UL 1277

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Electrical Power and Control Tray Cables with Optional Optical-Fiber Members

Underwriters Laboratories Inc. (UL)
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UL Standard for Safety for Electrical Power and Control Tray Cables with Optional Optical-Fiber Members, UL 1277

Fourth Edition, Dated November 14, 2001

The new and revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated May 31, 2001. The bulletin(s) is now obsolete and may be discarded.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Recognition and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

This Standard consists of pages dated as shown in the following checklist:

Page	Date
1-44	November 14, 2001

UL 1277

Standard for Electrical Power and Control Tray Cables with Optional Optical-Fiber Members

First Edition – January, 1986
Second Edition – March, 1989
Third Edition – March, 1996

Fourth Edition

November 14, 2001

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Revisions of this standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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MARKINGS

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FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this standard, and that involves a risk of fire or of electric shock or injury to persons shall be evaluated using appropriate additional component and end-product requirements to maintain the level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard does not comply with this standard. Revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

1.1 These requirements cover electrical power and control cables consisting of either two or more current-carrying copper, aluminum, or copper-clad aluminum circuit conductors, or one or more pairs of thermocouple-extension wires. Thermocouple-extension wires and circuit conductors shall not be mixed in the same cable. These cables are constructed with or without either or both:

a) One bare or one or more insulated grounding conductor(s), and

b) One or more individually jacketed 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 composite cable) in accordance with Article 336 and other applicable parts of the National Electrical Code (NEC), ANSI/NFPA 70-2002 in cable trays, in raceways, and where supported in outdoor locations by a messenger wire.

1.2 The conductors for these cables are described in Sections 8.2 (NEC types) and 8.3 (other conductors). Cables are surface marked with the conductor type letters and/or with the temperature and “wet”, “dry”, or “wet or dry” ratings applicable to the insulation. Cables for direct burial are so marked on the surface. Cables that have a sunlight-resistant jacket are surface marked “sun res” or “sunlight resistant”. Cables may include one or more optical-fiber member(s) and are surface marked to so indicate. Cables that are surface marked “oil resistant II” have a jacket that is for exposure to mineral oil at temperatures not in excess of 75°C (167°F). Cables that are surface marked “oil resistant I” have a jacket that is for exposure to mineral oil at temperatures not in excess of 60°C (140°F). Each insulated conductor that is oil resistant II, oil resistant I, VW-1, gasoline-resistant, or has another individual conductor use is individually so marked.

1.3 The overall jacket on these cables is a “gas/vapor-tight continuous sheath” in the sense discussed in Sections 501.5(D) and 501.5(E) of the NEC (see 11.1.1). However, these requirements do not cover investigation of these cables for transmission of gases or vapors through the core so, when these cables are used in a hazardous location, they may need to be sealed as described in the NEC.

1.4 These cables may contain one or more metal shields but do not have a metal sheath or armor. Electrical cables with a metal sheath or armor are covered as Type MC in the Standard for Metal-Clad Cables (UL 1569).

1.5 Connectors and other fittings for these cables are covered in the Standard for Fittings for Cable and Conduit (UL 514B).

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

2 Units of Measurement

2.1 In addition to being stated in the inch/pound units that are customary in the USA, each numerical requirement 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 *Deleted November 14, 2001*

3.2 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).

CONSTRUCTION

4 Materials

4.1 Only materials that are acceptable for the particular use shall be employed in a cable.

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

5 General

5.1 Power and control tray cable shall be designated as Type TC and shall comply in all respects with the applicable requirements for construction details, test performance, and markings.

5.2 The electrical insulation in each of the following cables shall be of a material that is acceptable for use in wet locations:

a) Cable that is marked for direct burial.

b) Cable that is intended for use in wet locations.

6 All Conductors

6.1 Except for the thermocouple alloy for thermocouple exterior cables, only copper, copper-clad aluminum, or an acceptable aluminum alloy shall be used for the conductors in a cable. Soft-annealed copper shall comply with ASTM B 3-01. Solid aluminum conductors in sizes 12 – 8 AWG shall comply with the requirements for aluminum-wire stock (aluminum-alloy conductor material). All other aluminum conductors shall comply with the requirements for semi-annealed 8000 series aluminum conductors in Requirements for Aluminum Conductors of an 8000 Series Alloy, Section 10, of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. Copper-Clad aluminum conductors shall comply with the requirements in Requirements for Copper-Clad Aluminum Conductors, Section 11 of UL 1581.

6.2 A copper conductor shall not be smaller than 18 AWG and shall not be larger than 1000 kcmil. An aluminum or copper-clad aluminum conductor shall not be smaller than 12 AWG and shall not be larger than 1000 kcmil.

6.3 Each 6 – 4/0 AWG and 250 – 1000 kcmil conductor shall be stranded. An 18 or 16 AWG copper conductors shall comply with the requirements for fixture wire conductors in the Standard for Fixture Wire, UL 66. A 14 AWG or larger copper, or 12 AWG or larger aluminum conductor shall comply with the requirements in the Standard for Thermoset-Insulated Wires and Cables, UL 44, or in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, except as modified in this section.

6.4 Any joint in a conductor shall comply with the applicable standard indicated in 8.2, except that a splice is acceptable in an 18 – 10 AWG stranded conductor as a whole if the splice (butt splice) is made by machine brazing or welding such that the resulting solid section of the stranded conductor is not longer than 1/2 inch or 13 mm, the splice does not increase the diameter of the conductor, there are no sharp points, and the distance between splices in a single conductor does not average less than 3000 ft or 915 m in any reel length of that single insulated conductor. A butt splice shall be made before insulating or after insulating and prior to further processing. Butt splices of stranded conductors made after insulating and splices of insulated solid conductors made with other than the original insulation shall be the subject of an investigation that includes tests to determine that all electrical, physical, and mechanical properties of the original system of insulation and any jacket on the conductor have been restored at the point of each splice. All finished, insulated stranded conductors containing a butt splice or splice made with other than the original insulation shall not be marked as an NEC type but, for polarity identification, color coding and/or surface printing of hash marks, numbers, color names, or the like are acceptable.

7 Grounding Conductors

7.1 The cable may contain one or more grounding conductors. Each grounding conductor that is provided shall be of copper, aluminum, or copper-clad aluminum and shall not be smaller than indicated in the applicable Table 7.1 (90°C or 194°F conductors), Table 7.2 (75°C or 167°F conductors), or Table 7.3 (60°C or 140°F conductors). See 10.4.2(b) (shield as grounding conductor).

7.2 One grounding conductor (bare or insulated) in a flat cable (see 10.1.6 for round cable) may be in one location or in several sections (see size limits in 7.3) or may be distributed helically (concentric– see size limits in 7.4) over all of the conductors in the cable. Every other grounding conductor in a flat cable shall not be sectioned or distributed helically.

7.3 A grounding conductor smaller than 14 AWG shall not be sectioned. A sectioned grounding conductor shall not have any part (section) smaller than 18 AWG. See 6.2.

7.4 A copper grounding conductor smaller than 14 AWG shall not be distributed helically (concentric). A helically distributed grounding conductor shall not have any of its wires smaller than 26 AWG (15.9 mils or 0.404 mm in diameter) if of copper or 22 AWG (25.3 mils or 0.643 mm in diameter) if of aluminum.

7.5 One grounding conductor may be bare. All others shall be insulated. Grounding-conductor insulation and any individual covering over that insulation shall comply with Circuit Conductors, Section 8, as if the insulated grounding conductor were a circuit conductor and shall comply with 10.1.2 (insulation ratings) and 10.1.3 (assembly limits). See 10.1.4 (placement in a flat cable), 10.1.6 (placement in a round cable), 25.1 (color), and Insulated Equipment-Grounding Conductors, Section 32 and Isolated-Grounding Conductors, Section 33, (differentiation).

7.6 Any or all insulated grounding conductors may be designated as isolated-grounding conductors, with the outer surface of each such conductor marked as indicated in Isolated-Grounding Conductors, Section 33. See 10.1.4, 10.1.6 (cabling), 25.1 (color), and 29.1(l) (tag marking).

Table 7.1
Smallest grounding conductor in cable containing 90°C (194°F) circuit conductors

Size of largest ungrounded circuit conductor in cable		Grounding conductor		Maximum D-C resistance of sectioned or concentric grounding conductor			
		Copper	Aluminum or copper-clad aluminum				
				20°C (68°F)		25°C (77°F)	
Copper	Aluminum or copper-clad aluminum	Smallest AWG size of unsectioned grounding conductor	Smallest AWG size of unsectioned grounding conductor	Ohms based on 1000 feet	Ohms based on 1000 meters	Ohms based on 1000 feet	Ohms based on 1000 meters
18 AWG	–	18	–	7.06	23.2	7.19	23.6
17	–	17	–	5.59	18.3	5.70	18.7
16	–	16	–	4.45	14.6	4.53	14.9
15	–	15	–	3.44	11.3	3.51	11.5
14	12 AWG	14	12	2.73	8.96	2.78	9.14
13	11	13	11	2.16	7.10	2.20	7.24
12	10	12	10	1.72	5.64	1.75	5.75
11	9	11	9	1.37	4.48	1.39	4.56
10 – 8	8 – 6	10	8	1.080	3.546	1.102	3.615
7 – 4	5 – 2	8	6	0.6795	2.230	0.6929	2.274
3 – 2/0	1 – 3/0	6	4	0.4276	1.403	0.4359	1.430
3/0 AWG – 250 kcmil	4/0 AWG – 350 kcmil	4	2	0.2689	0.8820	0.2742	0.8993
300 – 400	400 – 600	3	1	0.2132	0.6996	0.2175	0.7133
450 – 650	700 – 1000	2	1/0	0.1691	0.5548	0.1724	0.5657
700 – 900	–	1	2/0	0.1340	0.4398	0.1367	0.4485
1000	–	1/0	3/0	0.1063	0.3487	0.1084	0.3556

Table 7.2
Smallest grounding conductor in cable containing 75°C (167°F) circuit conductors

Size of largest ungrounded circuit conductor in cable		Grounding conductor		Maximum D-C resistance of sectioned or concentric grounding conductor			
		Copper	Aluminum or copper-clad aluminum				
				20°C (68°F)		25°C (77°F)	
Copper	Aluminum or copper-clad aluminum	Smallest AWG size of unsectioned grounding conductor	Smallest AWG size of unsectioned grounding conductor	Ohms based on 1000 feet	Ohms based on 1000 meters	Ohms based on 1000 feet	Ohms based on 1000 meters
18 AWG	–	18	–	7.06	23.2	7.19	23.6
17	–	17	–	5.59	18.3	5.70	18.7
16	–	16	–	4.45	14.6	4.53	14.9
15	–	15	–	3.44	11.3	3.51	11.5
14	12 AWG	14	12	2.73	8.96	2.78	9.14
13	11	13	11	2.16	7.10	2.20	7.24
12	10	12	10	1.72	5.64	1.75	5.75
11	9	11	9	1.37	4.48	1.39	4.56
10 – 7	8 – 5	10	8	1.080	3.546	1.102	3.615
6 – 3	4 – 1	8	6	0.6795	2.230	0.6929	2.274
2 – 3/0	1/0 – 4/0	6	4	0.4276	1.403	0.4359	1.430
4/0 AWG – 300 kcmil	250 – 450 kcmil	4	2	0.2689	0.8820	0.2742	0.8893
350 – 550	500 – 800	3	1	0.2132	0.6996	0.2175	0.7133
600 – 800	900 – 1000	2	1/0	0.1691	0.5548	0.1724	0.5657
900 – 1000	–	1	2/0	0.1340	0.4398	0.1367	0.4485

Table 7.3
Smallest grounding conductor in cable containing 60°C (140°F) circuit conductors

Size of largest ungrounded circuit conductor in cable		Grounding conductor		Maximum D-C resistance of sectioned or concentric grounding conductor			
		Copper	Aluminum or copper-clad aluminum				
				20°C (68°F)		25°C (77°F)	
Copper	Aluminum or copper-clad aluminum	Smallest AWG size of unsectioned grounding conductor	Smallest AWG size of unsectioned grounding conductor	Ohms based on 1000 feet	Ohms based on 1000 meters	Ohms based on 1000 feet	Ohms based on 1000 meters
18 AWG	–	18	–	7.06	23.2	7.19	23.6
17	–	17	–	5.59	18.3	5.70	18.7
16	–	16	–	4.45	14.6	4.53	14.9
15	–	15	–	3.44	11.3	3.51	11.5
14	12 AWG	14	12	2.73	8.96	2.78	9.14
13	11	13	11	2.16	7.10	2.20	7.24
12	10	12	10	1.72	5.64	1.75	5.75
11	9	11	9	1.37	4.48	1.39	4.56
10 – 6	8 – 4	10	8	1.080	3.546	1.102	3.615
4 – 2	3 – 1/0	8	6	0.6795	2.230	0.6929	2.274
1 – 4/0	2/0 AWG – 300 kcmil	6	4	0.4276	1.403	0.4359	1.430
250 – 400 kcmil	350 – 600	4	2	0.2689	0.8820	0.2742	0.8993
500 – 750	700 – 800	3	1	0.2132	0.6996	0.2175	0.7133
800 – 1000	900 – 1000	2	1/0	0.1691	0.5548	0.1724	0.5657

8 Circuit Conductors

8.1 General

8.1.1 Each power and control circuit conductor shall be insulated.

8.2 NEC types

8.2.1 Each power and control circuit conductor that is available as a National Electrical Code type shall comply with this standard and shall be of one of the following types:

a) 14 – 4/0 AWG and 250 – 1000 kcmil branch-circuit types complying with the Standard for Thermoset-Insulated Wires and Cables (UL 44) or the Standard for Thermoplastic-Insulated Wires and Cables (UL 83):

Type(s)	Ratings for Type TC application	Standard
FEP and FEPB	200°C (392°F) dry 600 V special applications	83
	or	
	90°C (194°F) dry 600 V	83
RHH	90°C (194°F) dry 600 V	44
	or 2 kV	
SA	200°C (392°F) dry 600 V	44
	special applications or	
	90°C (194°F) dry 600 V	44
RHW-2	90°C (194°F) wet or dry	44
	600 V or 2 kV	
RHW	75°C (167°F) wet or dry	44
	600 V or 2 kV	
RHH or RHW	90°C (194°F) dry	44
	75°C (167°F) wet	
	600 V or 2 kv	
XHHW-2	90°C (194°F) wet or dry 600 V	44
XHHW	90°C (194°F) dry	44
	75°C (167°F) wet	
	600 V	
THHN	90°C (194°F) dry 600 V	83
THHW	90°C (194°F) dry	83
	75°C (167°F) wet	
	600 V	
THWN-2	90°C (194°F) wet or dry 600 V	83
THWN	75°C (167°F) wet or dry 600 V	83
THHN or THWN	90°C (194°F) dry	83
	75°C (167°C) wet	
	600 V	
THW-2	90°C (194°F) wet or dry 600 V	83
THW	75°C (167°F) wet or dry 600 V	83
TW	60°C (140°F) wet or dry	83
Z	150°C (302°F) dry 600 V special applications	83

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Table Continued

Type(s)	Ratings for Type TC application	Standard
ZW	or 90°C (194°F) dry 600 V 150°C (302°F) dry 600 V special applications or 75°C (167°F) wet 90°C (194°f) dry 600 V	 83 83 83

b) Fixture-wire types complying with the Standard for Fixture Wire (UL 66):

Type(s)	Ratings for Type TC application	Size range
ZHF	200°C (392°F) dry 600 V	18 – 14
ZF and ZFE	150°C (302°F) dry 600 V	18 – 14
PTFF	150°C (302°F) dry 600 V	18 – 14
PF and PGF	200°C (392°F) dry 600 V	18 – 14
PFF and PGFF	150°C (302°F) dry 600 V	18 – 14
SF-2	90°C (194°F) dry 600 V	18 – 14
SFF-2	90°C (194°F) dry 600 V	18 – 14
TFN	90°C (194°F) dry 600 V	18 – 16
TFFN	90°C (194°F) dry 600 V	18 – 16
RFHH-2 and RFHH-3	90°C (194°F) dry 600 V	18 – 16
RFH-2	75°C (167°F) dry 600 V	18 – 16
FFH-2	75°C (167°F) dry 600 V	18 – 16
TF	60°C (140°F) dry 600 V	18 – 16
TFF	60°C (140°F) dry 600 V	18 – 16

8.3 Other insulated conductors

8.3.1 Insulated conductors other than those described in 8.2 shall have materials in thicknesses and with temperature ratings appropriate for the specific construction of Type TC cable in which they are to be used. The materials shall be evaluated for the requested temperature rating as described in Long-Term Aging, Section 481 of the UL 1581 Reference Standard for Electrical Wires, Cables, and Flexible Cords. Investigation of the electrical, mechanical, and physical characteristics of these insulated conductors shall show these conductors to be comparable to the conductors described in 8.2. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage-withstand. Each such 18 – 13 AWG power and control conductor shall be of coated or uncoated soft-annealed copper.

8.4 Thermocouple-extension wires

8.4.1 Cables may contain one or more pairs of insulated solid thermocouple-extension wire of a thermocouple alloy in 24 – 12 AWG sizes. The sizes are nominal and are intended only for use in the cable marking that is described in 28.1(o). The conductor in a thermocouple-extension wire is not required to comply with a diameter or resistance value. The insulation shall comply with the requirements for a 14 AWG conductor in accordance with 8.2 or 8.3 and 11.3.

9 Optical-Fiber Member(s)

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

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

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

9.2 No electrical element of the cable shall be located in an optical-fiber member or group of optical-fiber members. Strength members, moisture barriers, heat shields, and other nonelectrical parts of an optical-fiber member are not specified; however, where any such part is of metal or other electrically conductive material, its presence shall be indicated by a marking as detailed in 29.1(j).

9.3 The energy that an optical-fiber cable carries in some laser systems presents a potential risk of eye or other injury to people. Consequently, where optical-fiber cables are installed in a laser system, the recommendations of the ANSI Z136 laser system safety standards should be applied. To help protect optical-fiber cable installers, users, service personnel, and anyone who handles the optical-fiber cable component of the system after installation, 29.1(i) specifies a tag, reel, or carton marking.

10 Assembly

10.1 Optical-fiber member(s) and circuit conductors

10.1.1 Optical-fiber member(s) alone shall not constitute a cable. One or more optical-fiber members may be included in a round or flat 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.

10.1.2 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. Insulated conductors with wet and dry ratings may be mixed in a given cable if the cable is rated dry.

10.1.3 Two or more of the insulated conductors indicated in 8.2 and 8.3 shall be assembled in a cable. Sizes may be mixed within the indicated ranges. In a given cable, all of the power conductors shall be of the same metal. Control conductors of 18, 16, and 14 AWG copper may be in a cable with power conductors of aluminum or copper-clad aluminum. Otherwise, all of the control conductors in the cable shall be of the same metal as the power conductors. A cable may contain precabled groups of conductors as described in 10.1.5.

10.1.4 In a cable with two, three, or four circuit conductors, the circuit conductors and any insulated (see 7.5) or bare grounding conductor may be cabled (round cable – see 10.1.5 – 10.1.7) or laid parallel (flat cable). As specified in 28.1(s), flat cables with five to eight 18 – 10 AWG insulated conductors are to be marked for use only in specific wiring systems. In a flat cable, any insulated (see 7.5) or bare grounding conductor:

a) May be a single conductor laid parallel between or beside the two circuit conductors,

b) May be divided into two equal parts (see size limits in 7.3) with each such part or section laid in one of the valleys between the circuit conductors, or

c) May be evenly distributed helically (concentric) (see size limits in 7.4 and lay length in 10.1.7).

10.1.5 The insulated 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 10.1. 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 10.1. 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 not less than five 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 10.1, 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 10.1. 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 but the outer layer shall have a left-hand lay as defined in 10.1.8. If the direction of lay is not reversed in a single-layer cable, the conductors or groups shall have a left-hand lay. See 10.2.1 for fillers and 10.3.1 for binders.

10.1.6 If more than one grounding conductor is provided in a round cable (see 7.2 for flat cable), one insulated (see 7.5) or bare grounding conductor in the cable either:

a) May be cabled with the circuit conductors as a single conductor or divided into two or more equal parts (see size limits in 7.3) with each such part or section cabled separately, or

b) May be evenly distributed helically (concentric – see size limits in 7.4).

Every other grounding conductor in a round cable shall not be sectioned or distributed helically. A bare or insulated grounding conductor shall not be laid straight.

Table 10.1
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.

10.1.7 The length of lay of a concentrically distributed, helically applied, bare grounding conductor shall be uniform throughout the length of the cable and shall not be more than 10 or less than 6 times either the calculated diameter over the concentric wires in a round cable or the calculated length of the major axis over the concentric wires in a flat cable.

10.1.8 A left-hand lay is defined as a counterclockwise twist away from the observer.

10.2 Fillers

10.2.1 Fillers shall be provided in a flat or round cable if the fillers are needed to make the finished cable firm at all points. Fillers shall be provided in a cable that is intended to be round if they are needed 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.

10.3 Binders

10.3.1 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 10.4.1– 10.4.3) 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 temperature rating as the overall cable jacket. The thicknesses of a binder jacket (extruded binder) shall not be less than indicated in Table 10.2 when measured as described in 10.3.2 and 10.3.3.

Table 10.2
Thickness of binder jacket

Calculated diameter of round assembly under binder jacket or calculated length of major axis of flat assembly under binder jacket		Minimum average thickness		Minimum thickness at any point	
Inch	mm	mils	mm	mils	mm
0 – 0.425	0 – 10.80	15	0.38	12	0.30
Over 0.425 but not over 0.700	Over 10.80 but not over 17.78	30	0.76	24	0.61
Over 0.700 but not over 1.500	Over 17.78 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	152	48	1.22

10.3.2 The average thickness of the jacket is to be determined by the difference method, which is to consist of determining the average diameter over the finished jacket, subtracting from it the diameter of the assembly under the jacket, and dividing the result by 2. The diameters over and under the jacket are to be determined by means of a diameter tape capable of making measurements to at least 0.01 inch or 0.1 mm with estimates to 0.005 inch or 0.05 mm. The average thickness of the jacket is acceptable if the value determined from the diameter-tape measurements equals or exceeds the average indicated in the table. If the average thickness determined from the diameter-tape measurements is less than the average indicated in the table, the jacket may be removed from the cable and the average thickness determined using the following referee procedure. The thickest (measured at a conductor, not at a filler or elsewhere) and thinnest portions of the jacket are to be located and measured directly with one of the micrometers specified in 10.3.3 (a) and (b). The average of these two micrometer measurements is to be taken as the average thickness of the jacket and is not to be less than the average indicated in the table.

10.3.3 The minimum thickness at any point of the jacket is to be determined by measuring a specimen of the jacket removed from the finished cable. The specimen is to be cut from the cable with its ends perpendicular to the longitudinal axis of the cable. Measurements are to be made by means of one of the following instruments:

a) A machinist's micrometer caliper that has a flat surface on the anvil and on the end of the spindle and is calibrated to read directly to at least 0.001 inch or 0.01 mm.

b) A dead-weight dial micrometer that has a presser foot 0.250 ±0.010 inch or 6.4 ±0.2 mm in diameter and exerts a total of 3.0 ±0.1 ozf or 0.84 ±0.02 N or 85 ±3 gf on the specimen – the load being applied by means of a weight. The dial micrometer is to be calibrated to read directly to at least 0.001 inch or 0.01 mm.

c) An optical device calibrated to read directly to at least 0.001 inch or 0.01 mm.

The entire surface of the spindle of the machinist's micrometer caliper or the presser foot of the dial micrometer is to be in contact with the specimen during each measurement.

10.4 Shield(s)

10.4.1 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.

10.4.2 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. A wrap that serves as a shield and also complies with Grounding Conductors, Section 7 is acceptable as a grounding conductor. A braid is not acceptable (wires too small) as a grounding conductor.

c) A metal-coated or uncoated copper tape.

d) An evaluated equivalent of any of the above.

10.4.3 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.

10.5 Metal sheath or armor

10.5.1 Type TC cable shall not have a metal sheath or armor.

11 Overall Jacket

11.1 Material and application

11.1.1 A jacket 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 acceptable evidence of the integrity of the jacket – that is, that the jacket constitutes the gas/vapor-tight continuous sheath mentioned in 1.3. The outer surface of the overall jacket may show impressions of the underlying assembly but shall not show depressions caused by unfilled spaces beneath the overall jacket.

11.1.2 The overall or other jacket shall be of one of the materials in Table 11.1 or of a material generically different from any jacket material covered in this table, or that is of material covered in this table yet does not comply with the short-term tests specified for the material. The jacket material shall have the temperature rating required for the specific power and control tray cable construction. Jacket materials not in Table 11.1 shall be evaluated for the requested temperature rating as described in Long-Term Aging, Section 481 of UL 1581. The mechanical and physical characteristics of the cable using either material shall be comparable in performance to a jacket material covered in Table 11.1. An investigation shall include tests such as crushing, impact, abrasion, deformation, and heat shock.

11.2 Properties

11.2.1 Specimens prepared from samples of the overall jacket taken from the finished cable shall exhibit physical properties that comply with the applicable table referenced in Table 11.1 or requirements developed for the jackets in 11.1.2 when tested as indicated in 11.2.2.

11.2.2 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).

Table 11.1
Overall Jacket

	Table of applicable physical properties of UL 1581[a]							
	200°C (392°F) dry cables	150°C (302°F) dry cables	125°C (257°F) dry cables	90°C (194°F) wet or dry cables; 90°C (194°F) dry cables; 90°C (194°F) dry, and 75°C (167°F) wet cables		75°C (167°F) dry cables and 75°C (167°F) wet or dry cables		60°C (140°F) dry cables and 60°C (140°F) wet or dry cables
Jacket material[a]	Required 200°C (392°F) jacket	Required 150°C (302°F) jacket	Required 125°C (257°F) jacket	Optional 90°C (194°F) jacket	Required 75°C (167°F) jacket	Optional 75°C (167°F) jacket	Required 60°C (140°F) jacket	Required 60°C (140°F) jacket
CP	–	–	–	50.1	50.1	50.1	50.10	50.10
Thermoplastic CPE	–	–	–	50.28	50.28	50.28	50.28	50.28
Thermoset CPE	–	–	–	50.29	50.30	50.30	50.30	50.30
ETFE	–	–	50.63	50.63	50.63	50.63	50.63	50.63
FEP	50.70	50.70	50.70	50.70	50.70	50.70	50.70	50.70
NBR/PVC	–	–	–	50.83	50.80	50.80	50.96	50.96
Neoprene	–	–	–	50.124	50.123	50.123	50.122	50.122
PFA	50.137	50.137	50.137	50.137	50.137	50.137	50.137	50.137
PVC	–	–	–	50.182	50.182	50.182[a]	50.182	50.182
PVDF	–	50.185	50.185	50.185	50.185	50.185	50.185	50.185
LDFRPE and HDFRPE	–	–	–	–	50.133	50.133	50.133	50.133
TPE	–	–	–	50.224	50.224	50.224	50.224	50.224
XL	–	–	–	50.231	50.231	50.231	50.230	50.230

[a] See Table 11.2 for oil resistance requirements.

Table 11.2
Oil resistance of jackets

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	In accordance with requirements in UL 1581 from Table 11.1	
Specimens of 75°C (167°F) oil-resistant jacket from cable marked "oil resistant II"[see 28.1(i)]: Aged in oil for 60 d at 75.0 ±1.0°C (167.0 ±1.8°F)	65 percent of the result with unaged specimens	65 percent of the result with unaged specimens
Specimens of 60°C (140°F) oil-resistant jacket from cable marked "oil-resistant I" [see 28.1(j)]: Aged in oil for 96 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	50 percent of the result with unaged specimens

11.3 Thicknesses

11.3.1 The average thickness and the minimum thickness at any point of the overall jacket shall not be less than indicated in Table 11.3 when measured as described in 10.3.2 and 10.3.3.

Table 11.3
Thicknesses[a] of overall jacket

Calculated diameter of round assembly under jacket or calculated length of major axis of flat assembly under jacket		Minimum average thickness		Minimum thickness at any point	
inch	mm	mils	mm	mils	mm
0 – 0.425	0 – 10.80	45	1.14	36	0.91
Over 0.425 but not over 0.700	Over 10.80 but not over 17.78	60	1.52	48	1.22
Over 0.700 but not over 1.500	Over 17.78 but not over 38.10	80	2.03	64	1.63
Over 1.500 but not over 2.500	Over 38.10 but not over 63.50	110	2.79	88	2.24
Over 2.500	Over 63.50	140	3.56	112	2.84

[a] Thicknesses other than those covered in this table are acceptable if the finished cable employing a jacket with the other thicknesses performs acceptably in the tests described in this standard. Crushing, impact, abrasion, and other tests may be part of the evaluation.

PERFORMANCE

12 Continuity Test of Conductors

12.1 All of the circuit conductors and grounding conductor in the finished cable shall be continuous throughout the entire length of the cable.

12.2 Finished cable shall be tested for continuity of each 18 – 10 AWG circuit and grounding conductor. One hundred percent of the production of each cable containing one or more 18 – 10 AWG conductors shall be tested by the cable manufacturer at the cable factory.

12.3 To determine whether or not the finished cable complies with the requirement in 12.2, each of the 18 – 10 AWG circuit and grounding conductors (one at a time) is to be connected in series with a lamp, buzzer, bell, or other indicator, and a power supply. The conductor is continuous from end to end of the finished cable if the lamp lights, the bell or buzzer sounds, or other indicator signals as intended.

13 Dielectric Voltage-Withstand Test

13.1 Each insulated conductor (each circuit and any insulated grounding conductor) in finished cable shall withstand without breakdown the 48 – 62 Hz essentially sinusoidal rms potential indicated for the size of the insulated conductor in Table 13.1. The test potential shall be applied for 60 s in the manner described in 13.2 – 13.5. One hundred percent of production shall be tested by the cable manufacturer at the cable factory.

Table 13.1
Dielectric voltage-withstand RMS test potential in volts

Size of circuit or insulated grounding conductor being tested	Type TW	PVC-insulated conductor other than Type TW	Conductor not Insulated with PVC	
			600-V	2000-V
18 and 16 AWG	–	2000	3000	–
14 – 10	1500	2000	3000	6000
8	2000	2000	3500	6000
7 – 2	2000	2000	3500	7500
1 – 4/0	2500	2500	4000	9000
250 – 500 kcmil	3000	3000	5000	10,000
550 – 1000	3500	3500	6000	11,000

13.2 The apparatus is to consist of a circuit breaker, ammeter, lamp bank, or other means for indicating a heavy current flow in the test circuit, and a testing transformer that complies with the following. The test potential is to be supplied by a 48 – 62 Hz isolation transformer whose output potential is continuously variable from near zero to at least the specified rms test potential. With a specimen in the circuit, the output potential is to have a crest factor (peak voltage divided by rms voltage) equal to 95 – 105 percent of the crest factor of a pure sine wave over the upper half of the output range. The output voltage is to be monitored continuously by a voltmeter that:

a) If of the analog rather than digital type, shall have a response time that does not introduce a lagging error greater than 1 percent of full scale at the specified rate of increase in voltage, and that

b) Has an overall accuracy that does not introduce an error exceeding 5 percent.

The maximum current output of which the transformer is capable shall enable routine testing of full reels of the cable without tripping of the circuit breaker by the charging current.

13.3 The test potential is to be applied between each insulated conductor (each circuit conductor and insulated grounding conductor) in turn and all of the following connected together: the other insulated conductors and any shield(s), any non-current-carrying metal part(s) (see 10.1.1), and any bare grounding conductors.

13.4 The applied rms potential is to be increased from near zero at an essentially uniform rate that:

a) Is not less than 100 percent of the voltage rating for the cable in 60 s and

b) Is not more than 100 percent in 10 s (the rate of increase is not to exceed 500 V/s in any case).

The increase is to continue in this manner until the voltage reaches the level specified in Table 13.1. If this level is reached without breakdown, the voltage is to be held constant at the specified level for 60 s and is then to be reduced to near zero at the rate mentioned above. The cable is not acceptable if breakdown occurs at less than the specified voltage as the voltage is being increased or decreased or if breakdown occurs in less than 60 s at the applied voltage.

13.5 During the period of application of the test voltage, observation is to be made to determine whether there is any current leakage or rupture of the insulation as indicated by the tripping of the circuit breaker or a deflection of the needle of the ammeter. After the test, the test leads are to be connected together and the circuit is to be closed to make certain that the current-indicating means functions as intended.

14 Vertical-Tray Flame Test

14.1 The overall jacket on and the insulation and any other nonmetallic material in the finished cable shall not exhibit damage that reaches the upper end of any sample after two sets of samples of a cable containing nine insulated 12 AWG conductors are separately installed in a vertical ladder type of cable tray and subjected to 20 min of flame as described under “UL Flame Exposure” or “FT4/IEEE 1202 Type of Flame Exposure” in the Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685. Smoke measurements are not applicable. See 14.2 and the caveat in 14.3.

14.2 The results of this test are to be judged as specified in UL 1685. The results using 9-conductor 12 AWG samples are representative of the performance of finished cable of the same construction in all (18 – 4/0 AWG and 250 – 1000 kcmil) sizes.

14.3 The results obtained using this test do not imply that cables of similar construction will necessarily perform the same way in other cable arrangements, other cable-tray configurations, and other environments.

15 Limited Smoke

15.1 Finished cables are eligible to be marked [see 28.1(r)] to indicate limited smoke (-LS) after sets of specimens as described in 15.2 are tested in accordance with the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685, and comply with the smoke release and cable damage requirements therein.

15.2 Specimens for Flame Propagation and Smoke-Release (-LS) testing shall consist of the smallest, largest, and an intermediate size of each construction plus any other size(s) in each construction that is appropriate because of the cable geometry and/or materials. Only finished cable is to be tested.

16 Cold Bend Test of Complete Cable

16.1 While at a temperature of −25.0 ±2.0°C (−13.0 ±3.6°F), the finished cable shall be capable of being wound around a right-circular mandrel of the diameter indicated in Table 16.1 without being damaged.

16.2 Four essentially straight test lengths of the complete finished cable are to be cooled for 4 h in circulating air precooled and maintained at a temperature of −25.0 ±2.0°C (−13.0 ±3.6°F). At the end of the fourth hour, the specimens are to be removed from the cold chamber one at a time and separately bent for the number of turns indicated in Table 16.1 around a wooden mandrel of the diameter indicated in Table 16.1 without any more tension than is necessary to keep the specimen surface in contact with the mandrel. The bending is to be made at a uniform rate in the direction opposite to any curvature in the specimen, and the time taken to remove a specimen from the cold chamber and to complete the bending is not to exceed 30 s.

Table 16.1
Multiplying factor for determining mandrel diameter for cold bend test

Specimen	Calculated outside diameter of the cable		Diameter of wooden mandrel as a multiple of the calculated outside diameter of the cable	Number of turns
	inch	mm		
Cable not containing any shield	0 – 0.700	0 – 17.78	5	4
	Over 0.700	Over 17.78	5	180° bend
Cable containing one or more shields	0 – 0.700	0 – 17.78	12	4
	Over 0.700	Over 17.78	12	180° bend

16.3 With a minimum of handling and flexing, the test lengths are then to be removed from the mandrel and placed on a horizontal surface where they are to remain undisturbed for at least 4 h before being examined for surface damage and then are 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. Internal cracking can be detected as circumferential depressions in the outer surface. If the first test length has any of these faults, acceptance is to be governed by the results with the three remaining test lengths. The cable is not acceptable if any of the three additional test lengths have one or more of these faults.

17 Cold-Impact Test

17.1 A cable is to be considered resistant to a temperature of −40°C (−40°F) if the overall jacket, the insulation on any circuit conductor or insulated grounding conductor, and any individual jacket on an insulated conductor or optical-fiber member do not crack or rupture when specimens of the finished cable are subjected to impact at −40.0 ±2.0°C (−40.0 ±3.6°F) as described in Impact at Abnormally Low Temperature, Section 593 of UL 1581. Such cable is to be marked "−40C" or "minus 40C" on the surface [see 28.1(n)] and on the tag, reel, or carton [see 29.1(l)].

18 Crushing Test – Cable Marked for Direct Burial

18.1 Finished cable whose overall jacket is marked [see 28.1(k)] to indicate that the cable is for direct burial shall withstand:

a) Without rupture of the overall jacket,

b) Without rupture of the insulation on any circuit conductor or insulated grounding conductor, and

c) Without rupture of any individual jacket on an insulated 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 18.2 – 18.6.

18.2 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.

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

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

18.5 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. 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 specified in 18.1(c) 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 increasing the force on the cable until the level

indicated in 18.1 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.

18.6 The test sample of the cable is to be advanced and crushed at each of the successive marks for a total of three crushes. The overall jacket, the insulation and any jacket on each circuit conductor, and the insulation and any jacket on any insulated grounding 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 or any individual jacket or any of the insulation is split, torn, cracked, or otherwise ruptured at any of the three points. Flattening of the overall or any individual jacket, the insulation, or any combination of these without rupture is acceptable.

19 Sunlight-Resistance Test

19.1 Finished cable whose overall jacket is marked [see 28.1(h)] to indicate that the cable is for use in sunlight is to be considered acceptable for sunlight-resistant use if the ratio of the average tensile strength and ultimate elongation of five conditioned specimens of the overall jacket to the average tensile strength and ultimate elongation of five unconditioned specimens of the overall jacket is 0.80 or more when the jacket from the finished cable is conditioned and tested as outlined in Section 1200 of UL 1581 using 720 h of carbon-arc exposure or xenon-arc exposure.

20 Deformation Test of Overall Thermoplastic or XL Jacket

20.1 Specimens of a thermoplastic or XL overall jacket taken from the finished cable shall not decrease more in thickness than the percentage indicated for the jacket material in Table 20.1 under the load indicated in Table 20.1 while being maintained at a temperature of 100.0 ±1.0°C (212.0 ±1.8°F) for HDFRPE and LDFRPE, 150.0 ±1.0°C (302.0 ±1.8°F) for TPE, and 121.0 ±1.0°C (249.8 ±1.8°F) for all other materials. The test is to be made as described under Deformation Test, Section 560 of UL 1581.

Table 20.1
Load and decrease in thickness for deformation test

Jacket material	Maximum decrease in thickness in percent	Load exerted on specimen by presser foot[a]	
		gf	N
Thermoplastic CPE	25	2000	19.61
ETFE	25	4000	39.23
FEP	25	4000	39.23
HDFRPE, LDFRPE	50	2000	19.61
PVC	50	2000	19.61
TPE	50	2000	19.61
XL	15	2000	19.61

[a] The specified load is not the weight to be added to the spindle of the dial micrometer but rather the total of the weight added and the weight of the spindle. Because the weight of the spindle varies from one dial micrometer to another, specifying the exact weight to be added to the spindle to achieve the specified load on the specimen is impractical in all cases except for an individual instrument.

21 Heat Shock Test of Overall Thermoplastic Jacket

21.1 An overall jacket of thermoplastic CPE, ETFE, FEP, PVC, or TPE shall not show any cracks either on the surface or internally after a specimen of the complete, finished cable is wound around a mandrel and is then subjected for 1 h to the temperature indicated in Table 21.1. The test is to be made as described in 21.2.

Table 21.1
Air temperature for heat shock test

Jacket material	Air-oven temperature
CPE and PVC	121.0 ±1.0°C (249.8 ±1.8°F)
TPE	150.0 ±1.0°C (302.0 ±1.8°F)
ETFE	180.0 ±1.0°C (365.0 ±1.8°F)
FEP	250.0 ±1.8°C (482.0 ±1.8°F)

21.2 A metal right-circular mandrel is to be used for this test. The mandrel is to have a diameter that is 3 times the outside diameter of finished cable that is 0 – 0.750 inches or 0 – 19.05 mm in calculated overall diameter, 8 times the outside diameter of finished cable that is 0.751 – 1.500 inches or 19.08 – 38.10 mm in calculated overall diameter, and 12 times the outside diameter of finished cable that is over 1.500 inches or 38.10 mm in calculated overall diameter. Four sample lengths of the complete cable are to be used. The diameter of the cable is to be measured by means of a diameter tape. One sample is to be bent for not less than 180° around the mandrel, with the cable in contact with the mandrel throughout the bend. The ends of the cable are to be securely held in place by a means such as friction tape. The assembly of cable and mandrel is to be heated in a full-draft circulating-air oven to the temperature indicated in Table 21.1 for 60 min. The assembly is to be removed from the oven and, while still hot and on the mandrel, the cable is to be examined for cracking of the inner and outer surfaces of the jacket. Cracking of the inner surface can be detected from circumferential depressions in the outer surface of the jacket. The overall jacket is acceptable if, for the first sample, there isn't any evidence of cracking. If the first sample shows any cracking, the test is to be repeated on each of the three remaining samples. The overall jacket is not acceptable if there is evidence of cracking in any of the three additional samples.

22 Impact Test

22.1 Finished cable marked for use in open wiring as indicated in 28.1 and 29.1 shall be capable of withstanding without contact between circuit conductors, and without contact between a circuit conductor and any shield and any bare or insulated grounding conductor connected together, 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 22.2 – 22.10. 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).

22.2 The results of testing finished cable containing three circuit conductors that are of identical size and kind and one bare or insulated grounding conductor of one or several sections (see 7.2 and 7.3) are to be considered representative of other cable constructions, of similar design, as indicated in Table 22.1.

22.3 A solid rectangular block of steel 4-3/4 inches or 121 mm long by 3 inches or 76 mm wide by 5 inch or 127 mm high, with its upper face (4-3/4 by 3 inches 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 inch or 19 mm in diameter and 4-3/4 inches 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.

22.4 An impact weight of 10 lb or 4.54 kg is to be used for test samples containing 14 AWG conductors, and an impact weight of 50 lb or 22.7 kg is to be used for test samples containing 2 AWG conductors. In each case, the impact weight is to consist of a solid rectangular block of steel with its lower face (the face that strikes the cable) 2 inches or 51 mm wide and 6 inches or 152 mm long. The edges of the lower face are to be rounded to a radius of 1/16 inch or 1.5 mm.

Table 22.1
Test samples and constructions that they represent

Construction of test samples	Cable constructions that are acceptable if the results of testing the samples are acceptable
Three 14 AWG circuit conductors with ground	Any number of conductors and mixture of sizes in the range of 18 – 5 AWG
Three 2 AWG circuit conductors with ground	Any number of conductors and mixture of sizes in the range of 4 AWG – 1000 kcmil
Both of the above tested separately	Any number of conductors and mixture of sizes in the range of 18 AWG – 1000 kcmil
[a] Cables containing at least three 4 AWG or larger conductors may also include 18 – 5 AWG conductors.	

22.5 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. A means is also to be provided to keep the weight from striking the cable more than once during each drop.

22.6 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 24.0 ±8.0°C (75.2 ±14.4°F) throughout the test.

22.7 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 inches or 305 mm from one end of the test length and the nine remaining marks are to be made at succeeding intervals of 12 inches or 305 mm down the length of the cable.

22.8 Each of the two insulated circuit conductors in the length of cable being tested is 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 supply circuit. The 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.

22.9 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 22.5. 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 for test samples containing 14 AWG conductors). The position of the 50 lb or 22.7 kg impact weight is to be adjusted to place the lower face of the weight 1 ft or 30.5 cm above the upper surface of the cable (this height results in an impact energy of 50 ft-lbf or 67.8 J or 691 kgf-cm for test samples containing 2 AWG conductors). 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 the grounding conductor.

22.10 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. The cable is not acceptable if any lamp lights at more than two of the ten impact points on any test length.

23 Crushing Test

23.1 Finished cable for use as indicated in 28.1 and 29.1 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. The test shall be conducted and the results evaluated as described in 22.2, in Table 22.1, and in 23.2 – 23.6.

23.2 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 inches or 50 mm wide. A solid steel rod 3/4 inch 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. See 22.6.

23.3 Round cable is to be tested in a continuous length of at least 100 inches 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 inches or 230 mm from one end of the test length and the nine remaining marks are to be made at succeeding intervals of 9 inches or 230 mm down the length of the cable.

23.4 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.

23.5 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.

23.6 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. Round cable is not acceptable if the average of the ten crushing trials is less than 1000 lbf or 4448 N or 454 kgf for a test sample containing 14 AWG conductors. Round cable is not acceptable if the average of the ten crushing trials is less than 2000 lbf or 8896 N or 907 kgf for a test sample containing 2 AWG conductors. Flat cable containing 14 AWG conductors is not acceptable if the average of the ten crushing trials is less than 1000 lbf or 4448 N or 454 kgf for either test length. Flat cable containing 2 AWG conductors is not acceptable if the average of the ten crushing trials is less than 2000 lbf or 8896 N or 907 kgf for either test length.

24 Test for Durability of Ink Printing

24.1 Printing of the identification of the responsible organization required in 28.1(g) and the identification of the factory required in 28.3 on the outside surface of the overall cable jacket qualifies where the ink printing on each of two specimens of the printed area of the finished cable remains legible after being rubbed repeatedly with felt as described in Durability of Indelible-Ink Printing, Section 1690 of UL 1581. Round cable is to be tested complete. The printed portions of flat cable are to be separated from the the rest of the cable and tested alone.

MARKINGS

25 Color of Insulated Grounding Conductor

25.1 An insulated grounding conductor, whether the conductor is sectioned or not, shall be finished to show the color green throughout the entire length and circumference of its outer surface with or without one or more straight or helical, broken (non-continuous) or unbroken yellow stripes. See 25.2 for details on stripes. No circuit conductor in the cable shall be green.

25.2 Stripes as specified in 25.1, 26.1, 27.1, 31.1, 31.2, 31.5, and 31.6 shall be of even or varying width and shall occupy a total of 5 – 70 percent of the calculated circumference of the outer surface of the finished insulated conductor with no individual width less than 5 percent of that same circumference. The width shall be measured perpendicular to each stripe. Where broken stripes are appropriate, they shall consist of a series of identical marks and spaces, the length of each mark shall be at least 1/8 inch or 3 mm and the linear spacing between marks shall not be greater than 3/4 inch or 19 mm.

26 Identification of Ungrounded Circuit Conductor(s)

26.1 Each ungrounded electrical circuit conductor in the cable shall be finished to show a color or combination of colors other than and in contrast with white, grey, or green. The outer surface so colored also complies with the intent of this requirement where it contains any one of the following added throughout the entire length of the cable in a color or combination of colors other than and in contrast with white, grey, and green.

a) One or more broken or unbroken straight or helical stripes. See 25.2 for details on stripes.

b) An unbroken series of identical hash marks or other symbols with dimensions as specified for stripes and with regular spacing.

c) Numerals, letters, words, or a combination thereof, that comply with this standard.

26.2 The markings covered in 26.1 and 27.1 shall not conflict with or be confusable with any of the other markings required or otherwise covered in this standard.

27 Identification of Grounded Circuit Conductor(s)

27.1 Where only one conductor is intended for use as a grounded circuit conductor, it shall be finished to show the color white or grey throughout the entire length and circumference of its outer surface, or shall be identified by three continuous straight or helical, unbroken white stripes on other than green insulation, along its entire length. Straight stripes are to be placed a nominal 120° apart. Where multiple grounded circuit conductors are used in a cable, no more than one shall employ white stripes. Additional conductors intended to be grounded circuit conductors shall be finished white (grey is not appropriate except in a 4 circuit conductor cable) and shall have any one of the following throughout the length of the wire or cable in a color or combination of colors other than and in contrast with, white, grey, or green (see 26.2):

a) One or more broken (non-continuous) or unbroken straight or helical stripes.

b) Numbers, letters and/or words that comply with this standard and are repeated at intervals no longer than 3 inches or 76 mm.

c) A raised tracer.

See 25.2 for details on stripes.

28 Information on the Cable

28.1 The following information (the sequence of the items is not specified) shall appear at the intervals specified in 28.2 on the outer surface of all cable that is made. Other information, where added, shall not confuse or mislead and shall not conflict with these requirements. See 30.1 for date marking. See also 33.1 – 37.3.1.

a) "Type TC" or "TC".

b) From Section 8 for the insulated conductors used, the maximum working potential of the cable:

For cables consisting of thermocouple-extension wires; no voltage marking is permitted.

For all other cables:

1) "600 volts" or "600 V".

2) "2000 volts", "2000 V", or "2 kV".

c) The type letters for each NEC conductor type used that is not individually marked with its type letters. The conductor type letters shall appear alone or shall be preceded by the word "Type" and/or followed by one of the designations "cdrs", "condrs", or "conductors". Cables consisting of thermocouple-extension wires shall not be marked with an NEC type designation [see (o) for the thermocouple-extension identification marking].

d) Either or both of the following for each NEC conductor type used that is individually marked with its type letters:

1) The conductor type letters marked as indicated in (c).

2) The cable temperature and wet/dry ratings from the center column of 8.2 (a) or (b) for the insulated conductors used. The designation "special applications" or a meaningful abbreviation such as "spec app" shall be included where an indication of the temperature 200°C is marked on a cable containing Type FEP or FEPB conductors, where an indication of the temperature 150°C is marked on a cable containing Type Z or ZW conductors, and where an indication of the temperature 200°C is marked on a cable containing Type SA conductors. The temperature rating shall be shown in one of the following ways. Degrees F shall not appear in any other manner.

___°C

___C

___°C (___°F)

___C (___F)

e) The cable temperature (90°C or 194°F maximum) and wet/dry ratings for the insulated conductors used that are not of the NEC type. The temperature rating shall be marked as indicated in the third and fourth sentences of (d)(2). A cable containing insulated conductors of

different temperature ratings shall be assigned the lowest temperature rating of any of the constituent conductors. A cable containing any insulated conductor that does not have wet-locations insulation shall be surface marked “dry”.

f) AWG or kcmil size (quantity not required) for a cable containing conductors that are all of the same size. For a cable containing a mixture of conductors sizes, the sizes and quantity of each are required on the cable surface except these markings are not required on the cable surface where each individual conductor is marked with its size. A single insulated conductor complying with the requirements in this standard and intended for use in voice communications during installation of the cable, may be surface marked “communications conductor”. This conductor is not required to be included in the cable surface marking.

g) Surface printing of the name of the cable manufacturer, that manufacturer’s trade name for the cable, or both, or any other appropriate distinctive marking by means of which the organization responsible for the cable is readily identifiable. Where the organization that is responsible for the cable is different from the actual manufacturer, both the responsible organization and the actual manufacturer shall be identified by name or by appropriate coding such as by trade name, trademark, or the assigned electrical reference number. It is appropriate to identify the actual manufacturer by the assigned colored marker thread or combination of colored marker threads; however, unless it or they supplement ink printing as stated in 28.4 and 28.5, colored thread(s) shall not be used to identify the responsible organization. The meaning of any coded identification shall be made available by the organization responsible for the cable. It is appropriate also to identify a private labeler; the means is not specified. See 28.3 – 28.6.

h) The designation “sun res” or “sunlight resistant” for cable that has an overall jacket complying with the sunlight-resistance test requirement in 19.1.

i) The designation “oil res II” or “oil resistant II” for cable that has an overall jacket complying with the 75°C (167°F) oil-resistance requirements in Table 11.2.

j) The designation “oil res I” or “oil resistant I” for cable that has an overall jacket complying with the 60°C (140°F) oil-resistance requirements in Table 11.2.

k) The designation “dir bur”, “direct burial”, or “for direct burial” for cable that complies with 5.2 (wet-locations insulation) and 18.1 – 18.6 (crushing test).

l) The supplementary letters “-OF” shall be added immediately after the type letters for each cable that includes one or more optical-fiber member or members.

m) The jacket temperature rating from Table 11.1 in the form “___C jkt” or “___C jacket” for 90, 75, or 60°C cable on which the overall jacket has the same temperature rating (rating not required) as the cable instead of 15°C (27°F) lower (rating required) than the cable rating.

n) A cable that complies with 17.1 (cold impact) shall be surface marked “−40C” or “minus 40C”. This marking is also required on the tag, reel, or carton – see 29.1(l).

o) For a cable consisting of thermocouple-extension wires, the cable surface shall be marked with the nominal AWG size(s) (see 8.4.1), and one of the designations “THCPL EXTN”, “For thermocouple-extension use only”, or “Thermocouple-extension wire only” plus either the combination(s) of thermocouple-extension conductor metals used or an industry designation for the combination.

p) The designation “Open Wiring” for cable that complies with the test requirements in Sections 22 and 23 and contains a grounding conductor complying with Section 7.

q) Where the vertical-tray flame test with which the cable complies (see 14.1) consists of the FT4/IEEE 1202 Type of Flame Exposure, the cable may be marked “FT4/IEEE 1202” or “FT4”. Where used, this marking is to be spaced from the other cable markings required in this paragraph.

r) Finished cables that comply with the flame-propagation and smoke-release requirements indicated in 15.1 and 15.2 are eligible to be marked on the outer surface with the designation “-LS”. Where used on cables which include one or more optical-fiber member(s) the “LS” designation shall be added as a suffix immediately following the “-OF” designation. Where used on cables which do not include optical-fiber members, the “-LS” designation shall be added as a suffix immediately following the type letters (“Type TC” or “TC”).

s) “For use in (name of system) only” for flat cable with five to eight 18 – 10 AWG insulated conductors.

28.2 The information specified in 28.1 and 35.2 shall be repeated at the following intervals throughout the entire length of the finished cable:

a) Size shall be repeated at intervals that are not longer than a nominal 24 inches or 610 mm (maximum 25 inches or 635 mm).

b) The marking in 35.2 for identification of copper-clad aluminum shall be repeated at intervals that are not longer than 6 inches or 150 mm.

c) All information other than size and the identification of copper-clad aluminum shall be repeated at intervals that are not longer than 40 inches or 1.02 m

28.3 One of the following means shall be used to identify the organization that is responsible for the cable [28.1(g)]:

a) Ink printing on the outer surface of the overall cable jacket, with the ink printing complying with the test in 24.1. See 28.4 in the case of ink printing that is not tested or does not comply with the test.

b) Indented or embossed printing on the outer surface of the overall cable jacket. See 28.6.

28.4 If ink printing of the organization identification required in 28.1(g) is not tested or does not remain legible after the test described in 24.1, the ink printing shall be supplemented by a thread or threads whose color or combination of colors is assigned to the responsible organization. If a glass-fiber thread or threads are used, the length of lay of the filaments in each basic strand shall not be longer than 1/3 inch or 8.5 mm. Marker threads may be located anywhere in the cable other than under the insulation.

28.5 If the organization responsible for the cable produces Type TC cable in more than one factory, the marking in 28.1(g) shall include an identification of the factory. If a colored thread or threads are used to supplement ink printing as stated in 28.4, the ply or the material of one or more of the threads used at each factory shall be different from the ply or material of the same color thread or threads used at every other factory. The organization responsible for the cable shall make available the meaning of the different plies and materials.

28.6 Indented printing and embossed printing shall not reduce the thickness of the overall cable jacket below the minimum acceptable at any point indicated in Table 11.3.

29 Information on the Tag, Reel, or Carton

29.1 A tag on which the following information is indicated plainly (the sequence of the items is not specified) shall be tied to every shipping length of the finished cable. However, where the cable is wound on a reel or coiled in a carton, it is appropriate for the tag to be glued, tied, stapled, or otherwise attached to the reel or carton instead of to the cable, or for the tag to be eliminated and the information printed or stenciled directly onto the reel or carton. Other information, where added, shall not confuse or mislead and shall not conflict with these requirements. See 30.1 for date marking. See also 33.1 – 37.3.1.

a) The following statement (use of the word “Type” is not required):

“Type TC cable for installation in accordance with Article 340 and other applicable parts of the National Electrical Code”.

b) From Section 8 for the insulated conductors used, the maximum working potential of the cable:

For cables consisting of thermocouple-extension wires:

1) No voltage marking.

For all other cables:

1) “600 volts” or “600 V”.

2) “2000 volts”, or “2000 V”, or “2 kV”.

c) The type letters for each NEC conductor type used that is not individually marked with its type letters. The conductor type letters shall appear alone or shall be preceded by the word “Type” and/or followed by one of the designations “cdrs”, “condrs”, or “conductors”. For cables consisting of thermocouple-extension wires, an NEC type designation shall not be used [see (m) for the thermocouple-extension identification marking].

d) Either or both of the following for each NEC conductor type used that is individually marked with its type letters:

1) The conductor type letters marked as indicated in (c).

2) The cable temperature and wet/dry ratings from the center column of 8.2(a) or (b) for the insulated conductors used. The designation “special applications” or a meaningful abbreviation such as “spec app” shall be included where an indication of the temperature 200°C is marked on a cable containing Type FEP or FEPB conductors, where an indication of the temperature 150°C is marked on a cable containing Type Z or ZW conductors, and where an indication of the temperature 200°C is marked on a cable containing Type SA conductors. The temperature rating shall be shown in one of the following ways. Degrees F shall not appear in any other manner.

___°C

___C

___°C (___°F)

___C (___F)

e) The cable temperature (90°C or 194°F maximum) and wet/dry ratings for the insulated conductors used that are not of an NEC type. The temperature rating shall be marked as indicated in the third and fourth sentences of (d)(2). A cable containing insulated conductors of different temperature ratings shall be assigned the lowest temperature rating of any of the constituent conductors. A cable containing any insulated conductor that does not have wet-locations insulation shall be surface marked "dry". Marking of the cable temperature and wet/dry ratings is not required on cable that is for 60°C (140°F) dry use.

f) The quantity (not required where all conductors are of the same size) and AWG or kcmil size of the insulated conductors that are not individually marked with a size designation. Where more than one size is used, the quantity and AWG or kcmil designations of each size that is included.

g) The name of the cable manufacturer, that manufacturer's trade name for the cable, or both, or any other appropriate distinctive marking by means of which the organization responsible for the cable is readily identifiable. Where the organization that is responsible for the cable is different from the actual manufacturer, both the responsible organization and the actual manufacturer shall be identified by name or by appropriate coding such as by trade name, trademark, or the assigned electrical reference number. It is appropriate to identify the actual manufacturer by the assigned colored marker thread or combination of colored marker threads. The meaning of any coded identification shall be made available by the organization responsible for the cable. It is appropriate also to identify a private labeler; the means is not specified.

h) A description of the colored marker thread(s) assigned to identify the organization that is responsible for the cable where the thread(s) are used in the cable to supplement ink printing on the cable as stated in 28.4 and 28.5.

i) For a cable that contains one or more optical fibers, the following statement or another statement to the same effect:

> "Optical-fiber portion(s) of cable are for installation (optical and electrical functions associated) as described in Article 770 and other applicable parts of the (National Electrical Code NFPA 70). Where optical fibers are installed in a laser system, the system shall comply with the ANSI Z136 laser system safety standards."

j) For a cable that contains one or more optical-fiber members with any individual optical-fiber member or group of such members having a metal or other electrically conductive part as described in 9.1 or 10.1.1, the following wording or other wording to the same effect:

> "Optical-fiber portion(s) of cable contain non-current-carrying metal or other electrically conductive parts."

k) For a cable that contains one or more isolated-grounding conductors, the quantity and AWG number or kcmil size of such conductor(s) in the following statement:

> "(Size) isolated-grounding conductor(s) included."

l) For a cable that complies with 17.1 (cold impact): "−40C" or "minus 40C".

m) For a cable consisting of thermocouple-extension wires, either of the designations (no abbreviation is to be used) "For thermocouple-extension use only" or "Thermocouple-extension wire only" plus either the combination of thermocouple-extension conductor metals used or an industry designation for the combination.

n) For a cable marked "Open Wiring", the words "For use in accordance with National Electrical Code Section 340.10(6)".

30 Date of Manufacture

30.1 The date of manufacture by month and year (or in the sequence month, day, and year) shall be included among the tag, reel, or carton markings described in 29.1, or shall be included among the cable markings described in 28.1 where legible on the outer surface of the cable. The date shall be shown in plain language, not in code.

31 Insulated Equipment-Grounding Conductors

31.1 Where one grounding conductor is provided and it is insulated, or where one insulated grounding conductor is provided in addition to a bare conductor:

a) The insulated grounding conductor shall be green or green with one or more straight or helical, broken (non-continuous) or unbroken yellow stripes (see 25.2 for details on stripes);

b) The surface of the conductor insulation shall be either unmarked or marked ("equipment ground" or equivalent) as indicated in 31.4 (it is also appropriate for a number or letter or other designation to be added as in "equipment ground 1", "equipment ground A", and the like); and

c) Where the insulated conductor is sectioned (as provided for in 10.1.6) and is marked, each section shall be identically marked.

31.2 Where two grounding conductors are provided and they are insulated, or where two insulated grounding conductors are provided in addition to a bare conductor, the insulated grounding conductors shall both be green or both shall be green with one or more yellow stripes, or one shall be green and the other green with one or more yellow stripes. Yellow stripes shall be straight or helical, broken (non-continuous) or unbroken. See 25.2 for details on stripes. Marking is not required where one conductor is green and the other is green and yellow. Where both conductors are green or both are green and yellow, the insulated grounding conductors shall be differentiated as follows:

a) NO BARE CONDUCTOR IN CABLE – Where one insulated grounding conductor is unmarked the other insulated grounding conductor shall be marked "equipment ground" or equivalent as indicated in 31.4. Where both insulated grounding conductors are marked, they shall be marked ("equipment ground" or equivalent) as indicated in 31.4 with the number "1" or the letter "A" or another initial designation of a series added on one conductor and the number "2" or the letter "B" or another second designation of a series added on the other conductor.

b) BARE CONDUCTOR INCLUDED IN CABLE – Where one insulated grounding conductor is unmarked the other insulated grounding conductor shall be marked "equipment ground" or equivalent as indicated in 31.4. Where both insulated grounding conductors are marked, they shall be marked ("equipment ground" or equivalent) as indicated in 31.4 and, counting the bare conductor as the first grounding conductor, the insulated grounding conductors shall be marked as "equipment ground 2" and "equipment ground 3" or equivalent, "equipment ground B" and

"equipment ground C" or equivalent, or otherwise as the second and third conductors of a series. The number "1", the letter "A", or any other initial designation of a series shall not be used.

31.3 Where more than two insulated grounding conductors are provided in the cable, they shall be identified and differentiated as indicated in 31.4 – 31.6.

31.4 Each insulated equipment-grounding conductor that is marked shall be marked "equipment ground" on its outer surface as specified in this section. The word "equipment" shall not be abbreviated. However, it is appropriate to substitute "grounding", "gnd", or "gndg" for "ground". It is also appropriate to add the word "conductor" or the abbreviation "cdr", "cndr", "condr", or "cond".

31.5 Where more than one insulated equipment-grounding conductor is surface-marked, each marked equipment-grounding conductor is to be differentiated from the other marked equipment-grounding conductor(s) by a number, letter, or other distinctive designation of a series – for example, "equipment ground 1", "equipment ground 2", and so forth in sequence. Where the cable contains surface-marked green conductors both with and without one or more straight or helical, broken (non-continuous) or unbroken yellow stripes, (see 25.2 for details on stripes), the designations on each shall be of a different type – for example, numbers on one and letters on the other as in "equipment ground 1", "equipment ground 2", and the like on the green conductors and "equipment ground A", "equipment ground B", etc. on the green and yellow conductors. Numbered (or lettered or otherwise designated) equipment-grounding conductors are appropriate in a cable containing identically designated isolated-grounding conductors – for example, "equipment ground 1", "equipment ground 2", "isolated grounding conductor 1", and "isolated grounding conductor 2" in the same cable (see the final sentence of 32.2).

31.6 Where the cable contains one or more surface-marked insulated equipment-grounding conductors in addition to:

a) One unmarked green conductor with or without one or more yellow stripes,

b) One unmarked green conductor plus one unmarked green conductor with one or more yellow stripes,

c) A bare conductor, or

d) 1 or 2 plus a bare conductor, the marked equipment-grounding conductors shall be designated with a sequence of numbers, letters, etc. that start above the total count of bare and/or unmarked equipment-grounding conductors in the cable. The intended sequencing is indicated in the following:

1) START WITH 2 OR ITS EQUIVALENT – Where there is a bare equipment-grounding conductor or a single unmarked insulated equipment-grounding conductor in the cable (count of 1), the marked conductors shall start with "equipment ground 2" or its equivalent. "Equipment ground", "equipment ground 1", and their equivalents shall not be used.

2) START WITH 3 OR ITS EQUIVALENT – Where there are two unmarked insulated equipment-grounding conductors in the cable without a bare conductor (count of 2), the marked conductors shall start with "equipment ground 3" or its equivalent. "Equipment ground", "equipment ground 1", "equipment ground 2", and their equivalents shall not be used.

3) START WITH 4 OR ITS EQUIVALENT – Where there are two unmarked insulated equipment-grounding conductors and a bare conductor in the cable (count of 3), the marked conductors shall start with “equipment ground 4” or its equivalent. “Equipment ground”, “equipment ground 1”, “equipment ground 2”, “equipment ground 3”, and their equivalents shall not be used.

Yellow stripes shall be straight or helical, broken (non-continuous) or unbroken. See 25.2 for details on stripes.

32 Isolated-Grounding Conductors

32.1 Each isolated-grounding conductor (see 7.6) shall be marked “isolated grounding conductor” on its outer surface. The word “isolated” shall not be abbreviated; however, the following substitutions are appropriate: “ground”, “gnd”, or “gndg” for “grounding” and “cdr”, “cndr”, “condr”, or “cond” for “conductor”.

32.2 Where more than one isolated-grounding conductor is used, each such conductor is to be differentiated from the other isolated-grounding conductor(s) by a number, letter, or other distinctive designation of a series in the surface marking – for example, “isolated grounding conductor 1”, “isolated grounding conductor 2”, and so forth in sequence. Where the cable contains isolated-grounding conductors both with and without one or more yellow stripes, the designations on each shall be of a different type – for example, numbers on one and letters on the other as in “isolated grounding conductor 1”, “isolated grounding conductor 2”, etc. on the green conductors and “isolated grounding conductor A”, “isolated grounding conductor B”, and the like on the green and yellow conductors. Numbered (or lettered or otherwise designated) isolated-grounding conductors are also appropriate in a cable containing identically designated equipment-grounding conductors – for example, “isolated grounding conductor 1”, “isolated grounding conductor 2”, “equipment ground 1”, and “equipment ground 2” in the same cable. An isolated-grounding conductor bearing the same number, letter, and the like as a marked equipment-grounding conductor in the cable are available for use as an equipment-grounding conductor by considering the two conductors to be distinguished by their respective word markings – for example, “isolated grounding conductor 1” and “equipment ground 1” are also appropriate for use as separate equipment-grounding conductors.

33 Additional Conductor Information

33.1 An insulated conductor that complies with the requirements for VW-1, oil-resistant, gasoline-resistant, reagent-resistant, or other individual conductor use may itself be marked “VW-1”, “oil res II”, or the like as applicable. Such designations applicable to one or more of the insulated conductors may also be marked on the tag, reel, or carton for the cable if they are followed by “cdrs”, “conds”, “conductors”, or the like to make it clear that they apply to the conductors rather than to the overall cable – for example, “VW-1 cdrs” or “gasoline-resistant cdrs”. Such designations shall not appear on the exterior of the cable or on any interior part of the cable other than on the affected conductor or conductors.

34 Compact-Stranded Copper Conductors

34.1 If a compact-stranded copper conductor is used, the AWG or kcmil size of the conductor – wherever the size appears (on the tag, reel, or carton, or on the surface) – shall be followed by "COMPACT COPPER" or "COMPACT CU". The word COMPACT may be abbreviated "CMPCT". Tags, reels, and cartons for compact-stranded copper wire shall have the following marking: "Terminate with connectors identified for use with compact-stranded copper conductors".

35 Copper-Clad Aluminum

35.1 If a copper-clad aluminum conductor or conductors are used, the AWG or kcmil size of the conductor(s), wherever the size appears (on the tag, reel, or carton, or on or in the cable), shall be followed by one of the designations "AL (CU-CLAD)", "ALUMINUM (COPPER-CLAD)", "CU-CLAD AL", or "COPPER-CLAD ALUMINUM". Tags, reels, and cartons for cable containing a copper-clad aluminum conductor or conductors shall have the following markings:

a) "Copper-clad aluminum shall be used only with equipment marked to indicate that it is for use with aluminum conductors. Terminate copper-clad aluminum with pressure wire connectors marked AL-CU or CC-CU".

b) For 12 – 10 AWG solid copper-clad aluminum "May be used with wire-binding screws and in pressure-plate and push-in spring-type connecting mechanisms that are acceptable for use with copper conductors".

c) "Where physical contact between any combination of copper-clad aluminum, copper, and aluminum conductors occurs in a wire connector, the connector shall be of a type marked for such intermixed use and the connection shall be limited to dry locations only".

35.2 The outer surface of the insulation or covering over the insulation on each insulated copper-clad aluminum conductor in a cable in which there are any conductors that are not of copper-clad aluminum shall be durably and legibly ink printed, indent printed, or embossed at 6-inches or 150-mm or shorter intervals throughout the entire length of the cable with one of the designations "AL (CU-CLAD)", "ALUMINUM (COPPER-CLAD)", "CU-CLAD AL", or "COPPER-CLAD ALUMINUM".

36 Aluminum

36.1 If an aluminum conductor or conductors are used, the AWG or kcmil size of the conductor(s), wherever the size appears (on the tag, reel, carton, or on or in the cable), shall be followed by the word "aluminum" or the abbreviation "AL".

36.2 The outer surface of the insulation or covering over the insulation on each insulated aluminum conductor in a cable in which there are any conductors that are not of aluminum shall be durably and legibly ink printed, indent printed, or embossed throughout the entire length of the cable with the word "aluminum" or the abbreviation "AL".

37 Responsibility for the Insulated Conductors

37.1 No identification needed

37.1.1 If the insulated conductors are made by or for the organization responsible for the cable in the same factory in which the cable is made, and if the organization responsible for the cable operates no other factory in which these conductors are made, no identification need be provided in or on any length of insulated conductor in a finished cable to mark the insulated conductor as the product of a particular organization or factory.

37.2 Only factory identification needed

37.2.1 If the organization responsible for the cable operates more than one factory in which the insulated conductors are made for the acceptable Type TC cables made by or for the organization responsible for the cable, a durable and distinctive identification shall be provided in or on every length of insulated conductor in all of the organization's acceptable Type TC cables to mark the insulated conductors as the product of a particular factory unless the conductors are made in the same factory in which the cable is made. The organization need not be identified.

37.3 Organization and factory identification needed

37.3.1 If the insulated conductors are made by or for an organization other than the organization responsible for the cable, a permanent and distinctive identification shall be provided on or in every length of insulated conductor in a finished cable to mark the insulated conductor as the product of a particular organization and factory.

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