [20.1 – 20.9](#) (d-c resistance).

^c Where conductors are smaller than 30 AWG for copper or silver-plated steel, 28 AWG for copper-clad steel, the cable is to be shown by test to have a breaking strength of at least 25 lbf or 111 N or 11.3 kgf in accordance with Section [44](#).

^d 25 AWG and smaller copper and silver-plated steel conductors are only for either of the following:

a) In a cable that has a breaking strength shown by test to be at least 25 lbf or 111 N or 11.3 kgf in accordance with Section [44](#). 30 – 25 AWG conductors are acceptable without the strength test in a cable that contains four or more conductors.

b) As the central conductor in a coaxial member.

^e For Class 2: 11 – 6 AWG copper conductors are only for multiple-conductor jacketed cables (integral or nonintegral) employing the surface marking AUDIO ONLY or as the central conductor in a coaxial member. 6 AWG and smaller copper-clad steel conductors are only for the central conductor in a coaxial member. Copper-clad steel conductors shall have 21 percent or higher conductivity in accordance with ASTM B 869. Silver plated steel conductors shall have 12 percent or higher conductivity.

^f For Class 3: 11 and 10 AWG copper conductors and 10 AWG and smaller copper-clad steel conductors are only for the central conductor in a coaxial member. Copper-clad steel conductors shall have 21 percent or higher conductivity in accordance with ASTM B 869.

^g Copper Clad Aluminum is permitted for HVAC and Thermostat wiring used in a Class 2 circuit. CCA conductors shall have 10 percent or higher conductivity in accordance with ASTM B 566.

Table 5.2
Conductor diameters

AWG size of conductor	Solid conductor				Nominal diameter of stranded conductor	
	Nominal diameter		Minimum diameter			
	inch	mm	inch	mm	inch	mm
36	0.0050	0.127	0.0049	0.126	0.0060	0.152
34	0.0063	0.160	0.0062	0.158	0.0075	0.191
32	0.0080	0.203	0.0079	0.201	0.0100	0.254
30	0.0100	0.254	0.0099	0.251	0.0113	0.287
29	0.0113	0.287	0.0112	0.284	0.0128	0.325
28	0.0126	0.320	0.0125	0.318	0.0143	0.363
27	0.0142	0.361	0.0141	0.358	0.0161	0.409
26	0.0159	0.404	0.0151 ^b	0.384 ^b	0.0180	0.457
25	0.0179	0.455	0.0170 ^b	0.432 ^b	0.0203	0.516

Table 5.2 Continued on Next Page

Table 5.2 Continued

AWG size of conductor	Solid conductor				Nominal diameter of stranded conductor	
	Nominal diameter		Minimum diameter			
	inch	mm	inch	mm	inch	mm
24	0.0201	0.511	0.0191 ^b	0.485 ^b	0.0228	0.579
23	0.0226	0.574	0.0215 ^b	0.546 ^a	0.0256	0.650
22 PLTC	0.0253	0.643	0.0250 ^a	0.635 ^a	0.0287	0.729
Others			0.0240 ^b	0.610 ^b		
21 PLTC	0.0285	0.724	0.0282 ^a	0.717 ^a	0.0323	0.820
Others			0.0271 ^b	0.688 ^b		
20 PLTC	0.0320	0.813	0.0317 ^a	0.805 ^a	0.0362	0.919
Others			0.0304 ^b	0.772 ^b		
19 PLTC	0.0359	0.912	0.0355 ^a	0.902 ^a	0.0407	1.03
Others			0.0341 ^b	0.866 ^b		
18	0.0403	1.020	0.0399	1.013	0.0456	1.16
17	0.0453	1.150	0.0448	1.138	0.0513	1.30
16 ^c	0.0508	1.290	0.0503	1.278	0.0576	1.46
15	0.0571	1.450	0.0565	1.435	0.0647	1.64
14	0.0641	1.630	0.0635	1.613	0.0727	1.85
13	0.0720	1.83	0.0713	1.81	0.0816	2.07
12	0.0808	2.05	0.0800	2.03	0.0915	2.32
11	0.0907	2.30	0.0900	2.28	0.103	2.62
10	0.1019	2.59	0.101	2.56	0.116	2.95
9	0.1144	2.906	0.113	2.88	0.130	3.30
8	0.1285	3.264	0.127	3.23	0.146	3.71
7	0.1443	3.665	0.143	3.63	0.164	4.17
6	0.1620	4.115	0.160	4.07	0.184	4.67

^a Minimum diameter (0.99 x nominal) of a solid conductor of this size in a Type PLTC cable. See corresponding resistance (1.02 x nominal) in [Table 20.1](#).

^b Minimum diameter (0.95 x nominal) of a solid conductor of this size in all cables other than Type PLTC. See corresponding resistance (1.1 x nominal) in [Table 20.1](#).

^c 16 AWG CCA is not available as a stranded conductor.

5.2 All solid and stranded conductors are to be identified in the cable, tag, reel, or carton size markings as a particular AWG size. The size of a solid conductor shall be verified either by determination of the d-c resistance or, as described in [5.6](#), by determination of the diameter. The size of a stranded conductor shall be verified either by determination of the d-c resistance or by determination of the cross-sectional area as described in [5.6](#). Determination of the conductor size by measurement of the d-c resistance is to be as described in D-C Resistance Test of Copper Conductors, Section [20](#), and Table 30.1 – 30.11 in UL 1581 when conductor size is smaller than 30 AWG, and is the referee method in all cases.

5.3 Each conductor shall be continuous throughout the entire length of the finished cable – see test in [16.1](#) and [16.2](#).

5.4 A joint in a solid conductor or in one of the individual wires of a stranded conductor shall be made in a workmanlike manner, shall be smooth, and shall not have any sharp projections. A joint in a stranded conductor is to be made by separately joining each individual wire, or is to be made by machine brazing or welding of the conductor as a whole provided that the resulting solid section of the stranded conductor is not longer than 1/2 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). A joint made after insulating shall not increase the diameter of the solid conductor or individual wire (strand) by more than 20 percent. Joints made after insulating shall be made prior to further processing and shall be insulated by heat-shrinkable tubing or by applying the original or investigated comparable insulation by means of a bonded patch or molding, and shall comply with the requirements in this Standard. A jacket that is damaged to the point that the underlying assembly is exposed or that is opened for the purpose of repairing a conductor either:

- a) Shall be stripped and replaced in its entirety, or
- b) A second, duplicate jacket shall be applied over the first for the entire length of the cable.

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

5.5 Any section of conductor that includes a factory joint shall have a tensile strength that is not less than 85 percent of the tensile strength of an adjacent section of the conductor without a joint.

5.6 In place of complying with the d-c resistance requirement in Section 20, at the cable manufacturer's option, a copper conductor shall instead comply with the following requirement:

a) **SOLID CONDUCTOR** – The diameter of a solid conductor shall not be smaller than the minimum diameter indicated for the size in [Table 5.2](#) (see [5.2](#)) when the diameter of the conductor is determined from measurements as follows:

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

2) Each minimum diameter indicated in [Table 5.2](#) is an absolute minimum. The unrounded average of the two diameter readings is therefore to be compared directly with the minimum in the table for the purpose of determining whether the solid conductor does or does not comply with the diameter requirement.

b) **STRANDED CONDUCTOR** – The cross-sectional area of a stranded copper conductor, copper-clad steel conductor or silver plated steel conductor of a standard (see [5.2](#)) AWG size and having only round strands shall not be smaller than the minimum area indicated for the size in the 0.98 × nominal column in Table 20.1 of UL 1581. The cross-sectional area of the stranded conductor is to be determined as the sum of the areas of its component round strands. However, when the sum of the strand areas does not comply, the result of a determination of the conductor area by the test Cross-Sectional Area by Mass (Weight) Method, in UL 2556 is to be taken as conclusive.

6 Metal Coating

6.1 If the insulation adjacent to the copper conductor is of a material that corrodes unprotected copper in the test Copper Corrosion, described in UL 2556, the conductor shall be covered with a coating of tin complying with ASTM B 33, of a tin/lead alloy complying with ASTM B 189, of nickel complying with ASTM B 355), of silver complying with ASTM B 298, or of another metal or alloy (evaluation required).

6.2 For silver plated steel conductors of a specific diameter, the plating thickness of silver or combined silver over nickel plating shall not be less than that specified for silver coating thickness of 1.25 percent as defined in ASTM B 501-93, Standard Specification for Silver-Coated, Copper-Clad Steel Wire for Electronic Application, Table 1.

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

6.4 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 accordance with [10.2](#) (c). Otherwise, conductors shall not be used in a cable with a temperature rating higher than indicated in [Table 6.1](#).

Table 6.1
Maximum temperature rating of cable relative to conductor material

Conductor composition	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
Copper or copper-clad steel, uncoated or coated with tin or a tin/lead alloy	150°C (302°F)	200°C (392°F)
Copper, coated with silver	200°C (392°F)	200°C (392°F)
Copper, coated with nickel	over 200°C (392°F)	over 200°C (392°F)
Silver-plated steel	200°C (392°F)	200°C (392°F)

7 Insulation

7.1 Material and application

7.1.1 Each conductor shall be insulated for its entire length with one or more of the insulation materials indicated in Section 50 of UL 1581. For those materials where there are multiple tables in Section 50 for a particular material/temperature rating combination, the table referencing power limited circuit cable in the title shall be used, otherwise the tables referenced in [Table 7.1](#) shall be used. The insulation shall be solid or may be expanded (foamed). In any case, a solid dielectric skin (a thin, solid, extruded layer that may or may not be separable) of the same or other material may be applied over the solid insulation or over the foam. The material insulation in an air-gap coaxial member shall consist of a solid tube over a solid spacer. Otherwise, the insulation shall be applied directly to the conductor, shall have a circular cross section, and shall fit tightly to the conductor but shall not adhere excessively (no test). The air gap coax construction consists of two concentric tubes with integral spacers to maintain an air gap between inner and outer tubes. The insulation shall be uniform and shall not have any defects (bubbles, open spots, rips, tears, cuts, or foreign material) that are visible with normal or corrected vision without magnification.

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

- a) Material generically different from any insulation or jacket material that is named in Section 50 of UL 1581 for the construction (new material).

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

The temperature rating of materials (a) and (b) shall be the temperature rating for the cable determined as specified in [13.1](#). The thicknesses of insulation and/or jacket using materials (a) and/or (b) shall be as required for the specific cable type. Investigation of the electrical, mechanical, and physical characteristics of the cable using material (a) and/or (b) shall show the material(s) to be comparable in performance to an insulation or jacket material named in Section 50 of UL 1581 for the required temperature rating. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage-withstand.

7.2 Properties

7.2.1 General

7.2.1.1 An integral insulation and jacket shall be tested to, and meet the requirements of, a jacket material. See [7.2.4](#) and [7.2.5](#).

7.2.2 Unaged and heat-aged requirements for insulation on conductors rated 60°C in all cables except Type PLTC

7.2.2.1 Specimens of unaged solid single-layer insulation removed from finished insulated conductors shall have a minimum tensile strength of 1200 lbf/in² or 8.27 MN/m² or 827 N/cm² or 0.844 kgf/mm² and a minimum elongation of 100 percent when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength), in UL 2556. There shall be no cracks on either the inside or the outside surface of solid, foamed, or multi-layered insulation after flexing around a mandrel after air-oven aging. Specimens of the insulated conductors approximately 12 in or 300 mm long shall be placed in a circulating air oven conforming to ASTM D 5423 (Type II ovens) and D 5374 and maintained at a temperature of 100 ±2°C (212 ±3.6°F) for 7 d (168 h) or 121 ±2°C (249.8 ±3.6°F) for 48 h at the manufacturer's option. After removal from the oven, the specimens shall be allowed to cool to room temperature and then wound tightly, for six close turns, around a mandrel having a diameter no greater than that of the insulated conductor under test. The insulation shall be examined for cracks using a lens having magnification of 5X. The insulated conductor shall then be straightened, one side of the tube of insulation sliced off with a knife or razor-blade, and the conductor removed to permit examination of the inner surface of the insulation.

7.2.3 Unaged and heat-aged insulation requirements for all cables to be rated 75°C or greater, and PLTC to be rated 60°C or greater

7.2.3.1 Specimens of solid single-layered insulations removed from finished insulated conductors shall comply with the values of unaged elongation and tensile strength shown in the applicable physical-properties table for the material referenced in Section 50 of UL 1581 when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength), in UL 2556. Specimens of solid single-layered insulations except PVDF rated 125°C shall comply with the values of aged retention of elongation and tensile strength shown in the applicable physical-properties table for the material referenced in Section 50 of UL 1581 when tested in accordance with the test procedures in UL 1581. PVDF rated 125°C, foamed, and multi-layered insulations shall comply with [7.2.3.2](#).

7.2.3.2 Specimens of PVDF rated 125°C, foamed, or multiple-layered insulations approximately 300 mm (12 in) long shall be placed in a circulating-air oven conforming to ASTM D 5423 (Type II ovens) and D 5374 and aged for the appropriate time and temperature shown in Section 50 of UL 1581 for the insulation adjacent to the conductor. When the insulation is foamed, the aging shall be as specified for the solid insulation. After removal from the oven, the specimens shall be allowed to cool to room temperature and then wound tightly, for six close turns, around a mandrel having a diameter no greater than that of the insulated conductor under test. The insulation shall be examined for cracks using a lens having

magnification of 5X. The insulated conductor shall then be straightened, one side of the tube of insulation sliced off with a knife or razor-blade, and the conductor removed to permit examination of the inner surface of the insulation. There shall be no cracks on either the inside or the outside surface of the insulation.

Table 7.1
Specific table references in UL 1581

Generic material	Temperature rating	Applicable table of physical properties in UL 1581
CP	75 and 90C	50.1
EPDM	75	50.52
Neoprene	60	50.24
XLPE	105	50.245
XLPO	105	50.245
FEP	150	50.73

7.2.4 Unaged and heat-aged jacket requirements for all cables, except PLTC, to be rated 60°C

7.2.4.1 Specimens of jacket removed from completed cable shall comply with the unaged values shown in the applicable physical-properties table for the material referenced in Section 50 of UL 1581 when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength), in UL 2556. For all jacketed types, except PLTC, jacket material removed from a length of finished cable shall comply with the aging test as follows: 7 d (168 hr) 100 ±2°C (212 ±3.6°F), and at least 50 percent retention of the unaged elongation and 75 percent retention of unaged tensile strength when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength), in UL 2556 with the following modifications:

- a) Jackets thinner than 0.46 mm (0.018 in) average, 0.36 mm (0.014 in) minimum at any point shall be buffed only to remove imperfections, not natural indentations.
- b) Cables with an overall diameter not greater than 5.1 mm (0.200 in) may have their jackets tested as tubular specimens rather than as die-cut specimens. Tubular specimens shall not be used for larger cables.

7.2.5 Unaged and heat-aged jacket requirements for all cables to be rated 75°C or greater, and PLTC to be rated 60°C or greater

7.2.5.1 Specimens of jacket removed from completed cable shall comply with the unaged values shown in the applicable physical-properties table for the material referenced in Section 50 of UL 1581 when tested in accordance with the test Physical Properties (Ultimate Elongation and Tensile Strength), in UL 2556 with the modifications shown in [7.2.4.1](#). Specimens shall be aged for the length of time and at the temperature shown in the applicable physical-properties table for the material referenced in Section 50 of UL 1581 and tested in accordance with the relevant procedures in Physical Properties (Ultimate Elongation and Tensile Strength), in UL 2556. Minimum retention of elongation and tensile strength requirements in the applicable physical-properties table referenced in Section 50 of UL 1581 shall be used to determine compliance. This shall apply to all jacket materials except PVDF and PVDF copolymers rated 125°C. For these materials, the flexibility test described in [7.2.5.2](#) shall be used.

7.2.5.2 Aged specimens of PVDF and PVDF copolymer jackets rated 125°C in place on the cable shall not show any cracks on either the inside or outside surface after specimens are wound onto a cylindrical mandrel of the diameter indicated in [7.2.5.3](#).

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

7.3 Thicknesses

7.3.1 The dimensions of the spacer (thread, webs, for example) portion of the air-gap coaxial member are not specified. The average thickness and the minimum thickness at any point of the tube portion of an air-gap coaxial member or added the thickness of inner and outer layer insulation shall not be less than indicated in [Table 7.3](#). The thicknesses of the integral insulation (solid) and jacket on a flat, parallel cable shall not be less than indicated in [Table 7.2](#). The average thickness and the minimum thickness at any point of solid insulation (including any skin) on single-conductor cable for Class 2 circuits and on any conductor in an unjacketed ribbon cable (before and after separation) and in a twisted pair or other twisted multiple-conductor cable that is without an overall jacket and is for Class 2 circuits shall not be less than indicated in [Table 7.4](#). The average thickness and the minimum thickness at any point of solid insulation (including any skin) in a coaxial member, on a thermocouple-extension wire, and on every other conductor, including each conductor in jacketed ribbon cable before and after separation and in nonintegral flat cable, shall not be less than indicated in [Table 7.3](#). The average thickness and the minimum thickness at any point of solid insulation (including any skin) on conductors in single-conductor and twisted-pair or other twisted multi-conductor Type CL3 cable without an overall jacket shall be not less than indicated in [Table 7.5](#). The thicknesses of foamed insulation (including any skin) shall be evaluated based on the performance of the finished cable when tested in accordance with this Standard. In any case, the thicknesses of solid and foamed insulations (including any skin) are to be determined by means of measurements made as described in the test Thickness, in UL 2556, with the following modifications for stranded conductors that leave one or more strand impressions in the insulation that are too small to accommodate a pin of 1 mm (0.04 in) in diameter:

- a) The 0.003-in or 0.08-mm thickness-reduction allowance mentioned in UL 2556 is applicable to both average and minimum at any point measurements, and is to be applied only to insulation that is from a stranded conductor as mentioned above and has an average thickness (including any skin) of at least 0.015 in or 0.38 mm where the measurements are made using a micrometer microscope.
- b) Only an optical method as applicable from [7.3.2](#) 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.

7.3.2 Thickness measurements of a nylon or similar covering (see note (b) to [Table 7.3](#), [Table 7.4](#), and [Table 7.5](#)) 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 [7.3.1](#) (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.

7.3.3 For [7.3.1](#) (b), the conductor and any covering over the insulation or skin are to be removed from the finished insulated conductor, 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 Sections [7.3.4](#) – [7.3.7](#)) to the same degree as stated in [7.3.2](#) 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 [Table 7.3](#) or with whatever lesser thicknesses are established for the construction as the result of the insulation-crushing test described in Crushing Resistance Test of Insulation, Section [31](#).

7.3.4 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 0 – 4 and the figure in the fourth decimal place is odd or even, or if the figure in the fifth decimal place is 5 and the figure in the fourth decimal place is even (0, 2, 4, and so forth). A figure in the fourth decimal place is to be increased by 1 if the figure in the fifth decimal place is 6 – 9 and the figure in the fourth decimal place is odd or even, or if the figure in the fifth decimal place is 5 and the figure in the fourth decimal place is odd (1, 3, 5, and so forth).

7.3.5 Rounding off to the nearest 0.001 in:

A figure in the third decimal place is to remain unchanged if the figure in the fourth decimal place is 0 – 4 and the figure in the third decimal place is odd or even, or if the figure in the fourth decimal place is 5 and the figure in the third decimal place is even (0, 2, 4, and so forth). A figure in the third decimal place is to be increased by 1 if the figure in the fourth decimal place is 6 – 9 and the figure in the third decimal place is odd or even, or if the figure in the fourth decimal place is 5 and the figure in the third decimal place is odd (1, 3, 5, and so forth).

7.3.6 Rounding off to the nearest 0.001 mm:

A figure in the third decimal place is to remain unchanged if the figure in the fourth decimal place is 0 – 4 and the figure in the third decimal place is odd or even, or if the figure in the fourth decimal place is 5 and the figure in the third decimal place is even (0, 2, 4, and so forth). A figure in the third decimal place is to be increased by 1 if the figure in the fourth decimal place is 6 – 9 and the figure in the third decimal place is odd or even, or if the figure in the fourth decimal place is 5 and the figure in the third decimal place is odd (1, 3, 5, and so forth).

7.3.7 Rounding off to the nearest 0.01 mm:

A figure in the second decimal place is to remain unchanged if the figure in the third decimal place is 0 – 4 and the figure in the second decimal place is odd or even, or if the figure in the third decimal place is 5 and the figure in the second decimal place is even (0, 2, 4, and so forth). A figure in the second decimal place is to be increased by 1 if the figure in the third decimal place is 6 – 9 and the figure in the second decimal place is odd or even, or if the figure in the third decimal place is 5 and the figure in the second decimal place is odd (1, 3, 5, and so forth).

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

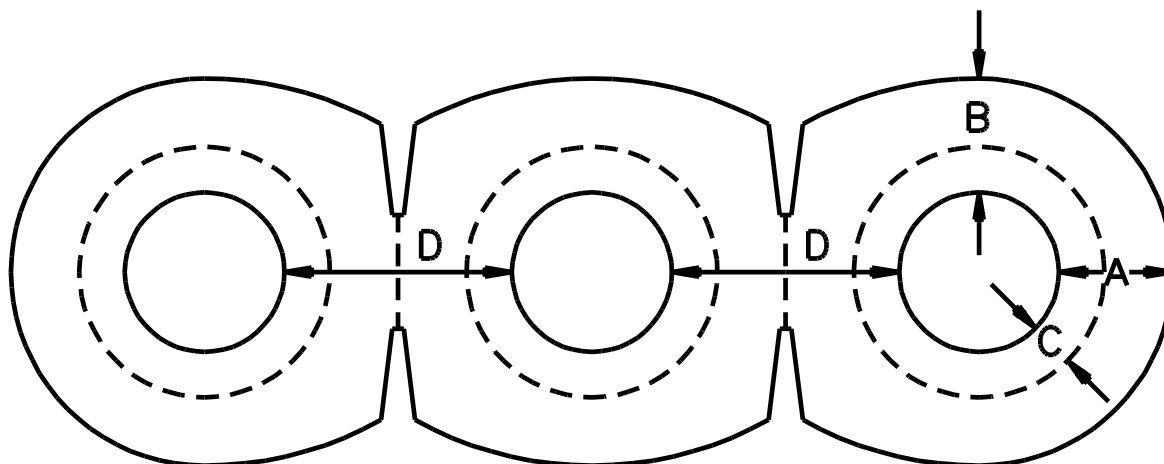
Cable types and sizes	Nominal thickness away from tear area(s) (vertical dashed line through web or webs in Figure 7.1) and outside point P or X (defined in Figure 7.2) A ^a (Information only – not a requirement)		Minimum thickness at any point before separation measured outside point P or X (defined in Figure 7.2) B ^a		Minimum thickness at any point after separation C ^a		Minimum distance between conductors D ^a	
	inch	mm	inch	mm	inch	mm	inch	mm
Types CL2P, CL3P, CL2R, CL3R, CL2, CL3, CL2X, and CL3X 24 – 12 AWG	0.020	0.51	0.018	0.46	0.010	0.25	0.030	0.76
11 – 8 AWG	0.030	0.76	0.027	0.69	0.013	0.33	0.047	1.19
7 – 6 AWG	0.045	1.14	0.040	1.02	0.027	0.69	0.080	2.03

^a Dimension A – D are illustrated in [Figure 7.1](#)

Figure 7.1

Integral flat cable

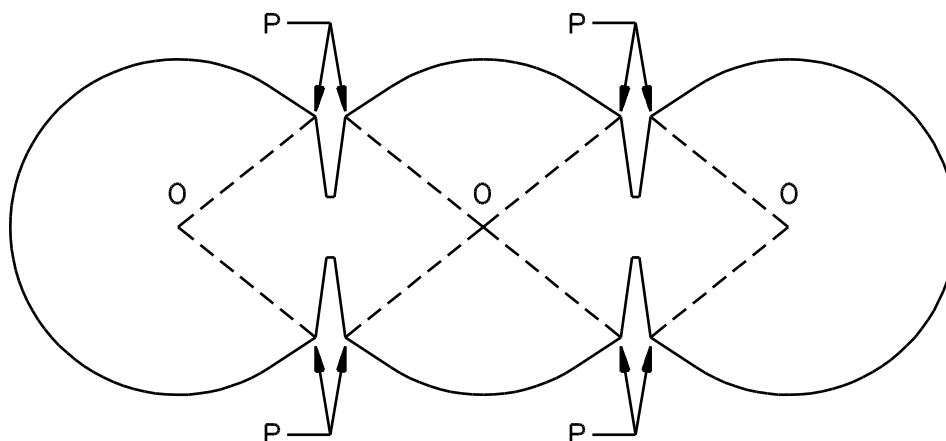
See [Table 7.2](#) for dimensions A – D



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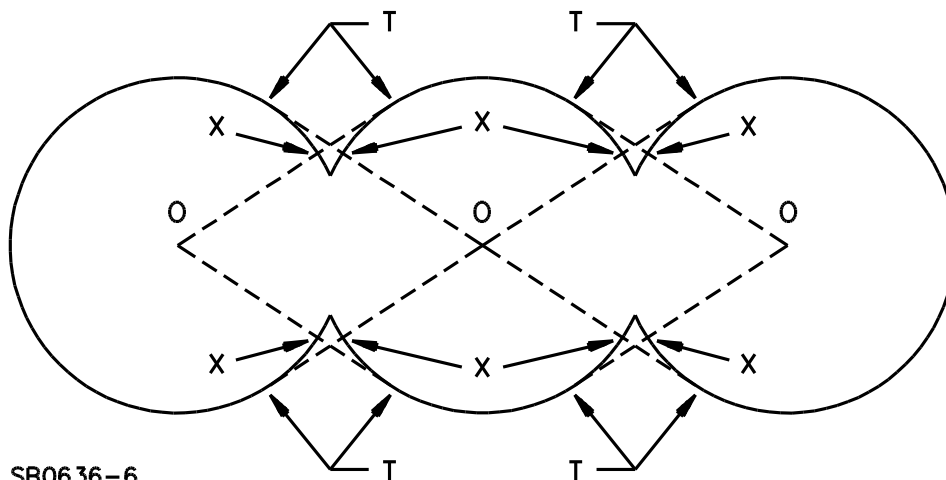
Figure 7.2

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



SB0636-5

Constructions with a Cross Section Having a Definite Point P at the Outer End of Each Valley Slope OP in each case is a straight line from the center O of a conductor to P on the same segment of the cross section. Thickness measurements are not to be made on any valley slope.



SB0636-6

Constructions with a Cross Section not Having a Definite Point to Mark the Outer End of Each Valley Slope OT in each case is a straight line from the center O of a conductor to T, the point of tangency, on the adjacent segment of the cross section. Thickness measurements are not to be made deeper on a valley slope than point X, which is the intersection of the line OT with the valley slope. Thickness measurements are to be made on each slope segment TX.

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

Cable Types	AWG size of conductor	Insulation whose unaged tensile strength is less than 2000 lbf/in ² or 13.79 MN/m ² or 1379 N/cm ² or 1.41 kgf/mm ²						PVC (1) with an unaged tensile strength of at least 2000 lbf/in ² or 13.79 MN/m ² or 1379 N/cm ² or 1.41 kgf/mm ² , and (2) with or without a covering ^b of nylon (see 3.3), PBT (see 3.4), or similar thermoplastic material or ECTFE, ETFE, FEP, HDPE, MFA, PFA, PTFE (TFE), PVDF, PVDF Copolymer, Semirigid PVC, PP, or XLPO	
		CP or silicone rubber		LDPE, PVC, or TPE (all without a nylon or similar covering)		PVC with a covering ^b of nylon (see 3.3), PBT (see 3.4), or similar thermoplastic material or TPE with a covering ^b of nylon or XL (without a nylon or similar covering)			
		A		B		C			
		Minimum acceptable average thickness	Minimum acceptable thickness at any point	Minimum acceptable average thickness	Minimum acceptable thickness at any point	Minimum acceptable average thickness	Minimum acceptable thickness at any point	Minimum acceptable average thickness	Minimum acceptable thickness at any point
		inch							
PLTC (not 28 – 23 AWG), CL3P, CL3R, CL3, CL3X	28 – 20	0.015	0.013	0.012	0.011	0.009 0.006	0.008 PLTC 0.005 Others	0.009 0.006	0.008 PLTC 0.005 Others
	19 – 15	0.015	0.013	0.015	0.013	0.009	0.008	0.009	0.008
	14 – 12, 11 ^d , 10 ^d	0.020	0.018	0.020	0.018	0.012	0.011	0.012	0.011
CL2P, CL2R, CL2, CL2X	36 – 32	0.009	0.008	0.009	0.008	0.0060	0.0050	0.0028	0.0022
	30 – 12, 11 ^c , 10 ^c	0.009	0.008	0.009	0.008	0.0060	0.0050	0.0050	0.0040
	9 ^c , 8 ^c	0.015	0.013	0.012	0.011	0.009	0.008	0.009	0.008
	7 ^c , 6 ^c	0.020	0.018	0.020	0.018	0.012	0.011	0.012	0.011
PLTC (not 28 – 23 AWG), CL3P, CL3R, CL3, CL3X	28 – 20	mm							
	28 – 20	0.38	0.33	0.30	0.28	0.23 0.152	0.20 PLTC 0.127 Others	0.23 0.152	0.20 PLTC 0.127 Others
	19 – 15	0.38	0.33	0.38	0.33	0.23	0.20	0.23	0.20
	14 – 12, 11 ^d , 10 ^d	0.51	0.46	0.51	0.46	0.30	0.28	0.30	0.28
CL2P, CL2R, CL2, CL2X	36 – 32	0.23	0.20	0.23	0.20	0.152	0.127	0.070	0.056
	30 – 12, 11 ^c , 10 ^c	0.23	0.20	0.23	0.20	0.152	0.127	0.127	0.102
	9 ^c , 8 ^c	0.38	0.33	0.33	0.28	0.23	0.20	0.23	0.20
	7 ^c , 6 ^c	0.51	0.46	0.51	0.46	0.30	0.28	0.30	0.28

^aConductors for Type PLTC cable shall not have insulation thicknesses less than the tabulated values. For cables other than Type PLTC, solid insulation for any size range indicated in column 2 is acceptable in average and point thicknesses thinner than indicated in this table if the insulation complies with the requirements in the Crushing Resistance Test of Insulation, Section 34:

Table 7.3 Continued on Next Page

Table 7.3 Continued

Cable Types	AWG size of conductor	Insulation whose unaged tensile strength is less than 2000 lbf/in ² or 13.79 MN/m ² or 1379 N/cm ² or 1.41 kgf/mm ²				PVC (1) with an unaged tensile strength of at least 2000 lbf/in ² or 13.79 MN/m ² or 1379 N/cm ² or 1.41 kgf/mm ² , and (2) with or without a covering ^b of nylon (see 3.3), PBT (see 3.4), or similar thermoplastic material or ECTFE, ETFE, FEP, HDPE, MFA, PFA, PTFE (TFE), PVDF, PVDF Copolymer, Semirigid PVC, PP, or XLPO			
		CP or silicone rubber		LDPE, PVC, or TPE (all without a nylon or similar covering)				PVC with a covering ^b of nylon (see 3.3), PBT (see 3.4), or similar thermoplastic material or TPE with a covering ^b of nylon or XL (without a nylon or similar covering)	
		A		B		C		D	
		Minimum acceptable average thickness	Minimum acceptable thickness at any point	Minimum acceptable average thickness	Minimum acceptable thickness at any point	Minimum acceptable average thickness	Minimum acceptable thickness at any point	Minimum acceptable average thickness	Minimum acceptable thickness at any point
a) When the 24 AWG size is tested for Types CL2P, CL2R, CL2, and CL2X, and b) When the smallest conductor in the size range desired is tested for Types CL3P, CL3R, CL3, and CL3X. ^b Measured by means of the micrometer microscope described in 7.3.2, the minimum thickness at any point of the nylon or similar covering shall not be less than 0.0020 in (2.0 mils) or 0.050 mm. A covering of a material other than nylon is acceptable in the same thickness as nylon if an engineering evaluation demonstrates that the other material has a temperature rating and flexibility, flammability, and other characteristics critical to the application that provide the particular construction with a comparable covering. Investigation of the mechanical-abuse characteristics is to include at least the crushing, impact, and abrasion comparison tests that are described in the tests Crush Resistance, Impact Resistance, and Abrasion Resistance, in UL 2556. ^c For Class 2: 11 – 6 AWG copper conductors are acceptable only in multiple-conductor jacketed cables (integral or nonintegral) employing the surface marking AUDIO ONLY or as the central conductor in a coaxial member. 6 AWG and smaller copper-clad steel conductors are acceptable only as the central conductor in a coaxial member. Copper-clad steel conductors shall have 21 percent or higher conductivity in accordance with ASTM B 869. ^d For Class 3: 11 and 10 AWG copper conductors and 10 AWG and smaller copper-clad steel conductors are acceptable only as the central conductor in a coaxial member. Copper-clad steel conductors shall have 21 percent or higher conductivity in accordance with ASTM B 869.									

Table 7.4
Thicknesses^a of solid insulation (including any skin) on 24 – 12 AWG conductors in single-conductor^b and twisted pair or other twisted multiple-conductor and ribbon type CL2P, CL2R, CL2, and CL2X cables without an overall jacket

Insulation material		Minimum average thickness of insulation		Minimum thickness at any point of insulation	
		inch	mm	inch	mm
CP, HDFRPE, LDFRPE, HDPE, LDPE, PP, PVC, SRPVC, TPE, XL, or XLPO	Without a nylon or similar covering	0.020	0.51	0.018	0.46
	With a covering ^b of nylon (see 3.3),	0.015	0.38	0.013	0.33

Table 7.4 Continued on Next Page