UL 758

STANDARD FOR SAFETY

Appliance Wiring Material

UL Standard for Safety for Appliance Wiring Material, UL 758

Third Edition, Dated May 2, 2014

Summary of Topics

This revision to ANSI/UL 758 dated July 3, 2024 includes the following changes in requirements:

– Conductor Material Clarification, Revised Table 5.3

– Large, Bunch Stranded Conductors, Revised Table 5.9

– Dielectric Test on Shielded Constructions, Revised 49.1

– Addition of Silvered Copper-Beryllium Alloy to Table 5.3

– Addition of Silver and Nickel Coated Copper Alloy to Table 5.3

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

The revised requirements are substantially in accordance with Proposal(s) on this subject dated September 1, 2023, January 5, 2024, April 19, 2024, and April 26, 2024.

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ANSI/UL 758-2024

UL 758

Standard for Appliance Wiring Material

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Third Edition

May 2, 2014

This ANSI/UL Standard for Safety consists of the Third Edition including revisions through July 3, 2024.

The most recent designation of ANSI/UL 758 as an American National Standard (ANSI) occurred on July 3, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover Appliance Wiring Material (AWM) in the form of single insulated conductors, multi-conductor cables, optical fibers, individual insulated conductors, and fiber optic members for use as components in multi-conductor cables.

1.2 The appliance wiring material covered by the requirements of this Standard are solely for use as factory-installed wiring either within the overall enclosure of appliances and other equipment (internal wiring) or as external interconnecting cable for appliances (external wiring), or for further processing as components in multi-conductor cables.

1.3 These requirements do not cover any wire, cable, or cord types that are presently covered in the National Electrical Code (NEC), NFPA 70, and are not intended for installation in buildings or structures in accordance with the NEC except within the scope of the installation instructions of the end-product for which their use is intended.

1.4 These requirements cover appliance wiring material with operating temperatures from a minimum 60°C (140°F) dry temperature rating and voltage ratings from a minimum 30-volt rating. Conductor size ranges from 50 AWG to 2000 kcmil. Appliance wiring material (AWM) composed entirely of optical fiber members or electrical conductors in combination with optical fiber members are also covered by these requirements.

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

1.6 These requirements do not cover constructions which utilize flat, insulated conductors that are not laid parallel. The requirements for these products are found in the Standard for Flexible Materials Interconnect Constructions, UL 796F.

1.7 The evaluation of the performance of the semi-conductive polymeric layer described in 5.9 is not covered by this Standard.

1.8 In addition to these constructions, this Standard establishes guidelines for the evaluation of special constructions that, due to their specific end product use, are not required to meet all of the requirements for general construction AWM.

1.9 The final acceptance of AWM is dependent upon its use in complete equipment that conforms with the standards applicable to such equipment.

2 General

2.1 Components

2.1.1 Except as indicated in 2.1.2, a component of a product covered by this Standard shall comply with the requirements for that component.

2.1.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

2.1.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.1.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

2.1.5 Polymeric materials evaluated for its intended use, are not prohibited from being used in the insulation and jacket applications indicated in Table 2.1.

Table 2.1
Polymeric materials for use in wire and cable and associated AWM ratings

AWM rating	Component	Minimum average thickness, inch	(mm)	Compound's use or rating
Sunlight resistant	Insulation	0.030	0.76	Outer PVC or TPE insulation rated for 720 hours sunlight resistance
Sunlight resistant	Jacket	0.030	0.76	Outer PVC or TPE jacket rated for 720 hours sunlight resistance
60°C Wet	Insulation	0.030	0.76	PVC insulation rated for use in Type TW thermoplastic-insulated wire
60°C or 75°C Wet	Insulation	0.030	0.76	PVC insulation rated for use in Types THW or THHW thermoplastic-insulated wire
60°C or 75°C Wet	Insulation	0.015	0.38	PVC insulation rated for use in Type THWN thermoplastic-insulated wire
60°C, 75°C, or 90°C Wet	Insulation	0.015	0.38	PVC insulation rated for use in Type THWN-2 thermoplastic-insulated wire

2.2 Units of measurement

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

2.2.2 Unless otherwise indicated, all voltage values mentioned in this Standard are root-mean-square (rms).

2.2.3 Equipment calibrated in metric units is to be used when a requirement is applied in metric terms.

2.3 Undated references

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

2.3.2 Wherever the designation "UL 1581" is used in this Standard, reference is to be made to the designated part(s) of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. Wherever the designation "UL 62" is used in this Standard, reference is to be made to the designated part(s) of the Standard for Flexible Cords and Cables, UL 62.

CONSTRUCTION

3 General

3.1 The acceptability of an AWM for use in a specific end-product is based on the construction and flame rating of each individual construction.

3.2 Table 3.1 – Table 3.9 serve as indices to requirements for construction details and basic test methods for typical AWM constructions.

3.3 Coiled cables shall comply with the requirements specified in this Standard. All tests and measurements shall be conducted on specimens obtained from the straight ends at each end of the coiled portion of the cable. The straight ends shall have been subjected to the same heat conditioning as the coiled portion during the coiling process. In addition, the minimum average thickness and minimum thickness at any point of insulation and jacket shall be made on the coiled portion and shall meet the requirements specified for an uncoiled construction.

3.4 Wires or cables which have a restricted use are those installed where not subject to movement or mechanical abuse, or where totally enclosed.

3.5 A wire or cable for Class 2 use shall have a voltage rating less than or equal to 150 V AC or DC.

3.6 The high voltage DC wire described in Table 3.6 and Table 3.6A shall have a minimum voltage rating of 3 kV DC. Wires with DC voltage rating less than 3 kV DC shall be evaluated in accordance with Table 3.1.

Table 3.1
Single or multiple conductor with extruded insulation

Conductors:		
	Material	See Conductor, Section 5
	Size	See Conductor, Section 5
Insulation:		
	Material	See Insulation, Section 7
	Thickness	See Insulation, Section 7
Covering:		
	Material	See Coverings, Section 8
Markings:		See Surface Marking of AWM, Section 50, and Markings on Tag, Reel or Carton, Section 51
Basic tests:		
	Physical Properties Unaged and Air Oven Aged, Section 14.	
	Conductor Corrosion Test, Section 18	
	Deformation Test (Thermoplastics and Class XL Only), Section 19.	
	Flexibility Test, Section. 21.	
	Heat Shock Test (Thermoplastic Materials Only), Section 22.	
	Cold Bend Test, Section 23.	
	Durability of Ink-Print Test, Section27	
	Crush Resistance Test, Section 28.	
	Dielectric Test, Method I, Section 29.	
	Dielectric Test, Method II, Section 30.	
	Dielectric Test, Method III, Section 31.	
	Horizontal Flame Test for Internal Wiring, Section 40.	
Elective tests/ratings:		See Table 3.9

Table 3.2
Single conductor with other-than-extruded insulation

Conductors:		
	Material	See Conductor, Section 5
	Size	See Conductor, Section 5
Insulation:		
	Material	See Insulation, Section 7
	Thickness	See Insulation, Section 7
Markings:		See Surface Marking of AWM, Section 50, and Markings on Tag, Reel or Carton, Section 51
Basic tests:		
	Conductor Corrosion Test, Section 18.	
	Flexibility Test, Section 21.	
	Cold Bend Test, Section 23.	

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Table 3.2 Continued

	Durability of Ink-Print Test, Section 27 Crush Resistance Test, Section 28. Dielectric Test, Method I, Section 29. Dielectric Test, Method II, Section 30. Horizontal Flame Test for Internal Wiring, Section 40.
Elective tests/ratings:	See Table 3.9.
†Laminated, flat ribbon cable is covered in Table 3.5.	

Table 3.3
Single and parallel, multi-conductor cable with extruded integral insulation and jacket

Conductors:		
	Material	See Conductor, Section 5
	Size	See Conductor, Section 5
Integral insulation and jacket:		
	Material	See Insulation, Section 7; Overall Jacket, Section 13
	Thickness	See Insulation, Section 7; Overall Jacket, Section 13
Markings:		See Surface Marking of AWM, Section 50, and Markings on Tag, Reel or Carton, Section 51
Basic tests:		
	Physical Properties, Unaged and Air Oven Aged, Section 14. Conductor Corrosion Test, Section 18. Deformation Test (Thermoplastics and Class XL Only), Section 19. Flexibility Test, Section 21. Heat Shock Test (Thermoplastic Materials Only), Section 22. Cold Bend Test, Section 23. Durability of Ink-Print Test, Section 27 Dielectric Test, Method I, Section 29. Dielectric Test, Method II, Section 30. Dielectric Test, Method III, Section 31. Horizontal Flame Test for Internal Wiring, Section 40. Cable Flame Test, Section 41.	
Elective tests/ratings:		See Table 3.9.

Table 3.4
Single and multiple-conductor cable using non-integral jacket

Conductors:		
	Material	See Conductor, Section 5
	Size	See Conductor, Section 5

Table 3.4 Continued on Next Page

Table 3.4 Continued

Insulated conductors:		See Insulation, Section 7 The voltage and temperature rating of the cable shall not exceed the lowest rating of either the insulated conductors or the fiber optic members. Cables rated 60°C, 75°C, and 90°C wet shall use insulated conductors that comply with the applicable wet rating.
Covering:		
	Material	See Coverings, Section 8
Shield:		See Shield(s), Section 11
Jacket:		
	Material	See Overall Jacket, Section 13
	Thickness	See Overall Jacket, Section 13
Markings:		See Surface Marking of AWM, Section 50, and Markings on Tag, Reel, or Carton, Section 51
Basic tests:		
	Insulated conductors tested in accordance with Table 3.1, Table 3.2, Table 3.3, or Table 3.5.	
	Physical Properties, Unaged and Air Oven Aged, Section 14 – Test jacket only.	
	Deformation Test (Thermoplastics and Class XL Only), Section 19.	
	Flexibility Test, Section 21.	
	Heat Shock Test (Thermoplastic Materials Only), Section 22.	
	Cold Bend Test, Section 23.	
	Durability of Ink-Print Test, Section 27.	
	Horizontal Flame Test for Internal Wiring, Section 40.	
	Cable Flame Test, Section 41.	
Elective tests/ratings:		See Table 3.9.

Table 3.5
Bonded or laminated flat ribbon cable

Conductors:		
	Material	See Conductor, Section 5
	Size	See Conductor, Section 5
Insulation:		
	Material	See Insulation, Section 7
	Thickness	See Insulation, Section 7
Covering:		
	Material	See Coverings, Section 8
Markings:		See Surface Marking of AWM, Section 50, and Markings on Tag, Reel, or Carton, Section 51
Basic tests:		
	Physical Properties, Unaged and Air Oven Aged, Section 14 – Test bonded only.	
	Conductor Corrosion Test, Section 18.	
	Deformation Test (Thermoplastics and Class XL Only), Section 19.	
	Flexibility Test, and Jacket, Section 21.	

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Table 3.5 Continued

	Heat Shock Test (Thermoplastic Materials Only), Section 22. Cold Bend Test, Section 23. Durability of Ink-Print Test, Section 27. Delamination Test (Laminated Constructions Only), Section 24. Crush Resistance Test, Section 28. Dielectric Test, Method I, Section 29. Dielectric Test, Method II, Section 30. Dielectric Test, Method III, Section 31. Horizontal Flame Test for Internal Wiring, Section 40.
Elective tests/ratings:	See Table 3.9.

Table 3.6
High voltage* DC wire with extruded insulation

Conductors:		
	Material	See Conductor, Section 5
	Size	See Conductor, Section 5
Insulation:		
	Material	See Insulation, Section 7 (solid insulation only)
	Thickness	See Insulation, Section 7
Covering:		
	Material	See Coverings, Section 8
Jacket:		
	Material	See Overall Jacket, Section 13
	Thickness	See Overall Jacket, Section 13
Markings:		See Surface Marking of AWM, Section 50, and Markings on Tag, Reel, or Carton, Section 51
Basic tests:		
	Physical Properties, Unaged and Air Oven Aged, Section 14.	
	Conductor Corrosion Test, Section 18.	
	Deformation Test (Thermoplastics and Class XL Only), Section 19.	
	Flexibility Test, Section 21.	
	Heat Shock Test (Thermoplastic Materials Only), Section 22.	
	Shrinkback Test – Special Rating TV Wires Only, Section 25.	
	Ozone Resistance Test – Special Rating TV Use Wires Only, Section 26.	
	Durability of Ink-Print Test, Section 27.	
	Crush Resistance Test, Section 28.	
	High-Voltage DC Wire Dielectric Voltage-Withstand Test, Method I, Section 32.	
	High-Voltage DC Wire Dielectric Voltage-Withstand Test, Method II, Section 33.	
	High-Voltage Cut-Through Test, Special Rated TV Wire Only, Section 34.	
	Horizontal Flame Test for Internal Wiring, Section 40.	
	VW-1 Flame Test (required for TV wire), Section 41.	
Elective tests/ratings:		See Table 3.9.
*High voltage indicates wires rated 3kV DC or higher.		

Table 3.6A
High voltage* DC wire with other-than-extruded insulation

Conductors:		
	Material	See Conductor, Section 5
	Size	See Conductor, Section 5
Insulation:		
	Material	See Insulation, Section 7
	Thickness	See Insulation, Section 7

Table 3.6A Continued on Next Page

Table 3.6A Continued

Covering:		
	Material	See Coverings, Section 8
Jacket:		
	Material	See Overall Jacket, Section 13
	Thickness	See Overall Jacket, Section 13
Markings:		See Surface Marking of AWM, Section 50, and Markings on Tag, Reel, or Carton, Section 51
Basic tests:		
	Conductor Corrosion Test, Section 18.	
	Flexibility Test, Section 21.	
	Shrinkback Test – Special Rating TV Wires Only, Section 25.	
	Ozone Resistance Test – Special Rating TV Use Wires Only, Section 26.	
	Durability of Ink-Print Test, Section 27.	
	Crush Resistance Test, Section 28.	
	High-Voltage DC Wire Dielectric Voltage-Withstand Test, Method I, Section 32.	
	High-Voltage DC Wire Dielectric Voltage-Withstand Test, Method II, Section 33.	
	High-Voltage Cut-Through Test, Special Rated TV Wire Only, Section 34.	
	Horizontal Flame Test for Internal Wiring, Section 40.	
	VW-1 Flame Test (required for TV wire), Section 41.	
Elective tests/ratings:		See Table 3.9.
*High voltage indicates wires rated 3kV DC or higher.		

Table 3.7
Fiber optic cables*

Optical fiber:	See Cable composed entirely of optical-fiber members, 6.3
Buffer:	
Material	See Cable composed entirely of optical-fiber members, 6.3
Thickness	See Cable composed entirely of optical-fiber members,6.3
Covering:	
Material	See Coverings, Section 8
Jacket:	
Material	See Overall Jacket, Section 13
Thickness	See Overall Jacket, Section 13
Markings	See Surface Marking of AWM, Section 50, and Markings on Tag, Reel, or Carton, Section 51
Basic tests:	
Physical Properties, Unaged and Air Oven Aged, Section 14.	
Deformation Test (Thermoplastics and Class XL Only), Section 19.	
Flexibility Test, Section 21.	
Heat Shock Test (Thermoplastic materials only), Section 22.	
Cold Bend Test, Section 23.	
Durability of Ink- Print Test, Section 27.	
Horizontal Flame Test for Internal Wiring, Section 40.	
VW-1 Flame Test (required for external use), Section 42.	
*Cables covered by this table contain no current-carrying parts.	

Table 3.8
Single- and multiple-conductor cable employing a non-extruded covering as the outermost layer§

Conductors:	
Material	See Conductor, Section 5
Size	See Conductor, Section 5
Insulated conductors:	
Material	See Insulation, Section 7
Thickness	See Insulation, Section 7
Shield:	See Shield(s), Section 11
Covering:	
Material	See Coverings, Section 8
Markings:	See Surface Marking of AWM, Section 50, and Markings on Tag, Reel, or Carton, Section 51
Basic tests:	
Insulated conductors tested in accordance with Table 3.1, Table 3.2, Table 3.3, or Table 3.5.	
Flexibility Test, Section 21.	

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Table 3.8 Continued

	Cold Bend Test, Section 23. Durability of Ink-Print Test, Section 27. Horizontal Flame Test for Internal Wiring, Section 40.
Elective tests/ratings:	See Table 3.9.
§Laminated flat ribbon cable is covered in Table 3.5.	

Table 3.9
Elective tests and ratings

Flame tests:	VW-1 Flame Test, Section 42. FT1 Flame Test, Section 43. FT2 Flame Test, Section 44. IEC 60332-1 Flame Test, Section 45. IEC 60332-2 Flame Test, Section 46.
Mechanical test:	Crush Resistance Test, Section 28.
Sunlight resistance test:	Physical Properties, Sunlight Resistance, Section 17.
Oil and gasoline resistance tests:	Physical Properties, Oil Immersion Aging, Section 15. Physical Properties, Gasoline Conditioning, Section 16.
Wet ratings tests:	Temperature Correction Factor (Wet Rated AWM), Section 37. Capacitance and Relative Permittivity Tests (Wet Rated AWM), Section 38. Stability Factor (Wet Rated AWM) Section 39. Short Term Insulation-Resistance Test in Water at Room Temperature (Wet Rated AWM), Section 35, required for all wet rated wires. Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 36, at 50°C required for wires rated 60°C wet. Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 36, at 75°C required for wires rated 75°C wet. Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 36, at 90°C required for wires rated 90°C wet. Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 36, at 100°C required for wires rated 100°C wet.

4 Materials

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

4.2 Due to possible incompatibility, TPE materials of the styrenic type may not be suitable for use in cords whereby direct contact with PVC may occur. A separator is one acceptable means of avoiding direct contact. Other combinations of materials which could be incompatible, if any, are as yet undetected.

4.3 Due to possible incompatibility, uncoated copper, copper alloy, copper-clad aluminum, copper-clad steel, or other components with uncoated copper on the outer surface shall not be used in wire or cable whereby direct contact with aluminum may occur. A separator is one acceptable means of avoiding direct contact, or the copper components shall be metal-coated.

5 Conductor

5.1 General

5.1.1 A conductor consisting of a single wire is designated as a solid conductor, while one consisting of a number of individual wires is designated as a stranded conductor. The American Wire Gauge (AWG) numbers, the kcmil (thousands of circular mils) sizes, and the square-millimeter sizes each signify a definite nominal total cross-sectional area (see Table 5.1 or Table 5.2) independent of the conductor material. The individual wires used in making up a stranded conductor are not required to correspond to any particular AWG or other standard gauge size. A tinsel conductor consists of a number of strands, twisted together, a portion of, or all strands being composed of one or more flattened wires of copper or copper alloy, helically wound on a fibrous polymeric thread. A conductor with a tubular cross-section and uniform wall thickness shall be of copper, and may be metal coated. A bus bar conductor consists of a single bar, or two or more bars stacked to form two or more layers, with each bar of solid rectangular cross-section with two plane, parallel surfaces and round or other simple regularly shaped edges. Fibrous yarns impregnated or coated with metal or other conductive materials may be used as a conductor, or may be assembled with other types of conductor strands to form a conductor. A carbon fiber filament conductor consists of a number of carbon fibers twisted together to form the conductor and the carbon fibers may be metal coated. A resistance wire is a conductor material used in products primarily as the source of heat based on a designed resistance per finished unit length. A magnet wire conductor shall consist of an enameled single conductor or an assembly of individually enameled wires which may be assembled or twisted together with an overall covering of film fiber, tape, or extruded compound to form a Litz wire. The magnet wire conductor shall have a minimum temperature rating of the AWM and be evaluated in accordance with the requirements in the Standard for Systems of Insulation Materials – General, UL 1446. The size of a conductor composed of or containing conductive fibrous yarns and resistance wires including carbon fiber filament conductors, a conductor of a tubular shape, or a bus bar conductor, and a magnet wire conductor shall be determined by conductor resistance described in 5.6.1. The circular mil area (CMA) of a rectangular conductor shall be determined from the formula:

average width (mils) X average thickness (mils) X 1.273

The AWG size can then be determined using Table 5.1.

Table 5.1
Conductor dimensions

Size of conductor, AWG	Diameter of solid conductor				Cross-sectional area of stranded conductor			
	Nominal,		Minimum,		Nominal,		Minimum,	
	Mils	(mm)	Mils	(mm)	Cmils	(mm^2)	Cmils	(mm^2)
50	0.99	0.0251	0.98	0.025	0.980	0.000497	0.960	0.000486
49	1.11	0.0282	1.10	0.028	1.23	0.000624	1.21	0.000613
48	1.24	0.0315	1.23	0.031	1.54	0.000768	1.51	0.000765
47	1.40	0.0356	1.39	0.035	1.96	0.000993	1.92	0.000973
46	1.57	0.0399	1.55	0.039	2.46	0.00125	2.41	0.00122
45	1.76	0.0447	1.74	0.044	3.10	0.00157	3.04	0.00154
44	2.0	0.051	1.98	0.050	4.00	0.00203	3.92	0.00198
43	2.2	0.056	2.18	0.055	4.84	0.00245	4.74	0.00240
42	2.5	0.064	2.48	0.063	6.25	0.00317	6.13	0.003115
41	2.8	0.071	2.77	0.070	7.84	0.00397	7.68	0.00389

Table 5.1 Continued on Next Page

Table 5.1 Continued

Size of conductor, AWG	Diameter of solid conductor, Nominal, Mils	(mm)	Minimum, Mils	(mm)	Cross-sectional area of stranded conductor, Nominal, Cmils	(mm^2)	Minimum, Cmils	(mm^2)
40	3.1	0.079	3.07	0.078	9.61	0.00487	9.42	0.00477
39	3.5	0.089	3.47	0.088	12.2	0.00621	11.9	0.00603
38	4.0	0.102	3.96	0.101	16.0	0.00811	15.7	0.00796
37	4.5	0.114	4.46	0.113	20.2	0.0103	19.8	0.0100
36	5.0	0.127	4.95	0.126	25.0	0.0127	24.5	0.0124
35	5.6	0.142	5.54	0.141	31.4	0.0159	30.8	0.0156
34	6.3	0.160	6.24	0.158	39.7	0.020	38.9	0.0197
33	7.1	0.180	7.03	0.179	50.4	0.0255	49.4	0.0250
32	8.0	0.203	7.92	0.201	64.0	0.0324	62.7	0.0318
31	8.9	0.226	8.81	0.224	79.2	0.0401	77.6	0.0393
30	10.0	0.254	9.9	0.251	100	0.0507	98	0.0497
29	11.3	0.287	11.2	0.284	128	0.0647	125	0.0633
28	12.6	0.320	12.5	0.318	159	0.0804	156	0.0790
27	14.2	0.361	14.1	0.358	202	0.102	198	0.100
26	15.9	0.404	15.7	0.399	253	0.128	248	0.126
25	17.9	0.455	17.7	0.450	320	0.162	314	0.159
24	20.1	0.511	19.9	0.506	404	0.205	396	0.201
23	22.6	0.574	22.4	0.569	511	0.259	501	0.254
22	25.3	0.643	25.0	0.635	640	0.324	627	0.318
21	28.5	0.724	28.2	0.716	812	0.412	796	0.404
20	32.0	0.813	31.7	0.805	1020	0.519	1000	0.509
19	35.9	0.912	35.6	0.904	1290	0.653	1264	0.641
18	40.3	1.02	40.0	1.016	1620	0.823	1588	0.807
17	45.3	1.15	44.9	1.140	2050	1.04	2009	1.02
16	50.8	1.29	50.3	1.278	2580	1.31	2528	1.28
15	57.1	1.45	56.5	1.435	3260	1.65	3195	1.62
14	64.1	1.63	63.5	1.613	4110	2.08	4028	2.04
13	72.0	1.83	71	1.80	5180	2.63	5076	2.58
12	80.8	2.05	80	2.03	6530	3.31	6399	3.24
11	90.7	2.30	90	2.29	8230	4.17	8065	4.09
10	101.9	2.588	101	2.57	10380	5.261	10172	5.16
9	114.4	2.906	113	2.87	13090	6.631	12828	6.50
8	128.5	3.264	127	3.23	16510	8.367	16180	8.20
7	144.3	3.665	143	3.63	20820	10.55	20404	10.34
6	162.0	4.115	160	4.06	26240	13.30	25715	13.03
5	181.9	4.620	180	4.57	33090	16.77	32428	16.43
4	204.3	5.189	202	5.13	41740	21.15	40905	20.73
3	229.4	5.827	227	5.77	52620	26.67	51568	26.14

Table 5.1 Continued on Next Page

Table 5.1 Continued

Size of conductor, AWG	Diameter of solid conductor				Cross-sectional area of stranded conductor			
	Nominal,		Minimum,		Nominal,		Minimum,	
	Mils	(mm)	Mils	(mm)	Cmils	(mm^2)	Cmils	(mm^2)
2	257.6	6.543	255	6.48	66360	33.62	65033	32.95
1	289.3	7.348	286	7.26	83690	42.41	82016	41.56
1/0	324.9	8.252	322	8.18	105600	53.49	103488	52.42
2/0	364.8	9.226	361	9.17	133100	67.43	130438	66.08
3/0	409.6	10.40	406	10.31	167800	85.01	164444	83.31
4/0	460.0	11.68	455	11.56	211600	107.2	207368	105.1
kcmil	–	–	–	–	kcmil	–	kcmil	–
250	–	–	–	–	250	127	245	124.1
300	–	–	–	–	300	152	294	149.0
350	–	–	–	–	350	177	343	173.8
400	–	–	–	–	400	203	392	198.6
450	–	–	–	–	450	228	441	223.5
500	–	–	–	–	500	253	490	248.3
550	–	–	–	–	550	279	539	273.1
600	–	–	–	–	600	304	588	297.9
650	–	–	–	–	650	329	637	322.8
700	–	–	–	–	700	355	686	347.6
750	–	–	–	–	750	380	735	372.4
800	–	–	–	–	800	405	784	397.2
900	–	–	–	–	900	456	882	446.9
1000	–	–	–	–	1000	507	980	496.6
1100	–	–	–	–	1100	557	1078	546.2
1200	–	–	–	–	1200	608	1176	595.9
1250	–	–	–	–	1250	633	1225	620.7
1300	–	–	–	–	1300	659	1274	645.5
1400	–	–	–	–	1400	709	1372	695.2
1500	–	–	–	–	1500	760	1470	744.9
1600	–	–	–	–	1600	811	1568	794.5
1700	–	–	–	–	1700	861	1666	844.2
1750	–	–	–	–	1750	887	1715	869.0
1800	–	–	–	–	1800	912	1764	893.8
1900	–	–	–	–	1900	963	1862	943.5
2000	–	–	–	–	2000	1010	1960	993.1

Table 5.2
Conductor dimensions in metric sizes

Nominal cross-sectional area of conductor, mm^2	Minimum cross-sectional area of conductor, mm^2
0.01	0.0098
0.05	0.049
0.1	0.098
0.5	0.490
0.75	0.735
1.0	0.98
1.5	1.47
2.5	2.45
4	3.92
6	5.88
10	9.80
16	15.68
25	24.50
35	34.30
50	49.00
70	68.60
95	93.10
120	117.6
150	147.0
185	181.3
240	235.2
300	294.0
400	392.0
500	490.0
630	617.4
800	784.0
1000	980
1200	1176
1400	1372
1600	1568
1800	1764
2000	1960
2500	2450

5.1.2 A fibrous thread used within the conductor stranding and used as a reinforcing member to improve breaking strength is not prohibited from being used. The construction and arrangement of the threads is not specified.

5.1.3 *Deleted*

5.2 Metal

5.2.1 A solid or stranded conductor shall not be used where subjected to any temperature that exceeds that shown for the metal as indicated in the third column of Table 5.3 . The metal shall comply with the applicable ASTM specification, when specified, as indicated in Table 5.3 .

Table 5.3
Conductor – metal specifications

Conductor metal	ASTM reference for the metal	Temperature limit for the metal, °C (°F)	Other limits
Copper, uncoated, diameter of each strand or thickness of rectangular or tubular conductor less than 0.015 inch (0.38 mm)	ANSI/ASTM B 3	150 (302)	Uncoated conductor smaller than 0.0031 inch (0.079 mm) meet the elongation requirements as defined for conductors with a diameter of 0.0031 inch (0.079 mm) as shown in ASTM B 3)
Copper, uncoated, diameter of each strand or thickness of rectangular or tubular conductor at least 0.015 inch (0.38 mm)	ANSI/ASTM B 3	200 (392)	Uncoated conductor smaller than 0.0031 inch (0.079 mm) meet the elongation requirements as defined for conductors with a diameter of 0.0031 inch (0.079 mm) as shown in ASTM B 3.
Copper, tin-coated, diameter of each strand or thickness of rectangular or tubular conductor less than 0.015 inch (0.38 mm)	ANSI/ASTM B 33	150 (302)	Tin-coated conductor smaller than 0.0031 inch (0.079 mm) meet the elongation requirements as defined for conductors with a diameter of 0.0031 inch (0.079 mm) as shown in ASTM B33.
Copper, tin-coated, diameter of each strand or thickness of rectangular or tubular conductor at least 0.015 inch (0.38 mm)	ANSI/ASTM B 33	200 (392)	Tin-coated conductor smaller than 0.0031 inch (0.079 mm) meet the elongation requirements as defined for conductors with a diameter of 0.0031 inch (0.079 mm) as shown in ASTM B 33.
Copper, hard-drawn, uncoated, each strand less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 1	150 (302)	
Copper, hard-drawn, uncoated, each strand at least 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 1	200 (392)	
Copper, medium-hard-drawn, uncoated, each strand less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 2	150 (302)	
Copper, medium-hard-drawn, uncoated, each strand at least 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 2	200 (392)	
Copper, hard-drawn or medium-hard-drawn, tin coated, each strand less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 246	150 (302)	
Copper, hard-drawn or medium-hard-drawn, tin	ANSI/ASTM B 246	200 (392)	

Table 5.3 Continued on Next Page

Table 5.3 Continued

Conductor metal	ASTM reference for the metal	Temperature limit for the metal, °C (°F)	Other limits
coated, each strand at least 0.015 inch (0.38 mm) in diameter			
Copper, lead-base-alloy coated, diameter of each strand or thickness of rectangular or tubular conductor less than 0.015 inch (0.38 mm)	ANSI/ASTM B 189	150 (302)	
Copper, lead-base alloy coated, diameter of each strand or thickness of rectangular or tubular conductor at least 0.015 inch (0.38 mm)	ANSI/ASTM B 189	200 (392)	
Copper, uncoated or tin coated, each strand less than 0.015 inch (0.38 mm) in diameter, metallurgically bonded	ANSI/ASTM B 286, B 470	150 (302)	For use where flexibility is not a concern. Metallurgically bonded via heat or the addition of tin (topcoated, over coated)
Copper, uncoated or tin coated, each strand at least 0.015 inch (0.38 mm) in diameter, metallurgically bonded	ANSI/ASTM B 286, B 470	200 (392)	For use where flexibility is not a concern. Metallurgically bonded via heat or the addition of tin (topcoated, over coated)
Copper, silver-coated	ANSI/ASTM B 298	200 (392)	
Copper, nickel-coated	ANSI/ASTM B 355	250 (482)	
Copper, nickel-coated, Class 10	ANSI/ASTM B 355	350 (662)	
Copper, nickel-coated, Type A, 27 percent minimum nickel coated copper	ANSI/ASTM B 355	550 (1022)	
Copper, gold coated	Per the requirements in the 'other limits' column	200 (392)	Copper per ASTM B 3 Gold coating per ANSI/ASTM B 488
Copper, oxygen free, each strand less than 0.015 inch (0.38) in diameter	ANSI/ASTM B 170	150 (302)	
Copper, oxygen free, each strand at least 0.015 inch (0.38) in diameter	ANSI/ASTM B 170	200 (392)	
Copper-nickel-zinc (nickel-silver)	ANSI/ASTM B 206	150 (302)	
Copper, bus bars, uncoated	ANSI/ASTM B 187	105 (221)	
Copper, bus bars, tin coated	ANSI/ASTM B 187	105 (221)	
Copper alloy, hard-drawn, diameter of each strand or thickness of rectangular or tubular conductor less than 0.015 inch (0.38 mm)	ANSI/ASTM B 105	150 (302)	May be uncoated or provided with a tin, or lead-base-alloy coating. Uncoated or tin-coated conductors smaller than 0.032 inch (0.813 mm) meet the tensile strength and elongation requirements as defined for conductors with a diameter of

Table 5.3 Continued on Next Page

Table 5.3 Continued

Conductor metal	ASTM reference for the metal	Temperature limit for the metal, °C (°F)	Other limits
			0.032 inch (0.813 mm) as shown in ASTM B 105.
Copper alloy, hard-drawn, silver coated, diameter of each strand less than 0.032 inch (0.81 mm)	–	200 (392)	May contain no more than 0.7% silver. Conductors smaller than 0.032 inch (0.81 mm) meet the tensile strength and elongation requirements for 0.032 inch (0.81 mm) conductors shown in ASTM B 105. Minimum 80% IACS.
Copper alloy, hard-drawn, silver coated	ANSI/ASTM B 105	200 (392)	Must be silver coated. Minimum 80% IACS.
Copper alloy, hard-drawn, diameter of each strand or thickness of rectangular or tubular conductor at least 0.015 inch (0.38 mm)	ANSI/ASTM B 105	200 (392)	May be uncoated or provided with a tin, lead-base-alloy, silver, or nickel coating
High strength copper alloy, annealed, diameter of each strand or thickness of rectangular or tubular conductor less than 0.015 inch (0.38 mm)	ANSI/ASTM B 624	150 (302)	May be uncoated or provided with a tin, or lead based alloy coating. Copper alloy employing 0.05 – 0.127 mm (1.969 – 5.0 mils) may be minimum 70 percent IACS and meets the same requirements as conductors meeting ASTM B624 except that the minimum tensile strength shall not be less than 294 MPa.
High strength copper alloy, annealed, diameter of each strand or thickness of rectangular or tubular conductor at least 0.015 inch (0.38 mm)	ANSI/ASTM B 624	200 (392)	May be uncoated or provided with a tin, or lead based alloy coating
Copper or copper alloy silver-coated	ANSI/ASTM B 961	200 (392)	
Copper alloy, hard-drawn or high strength nickel-coated	–	250 (482)	
Copper-zirconium alloy, less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 747	150 (302)	
Copper-zirconium alloy, less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 747	200 (392)	Shall be silver coated
Copper-zirconium alloy, at least 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 747	200 (392)	
Phosphor-bronze alloy, less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 159	150 (302)	
Phosphor-bronze alloy, at least 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 159	200 (392)	
Copper-clad aluminum, annealed, 6530 circular mils or 3.31 mm^2 (12 AWG) and larger	ASTM B 566	90 (194)	Class 10A

Table 5.3 Continued on Next Page

Table 5.3 Continued

Conductor metal	ASTM reference for the metal	Temperature limit for the metal, °C (°F)	Other limits
Copper-clad aluminum, hard-drawn, 6530 circular mils or 3.31 mm^2 (12 AWG) and larger	ASTM B 566	90 (194)	Class 10H
Copper-clad steel, diameter of each strand or thickness of rectangular or tubular conductor less than 0.015 inch (0.38 mm)	ANSI/ASTM B 452	150 (302)	Minimum conductivity of 30 percent IACS[a]
Copper-clad steel, diameter of each strand or thickness of rectangular or tubular conductor at least 0.015 inch (0.38 mm)	ANSI/ASTM B 452	200 (392)	Minimum conductivity of 30 percent IACS[a]
Copper-clad steel, silver-coated	ANSI/ASTM B 501	200 (392)	Minimum conductivity of 30 percent IACS[a]
Aluminum, 6,530 – 16,510 circular mils or 3.31 – 8.367 mm^2 (12 – 4/0 AWG), solid or stranded	ANSI/ASTM B 800	90 (194)	Tensile-strength 15,000 – 22,000 psi or 103 – 152 MN/m^2 or 10.3 – 15.2 kN/cm^2 or 10.5 – 15.5 kgf/mm^2, elongation 10 percent or more with 10-inch or 250-mm gauge length – component aluminum wire stock (conductor material), formerly "aluminum conductor material (ACM)"
Aluminum, 3/4 hard, 6530 – 16510 circular mils or 3.31 – 8.367 mm^2 (12 – 4/0 AWG), solid or stranded	ANSI/ASTM B 609	90 (194)	Tensile strength 17,000 – 22,000 psi or 117 – 152 MN/m^2 or 11.7 – 15.2 kN/cm^2 or 12 – 15.5 kgf/mm^2
Aluminum, 1/2 hard, 6530 – 16510 circular mils or 3.31 – 8.367 mm^2 (12 – 4/0 AWG), solid or stranded	ANSI/ASTM B 609	90 (194)	Tensile strength 15,000 – 20,000 psi or 103 – 138 MN/m^2 or 10.3 – 13.8 kN/cm^2 or 10.5 – 14.9 kgf/mm^2
Aluminum, hard, 6530 – 16510 circular mils or 3.31 – 8.367 mm^2 (12 – 4/0 AWG), solid or stranded	ANSI/ASTM B 609	90 (194)	
Aluminum 1100, H12 alloy 6530 – 16510 circular mils or 3.31 – 8.367 mm^2 (12 – 4/0 AWG), solid or stranded	ANSI/ASTM B 211	105	
Stainless steel alloys	ANSI/ASTM A 580 or A 555	250 (482)	
Nickel-coated iron	–	250 (482)	
Nickel, nickel alloy	ANSI/ASTM B 160 or B 473, or per the requirements in the 'other limits' column	550 (1022)	Minimum tensile strength 45,000 psi or 31.6 kgf/mm^2 elongation at least 10 percent, nominal volume resistivity 45 ohm circular mil/foot at 20°C (68°F)
Nickel-chromium-alloy	ANSI/ASTM B 344 or B 267, or B 166	550 (1022)	
Nickel-copper-iron alloy	ANSI/ASTM B 164	250 (482)	
Iron	ASTM E230/E230M	320 (608)	Thermocouple conductor, Type J

Table 5.3 Continued on Next Page

Table 5.3 Continued

Conductor metal	ASTM reference for the metal	Temperature limit for the metal, °C (°F)	Other limits
Copper, 45% nickel alloy (constantan)	ASTM E230/E230M	550 (1022)	Thermocouple conductor, Type E, J, T
Nickel, 10% chromium alloy (chromel)	ASTM E230/E230M	550 (1022)	Thermocouple conductor, Type E, K
Nickel, 5% aluminum, silicon alloy (alumel)	ASTM E230/E230M	550 (1022)	Thermocouple conductor, Type K
Nickel, 14% chromium, 1.5% silicon alloy (nicrosil)	ASTM E230/E230M	550 (1022)	Thermocouple conductor, Type N
Nickel, 4.5% silicon, 0.1% magnesium alloy (nisil)	ASTM E230/E230M	550 (1022)	Thermocouple conductor, Type N
Copper	ASTM E230/E230M	150 (302)	Thermocouple conductor, Type T
Copper-beryllium alloy, annealed or hard-drawn	ASTM B 193	200 (392)	May be uncoated or provided with a silver coating
High strength copper alloy, annealed, diameter of each strand or thickness of rectangular or tubular conductor less than 0.015 inch (0.38 mm)	ASTM B 624	150 (302)	May be uncoated or provided with a tin, silver, nickel, or lead based alloy coating. Copper alloy employing 0.05 – 0.127 mm (1.969 – 5.0 mils) may be minimum 70 percent IACS and meets the same requirements as conductors meeting ASTM B624 except that the minimum tensile strength shall not be less than 294 MPa.
High strength copper alloy, annealed, diameter of each strand or thickness of rectangular or tubular conductor at least 0.015 inch (0.38 mm)	ASTM B 624	200 (392)	May be uncoated or provided with a tin, silver, nickel, or lead based alloy coating.

NOTE 1 – "Copper, tin coated" mentioned in this table refers to copper strands of a conductor that are coated with tin before they are twisted. "Copper metallurgically bonded via the addition of tin, " mentioned in this table refers to copper strands that are twisted and then coated with tin.

[a] IACS – International Annealed Copper Standard

Table 5.4
Maximum direct-current resistance of stranded copper conductors, uncoated or with each strand coated with tin

Size of conductor, AWG	20°C				25°C			
	Tin coated copper		Uncoated copper		Tin coated copper		Uncoated copper	
	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m
50	11837	38878	11020	36122	12041	39490	11224	36837
49	9431	30976	8780	28780	9593	31463	8943	29350
48	7532	24740	7013	22987	7662	25130	7143	23442
47	5918	19439	5510	18061	6020	19745	5612	18418
46	4715	15488	4390	14390	4797	15732	4472	14675
45	3742	12290	3484	11419	3806	12484	3548	11645
44	2900	9525	2700	8850	2950	9675	2750	9025
43	2397	7872	2231	7314	2438	7996	2273	7459
42	1856	6096	1728	5664	1888	6192	1760	5776
41	1480	4860	1378	4515	1505	4936	1403	4605
40	1207	3965	1124	3684	1228	4027	1145	3757
39	951	3123	885	2902	967	3172	902	2959
38	725	2381	675	2213	738	2419	688	2256
37	574	1886	535	1752	584	1916	545	1787
36	464	1524	432	1416	472	1548	440	1444
35	369	1213	344	1127	376	1232	350	1150
34	292	960	272	892	297	975	277	909
33	230	756	214	702	234	768	218	716
32	181	595	169	553	184	605	172	564
31	146	481	136	447	149	489	139	456

Table 5.5
Maximum direct-current resistance of metric-sized solid conductors of aluminum, copper-clad aluminum, and uncoated copper[a]

Nominal size of conductor, mm^2	20°C			
	Aluminum and copper-clad aluminum		Uncoated copper	
	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m
0.01	–	–	538	1765
0.05	–	–	107	351
0.1	–	–	53.3	175
0.14	–	–	38.4	126
0.25	–	–	21.6	71
0.34	–	–	16.2	53
0.5	–	–	11	36.0
0.75	–	–	7.47	24.5

Table 5.5 Continued on Next Page

Table 5.5 Continued

Nominal size of conductor, mm^2	20°C			
	Aluminum and copper-clad aluminum		Uncoated copper	
	Ohms per 1000 ft	Ohms per 1000 m	Ohms per 1000 ft	Ohms per 1000 m
1	–	–	5.52	18.1
1.5	–	–	3.69	12.1
2.5	–	–	2.26	7.41
4	–	–	1.41	4.61
6	–	–	0.939	3.08
10	0.939	3.08	0.558	1.83
16	0.582	1.91	0.351	1.15
25	0.366	1.20	0.222	0.727
35	0.265	0.868	0.16	0.524
50	0.195	0.641	0.118	0.387
70	0.135	0.443	0.082	0.268
95	0.0975	0.320	0.0588	0.193
120	0.0771	0.253	0.0466	0.153
150	0.0628	0.206	0.0378	0.124
185	0.05	0.164	0.0308	0.101
240	0.0381	0.125	0.0236	0.0775
300	0.0305	0.100	0.0189	0.0620
400	0.0237	0.0778	0.0142	0.0465

Table 5.6
Maximum direct-current resistance of metric-sized solid conductors of tin coated copper[a]

Nominal size of conductor, mm^2	20°C	
	Ohms per 1000 ft	Ohms per 1000 m
0.01	559	1834
0.05	112	366
0.1	55.5	182
0.14	39.6	130
0.25	22.3	73.2
0.34	16.4	53.9
0.5	11.2	36.7
0.75	7.56	24.8
1	5.55	18.2
1.5	3.72	12.2
2.5	2.3	7.56
4	1.43	4.70

Table 5.6 Continued on Next Page

Table 5.6 Continued

Nominal size of conductor, mm^2	20°C	
	Ohms per 1000 ft	Ohms per 1000 m
6	0.948	3.11
10	0.561	1.84
16	0.354	1.16

Table 5.7
Maximum direct-current resistance of metric-sized stranded conductors of uncoated copper[a]

Nominal size of conductor, mm^2	20°C	
	Ohms per 1000 ft	Ohms per 1000 m
0.01	547	1796
0.05	109	359
0.1	54.6	179
0.14	42.5	139.3
0.25	23.8	78.0
0.34	17.5	57.4
0.5	11.9	39.0
0.75	7.92	26.0
1	5.94	19.5
1.5	4.05	13.3
2.5	2.43	7.98
4	1.51	4.95
6	1.006	3.30
10	0.582	1.91
16	0.369	1.21
25	0.238	0.780
35	0.169	0.554
50	0.118	0.386
70	0.0829	0.272
95	0.0628	0.206
120	0.0491	0.161
150	0.0393	0.129
185	0.0323	0.106
240	0.0244	0.0801
300	0.0195	0.0641
400	0.0148	0.0486
500	0.0117	0.0384
630	0.00849	0.02787

Table 5.8
Maximum direct-current resistance of metric-sized stranded copper conductors, with each strand coated with tin[a]

Nominal size of conductor, mm^2	20°C	
	Ohms per 1000 ft	Ohms per 1000 m
0.01	559	1835
0.05	118	386
0.1	58.5	192
0.14	43.6	143.2
0.25	24.4	80.1
0.34	18	59.0
0.5	12.2	40.1
0.75	8.14	26.7
1	6.1	20.0
1.5	4.18	13.7
2.5	2.5	8.21
4	1.55	5.09
6	1.033	3.39
10	0.594	1.95
16	0.378	1.24
25	0.242	0.795
35	0.172	0.565
50	0.12	0.393
70	0.0844	0.277
95	0.064	0.210
120	0.05	0.164
150	0.0402	0.132
185	0.0329	0.108
240	0.0249	0.0817
300	0.0199	0.0654
400	0.0151	0.0495
500	0.0119	0.0391
630	0.0089	0.0292

5.3 Size and cross-sectional area

5.3.1 The size of a round, solid conductor shall not be less than indicated in Table 5.1 or Table 5.2 (as applicable) when measured in accordance with Conductor Diameter, Section 200, of UL 1581, or 5.1.1 for a rectangular conductor. The size of a solid conductor shall not be greater than the nominal value of the next larger conductor size indicated in Table 5.1.

Exception: For a conductor composed of a round, solid metallic wire as described in Exception 6 to 51.2(d), the actual size of the conductor shall be within minus 1 percent, plus 10 percent of the diameter marked on the tag, reel, or carton.

5.3.2 The cross-sectional area of a rectangular, solid conductor shall not be less than indicated in Table 5.1 when measured in accordance with 5.1.1.

Exception: For a conductor composed of a rectangular, solid metallic wire as described in Exception 7 to 51.2(d), the actual width and thickness of the conductor shall be within minus 1 percent, plus 10 percent, respectively, of the width and thickness marked on the tag, reel, or carton.

5.3.3 The cross-sectional area of a stranded or braided conductor shall not be less than indicated in Table 5.1 or Table 5.2 (as applicable) when determined by either of the following:

a) The sum of the areas of its component round or rectangular strands.

b) The weight method outlined in UL 1581, for a round compact-stranded aluminum conductor or a round compressed-stranded copper or aluminum conductor.

For a conductor of tinned copper with minimum 98 percent IACS or unalloyed copper with minimum 100 percent IACS, the minimal cross-section area from Table 5.2 is not applicable.

The cross-sectional area of a stranded conductor shall not be greater than the nominal value of the next larger conductor size indicated in Table 5.1.

5.3.4 For a conductor composed of minimum 97 percent IACS unalloyed copper described in the Exception to 51.2(f) the determination of conductor resistance described in 5.6.1 – 5.6.3 may be used as an alternative method for determining conductor size and, in the case of a dispute, shall be used as the referee method of determining conductor size.

5.3.5 For a conductor composed of a material other than minimum 97 percent IACS unalloyed copper described in the Exception to 51.2(f), the determination of conductor resistance described in 5.6.1 – 5.6.3 shall be conducted.

5.3.6 For a tinsel conductor, the determination of the conductor resistance marked on the tag [see Exception 5 to 51.2(d)] shall be conducted in accordance with D-C Conductor Resistance, Section 220, in UL 1581.

5.4 Metal coating

5.4.1 When the insulation or other materials such as a fibrous thread or a separator adjacent to a copper, copper alloy, copper-clad aluminum, or copper-clad steel conductor is of a material that corrodes unprotected copper as determined in the test in Conductor Corrosion – General, Section 500, of UL 1581, and when a protective separator that prevents the corrosion of the copper conductor material is not provided, the solid conductor and each of the individual strands of a stranded conductor shall be separately covered with a metal or alloy coating complying with 4.1 as applicable to the finished wire.

5.4.2 In the case of a stranded conductor on which a coating is not required for corrosion protection and is solely to keep the insulation from adhering to copper, it is not prohibited to coat only the wires of the outer layer.

5.5 Joints

5.5.1 A joint (splice) in a solid conductor or in one of the individual wires of a stranded conductor shall not change the diameter of the solid conductor, the individual wire strand, or the overall stranded conductor. In other than flexing applications, a joint may be made in a stranded conductor as a whole or may be made by joining each individual wire. For flexing applications, joints shall be made by separately joining each individual strand. A joint shall be made only before any coverings are applied to an insulated conductor. The insulation applied to such joints shall be equivalent to that removed and shall comply with the requirements in this Standard. A joint in a compact or compressed-stranded conductor shall be made before compacting or compressing.

5.5.2 In a rope-lay-stranded conductor which consists of a central core surrounded by one or more layers of stranded members (primary groups), each member shall be spliced as a unit. These splices are not to be any closer together than two lay lengths.

5.6 Resistance

5.6.1 Conductor resistance shall be equal to or less than the maximum resistance values according to DC Conductor Resistance, Tables 30.1 – 30.11 of UL 1581 for conductors in Sizes 14 AWG through 2000 kcmil; Tables 30.1 – 30.5 of UL 1581 for conductors between 15 – 30 AWG; Table 5.4 for stranded copper for conductors smaller than 30 AWG; and Table 5.5, Table 5.6, Table 5.7, and Table 5.8 for metric-sized conductors. The formula[a]

$$k_{t,Cu} = \frac{254.5}{234.5 + t} = \frac{1}{1 + 0.00393(t - 20)}$$

$$k_{t,Al} = \frac{248}{228 + t} = \frac{1}{1 + 0.00403(t - 20)}$$

$$R_{20} = k_t \cdot R_t \cdot \frac{1000}{L}$$

in which:

t is the test temperature in degrees C,

k is the correction factor (see UL 2556, Table 1, Adjustment factor for DC resistance of conductors).

L is the length of the conductor in feet or meters, and

R_t is resistance measured other than 20°C,

shall be used to correct the conductor resistance values of the metric-sized conductors for measurements made at temperatures other than 20°C.

Compliance of the DC conductor resistance shall be determined in accordance with DC Conductor Resistance, Section 220, of UL 1581. For braided conductors, the following formula shall be used to calculate the DC resistance (DCR):

DCR = Resistance of one strand/[cos (braid angle)] X (number of ends) X (number of carriers)

Exception: The DC conductor resistance of tinsel conductor and magnet wire conductor shall not exceed the maximum value indicated on the tag, reel, or carton [see Exception 5 to 51.2(d)].

5.6.2 For conductors having a conductivity other than 100 percent as noted in Table 5.3 , the maximum resistance is to be determined by multiplying the maximum resistance for uncoated copper by the ratio of 100 percent IACS (International Annealed Copper Standard) to the percent conductivity applicable to the conductor under consideration. For example, to determine the maximum resistance of a 12 AWG (6530 cmil or 3.31 mm^2) solid 40-percent-conductivity copper-clad steel conductor:

a) R[12 AWG copper-clad steel at 20°C (68°F)] = R(12 AWG copper at 20°C) X 100/40 = R(12 AWG copper at 20°C or 68°F) X 2.5.

b) R[12 AWG copper at 20°C (68°F)] = 1.62 ohms/1000 feet or 5.31 ohms/kilometer.

c) R[12 AWG copper-clad at 20°C (68°F)] = 1.62 X 2.5 = 4.05 ohms/1000 feet or 5.31 X 2.5 = 13.28 ohms-kilometer.

5.6.3 Special alloy copper conductors having a conductivity of not less than 55 percent of 100 percent IACS (International Annealed Copper Standard) copper are not prohibited from being used when the finished wire or cable is suitable for the use, and when the cross section of the conductor is sufficient to give it a conductivity of not less than 55 percent of the 100 percent IACS (International Annealed Copper Standard) conductor and the tag is marked to indicate its nominal AWG size.

5.7 Stranding

5.7.1 Stranded conductors shall use a method of stranding that complies with the requirements in 5.7.2 – 5.7.8.

5.7.2 Conductors of intermediate nominal area shall comply with the requirement for the length of lay of the next smaller conductor as shown in Maximum lay of single-bunch, bunch stranded copper, copper alloy, copper-clad steel, copper-clad aluminum, and aluminum conductors, Table 5.9 . The American Wire Gauge (AWG) sizes shown in Table 5.9 represent conductors of intermediate nominal area.

5.7.3 Metric-sized conductors of intermediate nominal area shall comply with the requirement for the length of lay of the next larger AWG size (smaller conductor) as shown in Table 5.9 .

5.7.4 The individual wires used in making up a stranded conductor are usually drawn to the same diameter, which is not required to be the diameter of any AWG or other standard gauge number. The individual wires of a concentric-lay-stranded conductor are not required to be all of the same diameter.

5.7.5 A 19-wire combination round-wire unilay-stranded conductor of soft-annealed copper or an aluminum alloy indicated in this section shall be round and shall consist of:

a) A straight central wire,

b) An inner layer of six wires of the same diameter as the central wire with the six wires having identical lengths of lay, and

c) An outer layer consisting of six wires of the same diameter as the central wire alternated with six smaller wires having a diameter of 0.732 times the diameter of the central wire and with all twelve wires of the outer layer having the same length of lay and direction of lay as the six wires of the inner layer (see Nominal strand and conductor dimensions for 19-wire combination round-wire unilay-stranded copper conductors, Table 20.6 of UL 1581).

No particular assembly of the individual wires of any other stranded conductor is required. However, simple bunching (untwisted strands) shall not be used for the entire conductor or any part thereof. The length of lay of the strands in a single-bunch bunch-stranded conductor shall not be greater than indicated in Table 5.9 . The direction of lay of the strands in a single-bunch bunch-stranded conductor shall be left-hand unless specifically noted on the tag markings. Any type of stranding indicated in Nominal strand and conductor dimensions for 19-wire combination round-wire unilay-stranded copper conductors, concentric-lay Classes B, C, and D (round strands), compressed-stranded 19-wire combination round-wire unilay-stranded copper or aluminum, rope-lay (constructed of concentric-lay members composed of round strands) Classes G and H, rope-lay (constructed of bunch-stranded members composed of round strands) Classes I, K, and M shall comply with 5.7.7 or 5.7.8 as applicable. The direction of lay of the outer layer shall be left-hand in all cases unless specifically noted on the tag markings.

Table 5.9
Maximum lay of single-bunch, bunch stranded conductors

AWG size	Copper, copper alloy, copper-clad steel		Aluminum, copper-clad aluminum	
	Inches	(mm)	Inches	(mm)
28 or smaller	0.5	13	–	–
26	0.6	15	–	–
24	0.7	18	–	–
22	0.8	20	–	–
20	1.25	32	–	–
18	2.0	51	–	–
16	2.0	51	–	–
14	2.0	51	–	–
12	2.0	51	2.0	51
10	2.5	64	2.5	64
8	3.0	76	2.75	70
6	3.5	89	3.375	86
4 and larger	4.0	102	16 times the conductor diameter	

5.7.6 A compact-stranded conductor shall be a round conductor consisting of a central core wire (strand) surrounded by one or more layers of helically laid wires (strands). A compact-stranded copper conductor shall consist of uncoated strands. A compact-stranded aluminum conductor shall have all layers with the same direction of lay (left-hand unidirectional unless specifically noted on the tag markings). A compact-stranded copper conductor shall be either left-hand unidirectional or have the direction of lay reversed in adjacent layers (concentric-lay-stranded with the outer layer left-handed unless specifically noted on the tag markings) and with each layer rolled, drawn, or otherwise compressively formed to distort the originally round or partially preshaped strands to various close-fitting shapes that achieve almost complete filling of the spaces originally present between the strands. Each layer shall be compacted before the next layer is applied, and each compacted layer – including the outermost layer – shall have an essentially smooth, round outer surface. The length of lay of the strands in the outer layer of a 1 AWG – 1000 kcmil conductor shall be 8 – 16 times the overall diameter of that layer. The length of lay of the strands in the outer layer of a size 50 – 2 AWG conductor shall be 8.0 – 17.5 times the overall diameter of that layer.

5.7.7 A compressed-stranded conductor shall be a round conductor consisting of a central core wire surrounded by one or more layers of helically laid wires with either the direction of lay reversed in successive layers, or of unilay or unidirectional lay. The direction of lay of the outer layer shall be left-hand in all cases unless specifically noted on the tag markings. The strands of one or more layers are slightly compressed by rolling, drawing, or other means to change the originally round strands to various shapes that achieve filling of some of the spaces originally present between the strands.

5.7.8 Every stranded conductor other than a compact-stranded conductor or a single-bunch bunch-stranded conductor shall comply with the following:

a) The direction of lay of the strands, members, or ropes in a 6 AWG – 2000 kcmil conductor other than a combination unilay or compressed unilay or compressed unidirectional lay conductor shall be reversed in successive layers. Rope-lay conductors with bunch-stranded or concentric-stranded members shall be either unidirectional or reversed. All unidirectional lays and the outer layer of reversed lays shall be in the left-hand direction unless specifically noted on the tag markings.

b) For a bunch-stranded member of a rope-lay-stranded conductor in which the members are formed into rope-stranded components that are then cabled into the final conductor, the length of lay of the individual members within each component shall not be more than 30 times the outside diameter of one of those members.

c) For a concentric-stranded member of a rope-lay-stranded conductor, the length of lay of the individual strands in a member shall be 8 – 16 times the outside diameter of that layer. The direction of lay of the strands in each member shall be reversed in successive layers of the member.

d) The length of lay of the strands in both layers of a 19-wire combination round-wire unilay-stranded copper or aluminum conductor shall be 8 – 16 times the outside diameter of the completed conductor. Otherwise, the length of lay of the strands in every layer of a concentric-lay-stranded or compressed-stranded conductor consisting of fewer than 37 strands shall be a maximum of:

1) 40 times the outside diameter of the conductor for 30 AWG or smaller conductors;

2) 30 times the outside diameter of the conductor for size 29 – 15 AWG conductors;

3) 20 times the outside diameter of the conductor for size 14 – 6 AWG conductors; and

4) 16 times the outside diameter of the conductor for 5 AWG and larger conductors.

e) The length of lay of the strands in the outer two layers of a concentric-lay-stranded conductor consisting of 37 or more strands shall be 8 – 16 times the outside diameter of that layer.

f) The length of lay of the members or ropes in the outer layer of a rope-lay-stranded conductor shall be 8 – 16 times the outside diameter of that layer.

5.7.9 A composite conductor composed of six bare or metal-coated copper strands with one central steel strand may be accepted for internal wiring of electronic equipment where not subject to flexing.

5.7.9.1 A conductor composed of soft annealed copper and hard-drawn copper strands as specified by Table 5.3 is not prohibited. The orientation of the hard-drawn copper strands within the finished conductor are not specified.

5.7.10 A single conductor may consist of three bunch-stranded members laid parallel. The stranding within each member shall comply with the lay length requirements described in 5.7.2 and determined based on the size of each individual member.

5.8 Separator

5.8.1 The insulation shall be prevented, by the manufacturing process or by a separator constructed for the intended use, from penetrating between the strands of a stranded conductor for thermoset insulation.

5.8.2 A separator used between a conductor and insulation shall be clearly distinguishable from the conductor once the insulation is removed. The color shall be other than green or green and yellow; however, a separator that is solid, striped, or appears in some other pattern, complies with the intent of this requirement.

5.9 Semi-conductive polymeric layer

5.9.1 A semi-conductive polymeric layer may be provided over one or more conductors.

5.9.2 The layer shall be clearly distinguishable from the conductor once the insulation is removed. The color shall be other than green or green and yellow; however, the layer that is solid, striped, or appears in some other pattern, complies with the intent of this requirement.

6 Optical Fiber Member(s)

6.1 General

6.1.1 A cable is not prohibited from being composed entirely of optical-fiber members or a combination of electrical conductors and optical-fiber members.

6.2 Cable composed of both current-carrying conductors and optical-fiber members

6.2.1 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 a current-carrying cable, each optical-fiber member is to be evaluated as a filler.

6.2.2 A group of optical-fiber members without any electrical conductor(s) that includes one or more non-current-carrying metal parts such as metal strength elements or metal vapor barriers may be used in a group of optical-fiber members without any electrical conductor(s). 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 and shall be earth-grounded when the cable is installed.

6.3 Cable composed entirely of optical-fiber members

6.3.1 Construction and requirements

6.3.1.1 The optical fiber cable shall consist of one or more optical fibers, and may employ a buffer, a covering, and/or an overall jacket.

6.3.1.2 The thickness of the buffer is not specified. Buffers used as the outermost layer in a wire or cable construction shall be subjected to the same requirements as a jacket.

7 Insulation

7.1 General

7.1.1 A conductor shall be insulated for its entire length. The insulation shall:

a) Be applied directly to the surface of the conductor or to any separator;

b) Cover the conductor or any separator completely; and

c) Not have any defects that are visible with normal or corrected vision without magnification.

The insulation may be applied simultaneously in more than one color/layer provided that all layers are not separable and are of the same base compound (differ only in color). The thickness of each individual layer is not specified.

7.2 Materials

7.2.1 Specimens of solid, single layered and multi-layered non-separable extruded insulations and each layer of separable multi-layer extruded insulations removed from finished insulated conductors shall meet the appropriate values of unaged and oven aged elongation and tensile strength provided in Table 7.2, and Table 7.3, or any of the materials described in the Materials column in Table 7.1. Specimens shall be tested in accordance with the Physical Properties, Unaged and Air Oven Aged, Section 14, or shall be evaluated in accordance with the test, Dry temperature rating of new materials (long term aging test) in the Standard for Wire and Cable Test Methods, UL 2556.

7.2.2 Solid single-layer and multi-layered extruded insulation made from materials which are not described in Table 7.1, or Table 7.2, and Table 7.3, shall also be subjected to the Flexibility Test, Section 21, after 150 days of aging at the temperature described the test Dry temperature rating of new materials (long-term aging test) in the Standard for Wire and Cable Test Methods, UL 2556.

Table 7.1
Index to insulations, buffers, coverings, shields, and jackets

Materials	Dry temperature rating, °C	Applicable table of physical properties in UL 1581*	Notes
CP	60	50.1	–
CP	75	50.1	–
CP	90	50.23	–
CP	105	50.22	–
CPE	60	UL 62, Table 9, Class 13	Insulation only
CPE	60	UL 62, Table 12, Class 1.2	Jacket
CPE	75	50.34	Insulation only
CPE	75	UL 62, Table 12, Class 1.3	Jacket
CPE	90	UL 62, Table 9, Class 12	Insulation only
CPE	90	UL 62, Table 12, Class 1.4	Jacket
CPE	105	UL 62, Table 9, Class 18	Insulation only
CPE	105	UL 62, Table 12, Class 1.12	Jacket
ECA	300	50.40	–
ECTFE	150	50.63	–
EP	60	UL 62, Table 9, Class 1	Insulation only. Covering required, or evaluated for restricted use.
EP	60	UL 62, Table 12, Class 1.1	Jacket
EP	75	UL 62, Table 9, Class 2	Insulation only. Covering required, or evaluated for restricted use.
EP	75	UL 62, Table 12, Class 1.3	Jacket
EP	90	UL 62, Table 9, Class 3	Insulation only. Covering required, or evaluated for restricted use.

Table 7.1 Continued on Next Page

Table 7.1 Continued

Materials	Dry temperature rating, °C	Applicable table of physical properties in UL 1581*	Notes
EP	90	UL 62, Table 12, Class 1.4	Jacket
EP	105	UL 62, Table 9, Class 19	Insulation only. Covering required, or evaluated for restricted use.
EP	105	UL 62, Table 12, Class 1.12	Jacket
EPCV	90	50.62	–
EPDM	60	50.24	–
EPDM	75	50.54	–
EPDM	90	50.52	–
EPDM	105	50.55	Insulation only.
EPDM	125	50.56	–
ETFE	150	50.63	–
ETFE	200	50.64	–
FEP	150	50.73	–
FEP	200	50.70	–
FRPE	90	50.134	–
FRPP	60	50.139.1	–
FRPP	75	50.139.1	–
HDFRPE	75	50.133	–
HDPE	75	50.136	–
LDFRPE	75	50.133	–
LDPE	75	50.136	–
MFA	200	50.137	–
MFA	250	50.137	–
mPPE	90	50.77	–
mPPE	105	50.77	–
mPPE-PE	80	50.76	–
NBR/PVC	60	50.24	Insulation
NBR/PVC	60	UL 62, Table 12, Class 1.2	Jacket
NBR/PVC	75	50.97	Insulation
NBR/PVC	75	UL 62, Table 12, Class 1.3	Jacket
NBR/PVC	90	50.23	Insulation
NBR/PVC	90	UL 62, Table 12, Class 1.4	Jacket
Neoprene	60	50.120	Insulation
Neoprene	60	UL 62, Table 9, Class 1	Insulation. Covering required, or evaluated for restricted use.
Neoprene	60	UL 62, Table 12, Class 1.2	Jacket
Neoprene	75	UL 62, Table 9, Class 2	Insulation. Covering required, or evaluated for restricted use.
Neoprene	75	UL 62, Table 12, Class 1.3	Jacket

Table 7.1 Continued on Next Page

Table 7.1 Continued

Materials	Dry temperature rating, °C	Applicable table of physical properties in UL 1581*	Notes
Neoprene	90	50.125	Insulation
Neoprene	90	UL 62, Table 9, Class 3	Insulation. Covering required, or evaluated for restricted use.
Neoprene	90	UL 62, Table 12, Class 1.4	Jacket
PFA	200	50.137	–
PFA	250	50.137	–
PP	60	50.139	–
PP	75	50.139	–
PTFE	250	50.219	–
PVC	60	50.182	–
PVC	75	50.182	–
PVC	90	50.182	–
PVC	105	50.182	–
Blend of PVC and TPU	60	50.184	–
Blend of PVC and TPU	75	50.184	–
Blend of PVC and TPU	80	50.184	–
PVDF	125	50.185	–
PVDF	150	50.185	–
SBR/NR	60	50.200	Insulation only. Covering required, or evaluated for restricted use.
SBR/NR	60	50.196	Insulation only.
SBR/NR	75	UL 62, Table 9, Class 2	Insulation only. Covering required, or evaluated for restricted use.
SBR/NR	75	50.199	Jacket
SBR/NR	90	UL 62, Table 9, Class 3	Insulation only. Covering required, or evaluated for restricted use.
SR	150	50.210	Insulation only. Covering required, or evaluated for restricted use
SR	200	50.210	Insulation only. Covering required, or evaluated for restricted use
SRPVC	60	50.183	–
SRPVC	75	50.183	–
SRPVC	90	50.183	–
SRPVC	105	50.183	–
THV	80	50.221	–
TPE	90	50.224	–
TPE	105	50.223	–
TPES	60	50.226	–

Table 7.1 Continued on Next Page

Table 7.1 Continued

Materials	Dry temperature rating, °C	Applicable table of physical properties in UL 1581*	Notes
TPES	75	50.226	–
TPES	80	50.226	–
TPU	60	50.227	–
TPU	75	50.227	–
TPU	80	50.227	–
TPU	90	50.227.1	–
TPU	105	50.227	–
XL	75	50.231	–
XL	90	50.231	–
XL	105	50.245	–
XLPE, XLFRPE	105	50.245	–
XLEVA	105	50.245	–
XLPO	105	50.233	–
XLPO	125	50.232	–
XLPO	150	50.232	–

*Other standards may be used as indicated.

Table 7.2
Physical properties, unaged, of materials used for insulation, buffer, covering, and jacket

Polymer designation	Dry temperature rating, °C (°F)	Polymer type/test speed, inches (mm)	Physical properties, unaged — Minimum average — Elongation, percent	Physical properties, unaged — Minimum average — Tensile strength, psi (kgf/mm^2)
PTFE – Polytetrafluoroethylene or TFE – Tetrafluoroethylene	200 (392)	Thermoplastic/20 ±1 inch (508 ±25 mm) per minute	200	3000 (2.11)
Silicone without an outer covering or braid[a]	150 (302) or 200 (392)	Thermoset/20 ±1 inch (508 ±25 mm) per minute	250	1200 (0.84)
High Temperature Silicone Rubber[b]	250 (482)	Thermoset/20 ±1 inch (508 ±25 mm) per minute	100	700 (0.49)
Nylon	80 (176)	Thermoplastic/20 ±1 inch (508 ±25 mm) per minute	100	3000 (2.11)

[a] Applicable to wires that have not been evaluated for restricted use, such as for internal or external use. Wires provided with insulation or jacket made of silicone with braid and that have not been evaluated for restricted use, and wires that have been evaluated for restricted use shall comply with the requirements specified in the table, Physical properties 200°C and 150°C silicone rubber jackets from CATV cables and insulations from power-limited circuit cable, from cable for power-limited fire-alarm circuits, and from other cables and in the test, Flexing of Type SF-1, SF-2, SFF-1, AND SFF-2 Fixture Wires, Section 1560, of UL 1581. A 0.25 in (6.35 mm) diameter mandrel is to be used when the insulation is less than 0.030 in (0.76 mm) average thickness, and a 0.50 in (12.7 mm) diameter mandrel is to be used when the insulation has at least 0.030 in (0.76 mm) average thickness.

[b] Applicable to wires which have been evaluated for a restricted use or those which have an overall covering.

Table 7.3
Physical properties, air oven aged, of insulation, buffer, covering, and jackets

Polymer designation	Dry temperature rating, °C (°F)	Physical properties, air oven aged			
		Air oven conditioning		Minimum percent of unaged values	
		Oven temperature, °C ±2 (°F ±3)	Time, days	Elongation, percent	Tensile strength, percent
PTFE – Polytetrafluoroethylene or TFE – Tetrafluoroethylene	200 (392)	260 (500)	4	85	85
Silicone without an outer covering or braid[a]	150 (302)	158 (316)	60	25[b]	60[c]
	200 (392)	210 (410)	60	25[d]	60[e]
High Temperature Silicone Rubber[h]	250 (482)	260 (500)	60	f	g
Nylon	80 (176)	113 (235)	7	65	65

[a] Applicable to wires that have not been evaluated for restricted use, such as for internal or external use. Wires provided with insulation or jacket made of silicone with braid and that have not been evaluated for restricted use, and wires that have been evaluated for restricted use shall comply with the requirements specified in the table Physical properties 200°C and 150°C silicone rubber jackets from CATV cables and insulations from power-limited circuit cable, from cable for power-limited fire-alarm circuits, and from other cables and in the test, Flexing of Type SF-1, SF-2, SFF-1, AND SFF-2 Fixture Wires, Section 1560, of UL 1581. A 0.25 in (6.35 mm) diameter mandrel is to be used when the insulation is less than 0.030 in (0.76 mm) average thickness, and a 0.50 in (12.7 mm) diameter mandrel is to be used when the insulation has at least 0.030 in (0.76 mm) average thickness.

[b] Elongation of 150 percent complies with the intent of this requirement.

[c] Tensile strength of 850 psi (0.6 kgf/mm^2) complies with the intent of this requirement.

[d] Elongation of 100 percent complies with this requirement.

[e] Tensile strength of 600 psi (0.42 kgf/mm^2) complies with the intent of this requirement.

[f] Elongation of 50 percent complies with this requirement.

[g] Tensile strength of 500 psi (0.35 kgf/mm^2) complies with the intent of this requirement.

[h] Applicable to wires which have been evaluated for a restricted use or those which have an overall covering.

7.2.3 Foamed and foam/skin insulation and non-extruded insulations shall be evaluated in accordance with the Flexibility Test, Section 21.

7.2.4 Materials that are evaluated for use at 75°C (167°F) in UL 1581 may be evaluated for use at 80°C (176°F). The aging period shall be 7 days at 113°C (235°F) or 60 days at 87°C (189°F), and the physical-properties requirements shall be the same as for the 75°C rating.

7.3 Thickness

7.3.1 Measurements from which the average thickness is to be determined shall be made in accordance with Thicknesses of Insulation on Flexible Cord and on Fixture Wire, Section 250, of UL 1581. When the average thickness is equal to or less than 0.002 inch (0.05 mm), the average thickness shall be rounded to the nearest 0.0001 inch (0.0025 mm) and an optical measuring device capable of measuring to the nearest 0.0001 inch (0.0025 mm) shall be used for taking thickness measurement.

7.3.2 The minimum thickness at any point shall be at least 90 percent of the required average thickness, rounded to the nearest 0.001 inch (0.025 mm). When the minimum thickness at any point is equal to or less than 0.002 inch (0.05 mm), the minimum thickness at any point shall be rounded to the nearest 0.0001 inch (0.0025 mm) and an optical measuring device capable of measuring to the nearest 0.0001 inch (0.0025 mm) shall be used for taking thickness measurement.

7.3.3 When individual conductor strands of a stranded conductor are less than 0.040 in (1.0 mm) in diameter or width, and the measurement of the insulation thickness is made using an optical measuring device, 0.003 in (0.08 mm) shall be added to the measured value of average and minimum at any point of insulation thickness before comparing it with the required minimum thickness. The addition of the 0.003 in (0.08 mm) to the measured value does not apply to the following constructions:

a) Average thickness less than 15 mils (0.38 mm),

b) Minimum thickness at any point less than 13 mils (0.33 mm),

c) Compact or compressed stranded conductors,

d) A stranded conductor covered by a separator, or

e) A stranded conductor covered by a tape or braid insulation.

7.3.4 For wires with solid, extruded insulation which do not have a restricted use, the thicknesses shown in Table 7.4 and Table 7.5 apply. Thinner thicknesses than shown in Table 7.4 and Table 7.5, foamed and foam/skin, or non-extruded insulation may be evaluated for unrestricted use by subjecting the wires to the Crush Resistance Test, Section 28. Wires with solid, extruded insulation that are intended to be used in a jacketed cable or in a cable with an outermost layer of covering are not required to comply with either the thicknesses shown in Table 7.4 and Table 7.5 or with the Crush Resistance Test.

7.3.5 The requirements for the wires noted in Table 7.4 and Table 7.5 are applicable to wiring that is intended to be installed in a normal application, such as for use in environments where it is subject to flexing. Wiring is not prohibited from being evaluated for special ratings where the thickness shall be determined in accordance with the requirements of 7.3.1. Special applications for which the wiring has been evaluated shall be marked on the tag or spool of the finished product.

Table 7.4
Thickness requirements for solid, extruded, non-fluoropolymer insulation materials[a]

Conductor size, AWG	Conductor size, mm²	Minimum average wall thickness (Avg) and minimum wall thickness at any point (Min) of insulation									
		Wires rated 30 volts, inch (mm)		Wires rated 60, 90, 125, and 150 volts, inch (mm)		Wires rated 300 volts, inch (mm)		Wires rated 600, 1000 volts, inch (mm)		Wires rated over 1000 volts, inch (mm)	
		Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min
50 – 31	0.01	0.006 (0.15)	0.005 (0.13)	0.012 (0.30)	0.011 (0.28)	0.012 (0.30)	0.011 (0.28)	0.030 (0.76)	0.027 (0.69)	b	b
30 – 25	0.05 – 0.1	0.006 (0.15)	0.005 (0.13)	0.012 (0.30)	0.011 (0.28)	0.012 (0.30)	0.011 (0.28)	0.030 (0.76)	0.027 (0.69)	b	b
24 – 20	0.50	0.006 (0.15)	0.005 (0.13)	0.012 (0.30)	0.011 (0.28)	0.012 (0.30)	0.011 (0.28)	0.030 (0.76)	0.027 (0.69)	b	b
19 – 15	0.65 – 1.5	0.006 (0.15)	0.005 (0.13)	0.015 (0.38)	0.013 (0.33)	0.015 (0.38)	0.013 (0.33)	0.030 (0.76)	0.027 (0.69)	b	b
14 – 12	2.5	0.006 (0.15)	0.005 (0.13)	0.020 (0.51)	0.018 (0.46)	0.020 (0.51)	0.018 (0.46)	0.030 (0.76)	0.027 (0.69)	b	b
11, 10	4.0	0.006	0.005	0.030	0.027	0.030	0.027	0.030	0.027	b	b

Table 7.4 Continued on Next Page

Table 7.4 Continued

Conductor size, AWG	Conductor size, mm^2	Minimum average wall thickness (Avg) and minimum wall thickness at any point (Min) of insulation									
		Wires rated 30 volts, inch (mm)		Wires rated 60, 90, 125, and 150 volts, inch (mm)		Wires rated 300 volts, inch (mm)		Wires rated 600, 1000 volts, inch (mm)		Wires rated over 1000 volts, inch (mm)	
		Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min
		(0.15)	(0.13)	(0.76)	(0.69)	(0.76)	(0.69)	(0.76)	(0.69)		
9, 8	6.0	b	b	b	b	0.030	0.027	0.045	0.041	–	–
						(0.76)	(0.69)	(1.14)	(1.04)		
7, 6	10.0	b	b	b	b	0.045	0.041	0.060	0.054	–	–
						(1.14)	(1.04)	(1.52)	(1.37)		
5 – 2	16.0 – 25.0	b	b	b	b	0.045	0.041	0.060	0.054	–	–
						(1.14)	(1.04)	(1.52)	(1.37)		
1 – 4/0	35.0 – 95.0	b	b	b	b	0.060	0.054	0.080	0.072	–	–
						(1.52)	(1.37)	(2.03)	(1.83)		
250 – 500 kcmil	120 – 240	b	b	b	b	0.060	0.054	0.095	0.086	–	–
						(1.52)	(1.37)	(2.41)	(2.18)		
501 – 1000 kcmil	300 – 500	b	b	b	b	0.060	0.054	0.110	0.099	–	–
						(1.52)	(1.37)	(2.79)	(2.51)		
1001 – 2000 kcmil	630 – 1000	b	b	b	b	0.060	0.054	0.125	0.112	–	–
						(1.52)	(1.37)	(3.18)	(2.84)		

[a] This table is intended to show the required insulation thickness for a given AWG or metric diameter dimension. The conductor sizes are not intended to indicate equivalence between English and metric units. See Table 5.1, Conductor Dimensions, for equivalence between English and metric conductor sizes.

[b] See 7.3.5.

Table 7.5
Thickness requirements for solid, extruded, fluoropolymer insulation materials (ECA, ECTFE, ETFE, FEP, MFA, PFA, PTFE, and PVDF)[a]

Conductor size, AWG	Conductor size, mm^2	Minimum average wall thickness (Avg) and minimum wall thickness at any point (Min) of insulation									
		Wires rated 30 volts, inch (mm)		Wires rated 60, 90, 125, and 150 volts, inch (mm)		Wires rated 300 volts, inch (mm)		Wires rated 600, 1000 volts, inch (mm)		Wires rated over 1000 volts, inch (mm)	
		Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min
50 – 31	0.01	0.005	0.004	0.006	0.005	0.009	0.008	0.020	0.018	b	b
		(0.13)	(0.10)	(0.15)	(0.13)	(0.23)	(0.20)	(0.51)	(0.46)		
30 – 25	0.05 – 0.1	0.005	0.004	0.006	0.005	0.009	0.008	0.020	0.018	b	b
		(0.13)	(0.10)	(0.15)	(0.13)	(0.23)	(0.20)	(0.51)	(0.46)		

Table 7.5 Continued on Next Page

Table 7.5 Continued

Conductor size, AWG	Conductor size, mm^2	Minimum average wall thickness (Avg) and minimum wall thickness at any point (Min) of insulation									
		Wires rated 30 volts, inch (mm)		Wires rated 60, 90, 125, and 150 volts, inch (mm)		Wires rated 300 volts, inch (mm)		Wires rated 600, 1000 volts, inch (mm)		Wires rated over 1000 volts, inch (mm)	
		Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min
24 – 20	0.50	0.005 (0.13)	0.004 (0.10)	0.006 (0.15)	0.005 (0.13)	0.009 (0.23)	0.008 (0.20)	0.020 (0.51)	0.018 (0.46)	b	b
19	0.65	0.005 (0.13)	0.004 (0.10)	0.009 (0.23)	0.008 (0.20)	0.009 (0.23)	0.008 (0.20)	0.020 (0.51)	0.018 (0.46)	b	b
18 – 15	1.0 – 1.5	0.005 (0.13)	0.004 (0.10)	0.012 (0.30)	0.011 (0.28)	0.015 (0.38)	0.013 (0.33)	0.020 (0.51)	0.018 (0.46)	b	b
14 – 12	2.5	0.005 (0.13)	0.004 (0.10)	0.012 (0.30)	0.011 (0.28)	0.015 (0.38)	0.013 (0.33)	0.020 (0.51)	0.018 (0.46)	b	b
11, 10	4.0	0.005 (0.13)	0.004 (0.10)	0.012 (0.30)	0.011 (0.28)	0.015 (0.38)	0.013 (0.33)	0.030 (0.76)	0.027 (0.69)	–	–
9, 8	6.0	b	b	b	b	0.015 (0.38)	0.013 (0.33)	0.030 (0.76)	0.027 (0.69)	–	–
7, 6	10.0	b	b	b	b	b	b	0.030 (0.76)	0.027 (0.69)	–	–
5 – 2	16.0 – 25.0	b	b	b	b	b	b	0.030 (0.76)	0.027 (0.69)	–	–
1 – 4/0	35.0 – 95.0	b	b	b	b	b	b	0.045 (1.14)	0.041 (1.04)	–	–
250 – 2000 kcmil	120 – 1000	b	b	b	b	b	b	0.060 (1.52)	0.054 (1.37)	–	–

[a] This table is intended to show the required insulation thickness for a given AWG or metric diameter dimension. The conductor sizes are not intended to indicate equivalence between English and metric units. Please see Table 5.1, Conductor Dimensions, for equivalence between English and metric conductor sizes.

[b] See 7.3.5.

8 Coverings

8.1 Coverings over insulated conductors, groups of insulated conductors, or coaxial members are optional unless the covering is required in order for the construction to comply with a flame rating.

8.2 An overall braid may be of a close weave covering the insulation, shield, or other nonmetallic braid. The braid shall extend for the entire length of the finished wire and shall be consistent throughout its entire length. Each end shall consist of the same kind, size, and ply of yarn. The number of picks per inch or the number of picks per centimeter is not specified. A glass braid shall be lacquered or otherwise treated to prevent fraying. The temperature rating of the finished wire using a braid shall not exceed the temperature limit of the yarn specified in Table 8.1.

Table 8.1
Yarn material and temperature limits

Yarn type	Maximum temperature rating of wire, °C (°F)
Glass	550 (1022)
Aramid paper	250 (482)
Polyaramid fibers	250 (482)
Polyester	200 (392)
Polyethylene terephthalate	125 (257)
Acrylic or nylon	105 (221)
Cotton or rayon in any form; or cotton in any combination with glass, polyester, acrylic, or nylon; or rayon in any combination with glass, polyester, acrylic, or nylon.	90 (194)

8.3 The term "close weave" specified in 8.2 means that the braid is required to completely cover the material directly beneath the braid.

8.4 Extruded polymeric coverings used as the outermost layer in a wire or cable construction shall be subjected to the same requirements as a jacket.

Exception: Extruded nylon coverings per Table 8.2 shall meet the Flexibility Test of Nylon Covering, Section 20. The requirements in Physical Properties, Unaged and Air Oven Aged, Section 14 and the Flexibility Text, Section 21 shall not apply.

Table 8.2
Extruded Nylon Coverings

Conductor size, AWG	Conductor size, mm^2	300 V Nylon wall thickness, inch (mm), maximum average	600, 1000 V Nylon wall thickness, inch (mm), maximum average
50 – 12	0.0.1 – 2.5	0.004 (0.10)	0.006 (0.15)
11, 10	4.0	0.005 (0.13)	0.006 (0.15)
9, 8	6.0	0.005 (0.13)	0.007 (0.18)
7, 6	10.0	0.007 (0.18)	0.007 (0.18)
5 – 2	16.0 – 25.0	0.008 (0.20)	0.008 (0.20)
1 – 4/0	35.0 – 95.0	0.009 (0.23)	0.009 (0.23)
250 – 500 kcmil	127 – 253	0.010 (0.25)	0.010 (0.25)
501 – 1000 kcmil	279 – 507	0.011 (0.28)	0.011 (0.28)

8.5 Measurements from which the average thickness of coverings is to be determined shall be made in accordance with Thicknesses of Jacket on Thermoplastic- and Thermoset-Insulated Wires and Cables, Section 260, of UL 1581. When the average thickness is equal to or less than 0.002 inch (0.05 mm), the average thickness shall be rounded to the nearest 0.0001 inch (0.0025 mm) and an optical measuring device shall be used for making the thickness measurement.

8.6 The minimum thickness at any point shall be at least 80 percent of the required average thickness, rounded to the nearest 0.001 inch (0.025 mm). When the minimum thickness at any point is equal to or less than 0.002 inch (0.05 mm), the minimum thickness at any point shall be rounded to the nearest 0.0001 inch (0.0025 mm) and an optical measuring device shall be used for making the thickness measurement.

9 Fillers

9.1 The use of nonconductive, nonmetallic fillers in a cable is not required. Fillers may be integral with or separate from any binder jacket or overall cable jacket. When fillers are integral with a jacket, the underlying cable assembly shall be readily separable from the filler.

10 Binders

10.1 The entire cable assembly, or any group of conductors (including optical-fiber members), or several such groups within the cable may be enclosed in a binder consisting of a shield, a braid, a tape, or other unspecified means.

11 Shield(s)

11.1 A shield is not required; however, its use over an individual 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, is not prohibited. Several shields are not prohibited from being used in a given cable.

11.2 A shield may consist of a wire braid, wrap, serving, or metal tape.

11.3 A metal tape shall be applied helically or longitudinally with or without a drain wire. Uncoated copper or copper alloy drain wire is not acceptable to be in contact with an aluminum-faced tape.

11.4 A shield consisting of a metal faced paper or polyester tape shall be applied helically or longitudinally with or without a drain wire. Uncoated copper or copper alloy drain wire is not acceptable to be in contact with the aluminum surface of an aluminum-faced tape.

11.5 A shield consisting of a conductive polymeric layer shall have a volume resistivity not exceeding 50,000 ohm-centimeters at the rated temperature of the insulation and shall be provided with a drain wire or other means for termination. Wires or cables using conductive polymeric shields shall be marked in accordance with 50.3 and 51.2(k).

11.6 The details of the construction of a shield and the manner of its application are not specified. There are no requirements for the electromagnetic performance of a shield.

11.7 A shield consisting of a wrap, serving, or tape shall not be the outermost covering on a wire unless the wire is intended to be jacketed, or provided with an outer covering, or the wrap or tape is bonded with adhesive or by heat. Wires using such a shield shall have an overall jacket or covering. A shield consisting of a wire braid or a conductive extrusion is not required to be covered.

11.8 A shield in the form of a wrap, tape or other containing polymeric materials and used as the outermost layer in a wire or cable construction shall be subjected to the same requirements as a non-extruded covering in Table 3.8, or a laminated cable in Table 3.5 for the shield over the laminated cable.

12 Cable Assembly

12.1 Insulated conductors with different temperature ratings that are mixed in a given cable complies with the intent of this requirement when the cable is rated for the lowest temperature rating of any of the constituent insulated conductors. The insulated conductors shall not be marked with a temperature rating that is higher than that of the finished cable.

12.2 Insulated conductors with different voltage ratings that are mixed in a given cable complies with the intent of this requirement when the cable is rated for not higher than the lowest voltage rating of any of the constituent insulated conductors. When the insulated conductors are marked with a voltage rating, the voltage rating shall be the same as that of the finished cable.

12.3 In a given cable, all of the power conductors shall be of the same metal. Cables may contain conductors of different sizes and may contain precabled groups of conductors as described in 12.5.

12.4 In a cable with two conductors, the conductors and any grounding conductor may be either cabled (round) or laid parallel (flat cable).

12.5 The circuit conductors in a round cable shall be cabled with a length of lay that is uniform throughout the length of the cable in compliance with Table 12.1. Grouping of the circuit conductors into pairs, triads, quads, and other precabled subassemblies is not required.

12.6 The direction of lay may be changed (lay reversal) throughout the length of the cable. The intervals are not required to be uniform. In a cable whose direction of lay is changed, the following both apply:

a) Each area in which the lay is right- or left-hand for several (typically 10) complete twists (full 360-degree 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 12.1 and

b) The length of each transition zone (oscillated section) between these areas of right- and left-hand shall not exceed 1.8 times the maximum length of lay indicated in Table 12.1.

12.7 When 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. (A left-hand lay is defined as a counterclockwise twist away from the observer.)

Table 12.1
Length of lay of insulated conductors and precabled groups for cables rated greater than 30 volts

Number of insulated conductors in cable	Maximum length of lay of insulated conductors and precabled groups[a]
2	30 times the finished insulated conductor diameter[b]
3	35 times the finished insulated conductor diameter[b]
4	40 times the finished insulated conductor diameter[b]
5 or more	15 times the calculated diameter of the overall assembly. In a multiple-layer cable, the length of lay of the conductors in each of the inner layers of the cable is not specified.

NOTE – Length of lay of insulated conductors in cables rated 30 volts is not specified.

[a] The length of lay of each conductor in a group shall comply with the same values as those that are required for a cable. The length of lay of each group in a cable shall comply with the same values as those that are required for a conductor.

[b] Conductor diameter is the measured diameter of the largest individual finished conductor in the cable.

13 Overall Jacket

13.1 General

13.1.1 A protective jacket is not required for internal use cables. When used, the jacket shall be of an integral or nonintegral construction. The jacket material shall be in accordance with Table 7.2 and Table 7.3, or any of the materials described in Specific Materials, Section 50, of UL 1581. The jacket thickness is not specified, however, it must comply with the tests outlined in these requirements. The jacket may be applied simultaneously in more than one color/layer provided that all layers are not separable and are of the same base compound (differ only in color). Jackets with a total thickness of 1.14 mm (0.045 in) and greater may have a reinforcement consisting of an open weave or the like, placed between adjacent layers of the same base compound, that shall not be readily separable. The thickness of each individual layer is not specified.

13.1.2 A protective jacket is required for external use cables. The jacket shall be of an integral or nonintegral construction. The jacket material shall be in accordance with Table 7.2 and Table 7.3 or any of the materials described in Specific Materials, Section 50, of UL 1581. The jacket thickness shall comply with Table 13.1 – Table 13.4. An overall non-metallic covering complying with the requirements in Coverings, Section 8, or an overall shield complying with the requirements in Shield(s), Section 11, may be provided over the jacket. The thickness of the overall covering or shield over the jacket is not specified. The finished external use cable shall comply with the requirements of the Cable Flame Test, Section 41.

Exception: An external use cable composed entirely of optical-fiber members that complies with the requirements of Table 3.7 shall employ a jacket of a minimum average thickness of 0.005 inch (0.13 mm) and a minimum at any point thickness of 0.004 inch (0.10 mm), and the cable shall comply with the requirements of the VW-1 Flame Test, Section 42.

13.2 Materials

13.2.1 An overall jacket shall be solid and shall use one of the jacket materials indicated in Table 7.2 and Table 7.3, or any of the jacket materials described in Specific Materials, Section 50, of UL 1581. Other solid materials shall be evaluated in accordance with the test, Dry temperature rating of new materials (long-term aging test) in the Standard for Wire and Cable Test Methods, UL 2556. An overall jacket shall be applied directly over the cable assembly.

Exception: If the generic temperature rating of the material used (regardless of form) is equal to that described in the table, Relative thermal indices based upon past field-test performance and chemical structure, of the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, the aging time and the aging temperature will be as indicated in Table 14.1.

13.2.2 Jackets made from materials which are not described in Table 7.2 and Table 7.3, or Specific Materials, Section 50, of UL 1581, shall also be subjected to Flexibility Test, Section 21.

13.3 Thickness

13.3.1 Measurements from which the average thickness is to be determined shall be made in accordance with Thicknesses of Jacket on Thermoplastic- and Thermoset-Insulated Wires and Cables, Section 260, of UL 1581.

13.3.2 When the average thickness is equal to or less than 0.002 inch (0.05 mm), the average thickness shall be determined using an optical measuring device and rounded to the nearest 0.0001 inch (0.0025 mm).

13.3.3 When the minimum thickness at any point is equal to or less than 0.002 inch (0.05 mm), the minimum thickness at any point shall be determined using an optical measuring device and rounded to the nearest 0.0001 inch (0.0025 mm).

13.3.4 In some cases, the use of a jacket that is other than indicated in Table 13.1 – Table 13.4 is required to enable the cable to comply with any applicable flame or other test described in these requirements. In this case, the minimum thickness at any point of the heavier jacket shall not be less than 80 percent of the required average thickness of the heavier jacket.

13.3.5 Investigation of mechanical and physical characteristics of a construction using a jacket that is thinner than described in Table 13.1 – Table 13.4 and in the Exception to 13.1.2 shall show the construction to be comparable in performance to the constructions currently intended for the application and described in Table 13.1 – Table 13.4. Crush, impact, abrasion, and other tests may be used to compare the performance of the thinner construction to the constructions described in Table 13.1 – Table 13.4.

Table 13.1
Thickness[a] of nonintegral, non-fluoropolymer jackets for external use AWM cables

		Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket				
		0 – 0.400 inch (0 – 10.16 mm)	0.401 – 0.700 inch (10.17 – 17.78 mm)	0.701 – 1.000 inch (17.79 – 25.40 mm)	1.001 – 1.500 inches (25.41 – 38.10 mm)	1.501 – 2.500 inches (38.11 – 63.50 mm)
Less than 125 volt cable with non-fluoropolymer jacket	Minimum average thickness of jacket	0.024 inch (0.61 mm)	0.030 inch (0.76 mm)	0.045 inch (1.14 mm)		0.060 inch (1.52 mm)
	Minimum thickness at any point	0.019 inch (0.48 mm)	0.024 inch (0.61 mm)	0.036 inch (0.91 mm)		0.048 inch (1.22 mm)
Class 2 cable with non-fluoropolymer jacket	Minimum average thickness of jacket	0.005 inch (0.13 mm)	0.005 inch (0.13 mm)	0.010 inch (0.25 mm)		0.015 inch (0.38 mm)
	Minimum thickness at any point	0.004 inch (0.10 mm)	0.004 inch (0.10 mm)	0.008 inch (0.20 mm)		0.012 inch (0.30 mm)
125 and higher volt cable with non-fluoropolymer jacket	Minimum average thickness of jacket	0.030 inch (0.76 mm)		0.045 inch (1.14 mm)	0.060 inch (1.52 mm)	0.080 inch (2.03 mm)
	Minimum thickness at any point	0.024 inch (0.61 mm)		0.036 inch (0.91 mm)	0.048 inch (1.22 mm)	0.064 inch (1.63 mm)

[a] A thicker jacket is not prohibited from being used to enable the cable to comply with one or more tests covered in this Standard.

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

Table 13.2
Thickness[a] of nonintegral, fluoropolymer jackets for external use AWM cables

		Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket					
		0 – 0.250 inch (0 – 6.36 mm)	0.251 – 0.350 inch (6.37 – 8.91 mm)	0.351 – 0.500 inch (8.92 – 12.72 mm)	0.501 – 0.700 inch (12.73 – 17.80 mm)	0.701 – 1.500 inches (17.81 – 38.10 mm)	1.501 – 2.500 inches (38.11 – 63.50 mm)
30 – 1000 volt cables with fluoropolymer jacket	Minimum average thickness of jacket	0.008 inch (0.20 mm)	0.010 inch (0.25 mm)	0.013 inch (0.33 mm)	0.015 inch (0.38 mm)	0.020 inch (0.51 mm)	0.030 inch (0.76 mm)

Table 13.2 Continued on Next Page

Table 13.2 Continued

		Calculated diameter of round assembly under jacket or calculated equivalent diameter[b] of flat assembly under jacket					
		0 – 0.250 inch (0 – 6.36 mm)	0.251 – 0.350 inch (6.37 – 8.91 mm)	0.351 – 0.500 inch (8.92 – 12.72 mm)	0.501 – 0.700 inch (12.73 – 17.80 mm)	0.701 – 1.500 inches (17.81 – 38.10 mm)	1.501 – 2.500 inches (38.11 – 63.50 mm)
	Minimum thickness at any point	0.006 inch (0.16 mm)	0.008 inch (0.20 mm)	0.010 inch (0.25 mm)	0.012 inch (0.30 mm)	0.016 inch (0.41 mm)	0.024 inch (0.61 mm)

[a] A thicker jacket is not prohibited from being used to enable the cable to comply with one or more tests covered in this Standard.

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

Table 13.3
Thickness of integral insulation (solid)and jacket on 2-, 3-, or 4-conductor flat, parallel cable and distance between conductors for cables rated 125 – 600 volts, or less than 125 volts

Cable types and sizes	Nominal thickness away from tear area(s) (vertical dashed line through web or webs in Figure 13.1) and outside point P or X (defined in Figure 13.2 and Figure 13.3) (Information only – not a requirement), A[a]		Minimum thickness at any point before separation measured outside point P or X (defined in Figure 13.2 and Figure 13.3) B[a]		Minimum thickness at any point after separation C[a]		Minimum distance between copper conductors D[a]	
	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
50 – 12 AWG rated 125 – 600 volts	0.030	0.76	0.027	0.69	0.013	0.33	0.047	1.19
50 – 12 AWG rated less than 125 volts	0.020	0.51	0.018	0.46	0.010	0.25	0.030	0.76

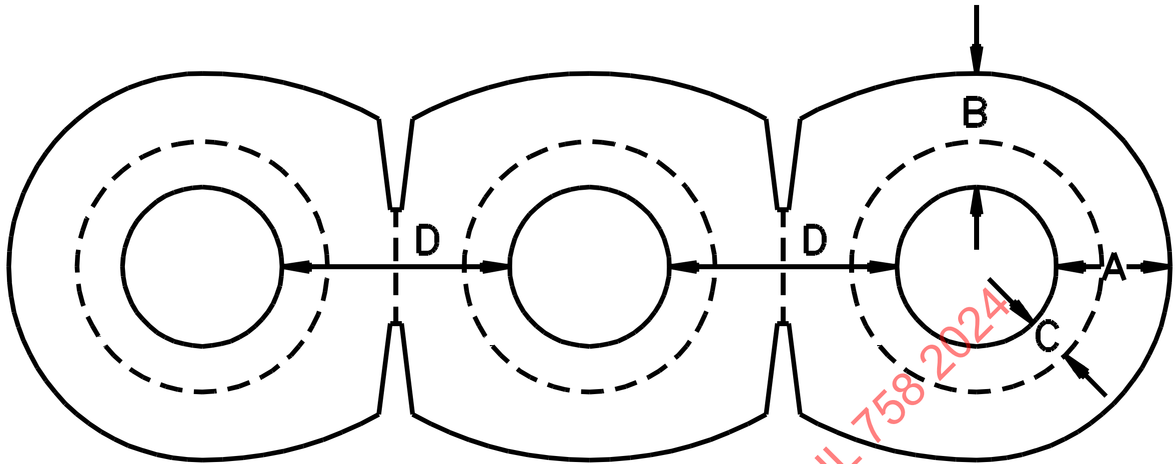
[a] Dimensions A – D are illustrated in Figure 13.1.

Table 13.4
Thickness of integral insulation (solid) and jacket on single conductor wire rated 125 – 600 volts, or less than 125 volts

Cable types and sizes	Minimum average thickness		Minimum thickness at any point	
	inch	(mm)	inch	(mm)
50 – 12 AWG rated less than 125 volts	0.020	0.51	0.018	0.46
50 – 12 AWG rated 125 – 600 volts	0.030	0.76	0.27	0.69

Figure 13.1

Integral flat cable



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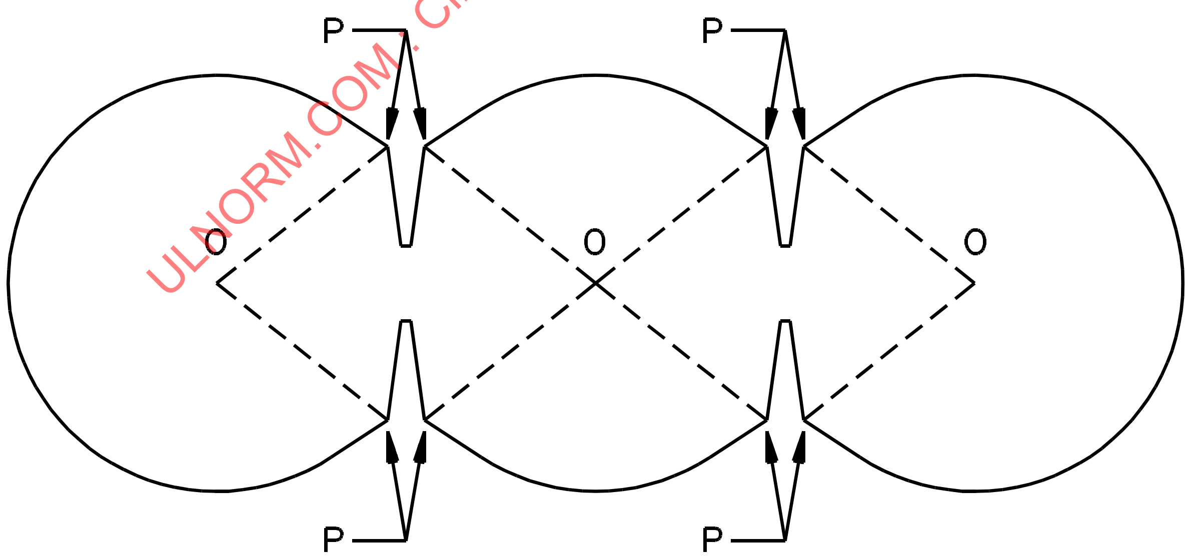
NOTE – See Table 13.3 for dimensions A – D

Figure 13.2

Definitions of regions of valley slopes in integral flat cables



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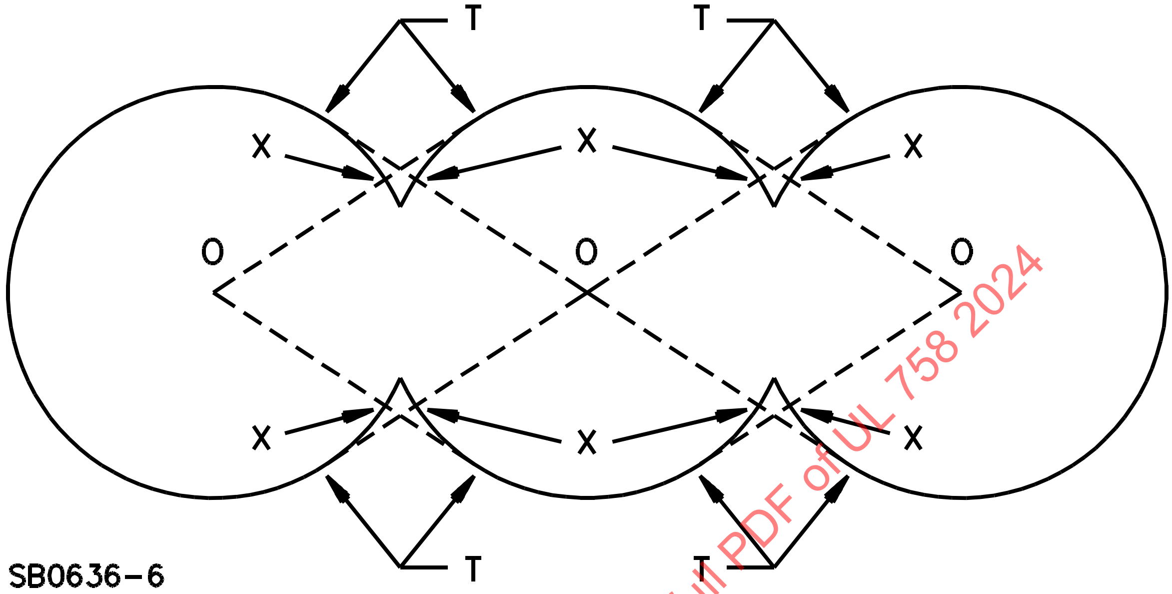
NOTE – Constructions with a cross section having a definite point P at the outer end of each valley slope OP in each case is a straight line from the center O of a conductor to P on the same segment of the cross section. Thickness measurements are not to be made on any valley slope.

Figure 13.3

Definition of regions of valley slopes in integral flat cables, without definite points



NOTE – Constructions with a cross section not having a definite point to mark the outer end of each valley slope OT in each case is a straight line from the center O of a conductor to T, the point of tangency, on the adjacent segment of the cross section. Thickness measurements are not to be made deeper on a valley slope than point X, which is the intersection of the line OT with the valley slope. Thickness measurements are to be made on each slope segment TX.

PERFORMANCE

TESTS FOR THERMAL AND CHEMICAL PROPERTIES

14 Physical Properties, Unaged and Air Oven Aged

14.1 The physical properties [tensile strength, elongation, and elongation recovery (when specified in Specific Materials, Section 50, of UL 1581)] of both unaged and oven aged specimens of insulation, buffer, covering, and jacket shall be in accordance with Table 7.2 and Table 7.3, or any of the materials described in Section 50, of UL 1581. Tensile strength and elongation are to be determined in accordance with the test, Physical Properties (Ultimate Elongation and Tensile Strength) in the Standard for Wire and Cable Test Methods, UL 2556. Elongation recovery is to be determined in accordance with Recovery, Section 460, of UL 1581. For materials with a temperature rating other than that specified in Table 7.3 or for those materials not described in Section 50, of UL 1581, the aging conditions in Table 14.1 are to be used for short term testing and the requirements in the test, Dry temperature rating of new materials (long-term aging test) in UL 2556 shall be applied.

Exception No. 1: Physical properties is not required for foamed and foamed/skin insulations.

Exception No. 2: Physical properties is not required for non-extruded insulations.

Exception No. 3: Physical properties is not required for buffer which is not separable from optical fiber and is not intended to be the outermost layer of the wire or cable construction.

Table 14.1
Aging conditions for insulation and jackets

Dry temperature rating,		Air oven conditioning		
		Oven temperature,		
°C	(°F)	°C ±2	(°F ±3)	Time, days
60	140	100	212	7
75	167	100	212	10
80	176	113	235	7
90	194	121	250	7
105	221	136	277	7
125	257	158	316	7
150	302	180	356	7
180	356	213	415	7
200	392	232	450	7
250	482	287	549	7

NOTE –

For temperatures other than those listed on the above table, the following formula shall be used to calculate the 7-day aging temperature:

$$T_c = 1.02\ (T_r + 296) - 273$$

in which:

T_c *is the conditioning temperature in °C and*

T_r *is the rated temperature in °C*

14.2 Five specimens each shall be tested in both unaged and air oven aged conditions. Jackets from cables less than 0.200 inches (5.08 mm) in core diameter may be tested tubular. Jackets from cables equal to or greater than 0.200 inches in core diameter shall be tested die-cut. When testing is to be conducted in accordance with Dry temperature rating of new materials (long-term aging test) in the Standard for Wire and Cable Test Methods, UL 2556, six specimens shall be tested.

14.3 Die-cut specimens specified in 14.2 are permitted to be buffed in accordance with the test Physical Properties (ultimate elongation and tensile strength) in the Standard for Wire and Cable Test Methods, UL 2556 for die-cut specimens prior to being subjected to the test.

14.4 After air oven conditioning, specimens are to be cooled to room temperature in still air for a period of 16 – 96 hours before testing. After the cooling period, samples of both the unaged and oven conditioned samples are to be tested. Maximum tensile strength and maximum elongation values are to be recorded separately for unaged specimens and oven aged specimens.

14.5 The average of the maximum tensile strength, maximum elongation, and elongation recovery (where required) values are to be calculated and recorded separately for unaged specimens and oven aged specimens.

14.6 After the temperature rating of a new material has been established in accordance with the long term aging test described in 14.1, the parameters and requirements for a short-term air oven aging test shall be developed in accordance with 14.7 – 14.10.

14.7 Using specimens from the same source as those used to determine the temperature rating of the material, the unaged and retention of ultimate elongation and tensile strength shall be determined.

14.8 The percent ultimate elongation that is to be established as the minimum value for unaged specimens is to be calculated as 0.85 times the percent elongation obtained for unaged specimens, with the result rounded down to the nearest 25 percent.

14.9 The tensile strength that is to be established as the minimum value for unaged specimens is to be calculated as 0.85 times the tensile strength obtained for unaged specimens, with the result rounded down to the nearest 25 lbf/in^2.

14.10 The percent retention of tensile strength and ultimate elongation that is to be established as the minimum value for aged specimens is in accordance with in accordance with Dry temperature rating of new materials (long-term aging test) in the Standard for Wire and Cable Test Methods, UL 2556.

15 Physical Properties, Oil Immersion Aging

15.1 Five specimens of oil resistant insulation, covering, and jacket are to be conditioned in IRM 902 oil in accordance with 480.5 of Accelerated Aging, in UL 1581 and Table 15.1. The Standard Test Method for Rubber Property-Effect of Liquids, ASTM D 471, specifies this oil as a standard test liquid. Jackets from cables larger than 0.200 inches (5.08 mm) in core diameter shall be tested die-cut. Jackets from cables less than 0.200 inches (5.08 mm) in core diameter may be tested die-cut or tubular. One side of tubular jacket specimens shall be carefully slit longitudinally and the specimens shall be entirely immersed in the oil so that both surfaces (inside and out) are exposed to the oil.

Exception No. 1: Specimens of finished wire in 7 AWG and smaller sizes are to be bent at the center to form a narrow "U" and are then to be suspended vertically in the oil with the end of each specimen projecting above the oil. Jacket specimens are to be die-cut and immersed in a similar fashion.

Exception No. 2: Nylon-jacketed wires are to be immersed with the nylon in place and then are to be tested for tensile strength and elongation with the nylon removed.

Exception No. 3: For constructions employing a non-extruded insulation or a non-extruded covering as the outermost layer, one specimen of the finished wire or cable is to be bent at the center to form a narrow "U" and is then to be suspended vertically in the oil with the end of the specimen projecting above the oil. After the required exposure time, the specimen shall be blotted to remove excess oil, and allowed to rest for 16 to 96 hours after oil immersion. The specimen is to be wound for six adjacent times onto a mandrel having a diameter twice the diameter of the finished wire measured before oil conditioning. Flat cables and cables greater than 0.625 inch (15.9 mm) in diameter are to be wrapped in a U-bend in which the specimen is in contact with a mandrel having a diameter of twice the minor axis diameter of the specimen measured before oil conditioning.

Table 15.1
Physical properties, oil aged

Polymer designation	Oil temperature rating, °C (°F)	Physical properties, oil aged			
		Oil conditioning		Minimum percent of unaged values	
		Oil temperature, °C ±2 (°F ±3)	Time, hours	Elongation, percent	Tensile strength, percent
CR – polychloroprene (neoprene)	60 (140)	121 (250)	18	60	60
CP – chlorosulfonated polyethylene	60 (140)	121 (250)	18	60	60
CPE – chlorinated polyethylene	60 (140)	121 (250)	18	60	60
NBR/PVC – acrylonitrile butadiene rubber/polyvinyl chloride	60 (140)	121 (250)	18	60	60
PVC – polyvinyl chloride	60 (140)	100 (212)	96	50	50
	75 (167)	75 (167)	1440	65	65
	80 (176)	80 (176)	1440	65	65
TPE – thermoplastic elastomer	60 (140)	60 (140)	168	75	75
XL – cross-linked thermosets	60 (140)	100 (212)	96	50	50
All other thermoplastics	60 (140)	100 (212)	96	50	50
	80 (176)	80 (176)	1440	65	65
All other thermosets	60 (140)	100 (212)	96	50	50
	80 (176)	80 (176)	1440	65	65

15.2 Specimens of oil resistant insulation, covering, or jacket shall comply with the requirements in Table 15.1 after oil immersion.

Exception: For constructions employing a non-extruded insulation or a non-extruded covering as the outermost layer, the specimen is to be visually examined for cracking on the outer surface. The visual examination is to be made without magnification. Upon examination, the specimen is not to show evidence of cracking.

15.3 Insulated conductors in a finished cable are not determined to be suitable for oil immersion unless specifically noted on the tag markings.

16 Physical Properties, Gasoline Conditioning

16.1 Five specimens each of gasoline resistant insulation, covering, and jacket are to be conditioned in a minimum 6-inch (152-mm) tall test tube containing 1 inch (25 mm) of tap water and the remainder containing ASTM Reference Fuel C (see the Standard Test Method for Rubber Property-Effect of Liquids, ASTM D 471) for 30 days at 23 ±1°C (73.4 ±1.8°F) in accordance with 480.9 of Accelerated Aging in UL 1581. Jackets from cables larger than 0.200 inches (5.08 mm) in core diameter shall be tested die-cut.

Jackets from cables less than 0.200 inches (5.08 mm) in core diameter may be tested die-cut or tubular. One side of tubular jacket specimens shall be carefully slit longitudinally and the specimens shall be entirely immersed in the oil so that both surfaces (inside and out) are exposed to the gasoline.

Exception No. 1: For constructions employing a non-extruded insulation or a non-extruded covering as the outermost layer, one specimen of the finished wire or cable is to be bent at the center to form a narrow "U" and is then to be suspended vertically in the gasoline with the end of the specimen projecting above the gasoline. After conditioning, the specimen shall be blotted to remove excess gasoline, and allowed to rest for 16 to 96 hours after gasoline conditioning. The specimen is to be wound for six adjacent times onto a mandrel having a diameter twice the diameter of the finished wire measured before gasoline conditioning. Flat cables and cables greater than 0.625 inch (15.9 mm) in diameter are to be wrapped in a U-bend in which the specimen is in contact with a mandrel having a diameter of twice the minor axis diameter of the specimen measured before gasoline conditioning.

Exception No. 2: Wires with nylon covering complying with the Exception to 8.4 and Table 8.2 are to be immersed with the nylon in place and then are to be tested for tensile strength and elongation with the nylon removed.

16.2 Specimens of gasoline resistant insulation, covering, and jacket shall have tensile and elongation values greater than or equal to 80 percent of unaged specimens after gasoline conditioning.

Exception: For constructions employing a non-extruded insulation or a non-extruded covering as the outermost layer, the specimen is to be visually examined for cracking on the outer surface. The visual examination is to be made without magnification. Upon examination, the specimen is not to show evidence of cracking.

16.3 Insulated conductors in a finished cable are not determined to be suitable for gasoline immersion unless specifically noted on the tag markings.

17 Physical Properties, Sunlight Resistance

17.1 Five specimens each of sunlight resistant rated insulation, covering, and jacket are to be conditioned for 720 hours in a xenon-arc weatherometer and evaluated in accordance with the Xenon-Arc Tests, Section 1200, of UL 1581.

17.2 Specimens of sunlight resistant insulation, covering, and jacket shall have tensile and elongation values greater than or equal to 80 percent of unaged specimens after weatherometer conditioning.

17.3 Sunlight resistant rating applies to the complete finished wire or cable. Insulated conductors in a finished cable are not determined to be sunlight resistant unless specifically noted on the tag markings.

18 Conductor Corrosion Test

18.1 Bare copper, copper alloy, copper-clad aluminum, and copper-clad steel conductors without a metal coating are required to be tested. One specimen of an insulated conductor is to be tested in accordance with Conductor Corrosion – General, Section 500, of UL 1581. The specimen is to be conditioned with the conductor in place, in an air oven for the same time and temperature as described in Table 7.1, Table 7.2, and Table 7.3 for the specific material and its associated temperature rating. When the material is not specified, aging in accordance with Table 14.1 is to be used. Insulated conductors in a jacketed cable are to be removed and tested independently of the finished cable.

18.2 After air oven conditioning, the test specimen is to be cooled to room temperature. Once at room temperature, the insulation and other materials such as a fibrous thread or a separator, if any, is to be removed from the bare conductor of the specimen. The conductor is to be examined visually for evidence of corrosion. The visual examination of the conductor is to be made without use of any equipment other than the examiner's normal corrective lenses, when required.

18.3 A specimen not showing any evidence of pitting nor corrosion compounds in a close visual examination with normal or corrected vision without magnification is determined to be in compliance. Normal discoloration not induced by the insulation or other materials such as a fibrous thread or a separator is to be disregarded.

18.4 Specimens of wire that do not comply with the conductor corrosion test are required to use tinning or other protective metal coating.

19 Deformation Test (Thermoplastics and Class XL Only)

19.1 Only thermoplastic elastomer (TPE), thermoplastics (except for fluoropolymers rated 125°C and higher in Table 7.1, Table 7.2, and Table 7.3), and XL materials are required to be tested. One specimen of finished wire is to be tested in accordance with Deformation Test, Section 560, of UL 1581, and Table 19.1 for the specific construction, wire size, material, and the specimen's associated temperature rating. The maximum decrease in thickness shall not be more than indicated in Table 19.1 and the insulation shall not split, exposing the conductor. Insulated conductors as well as the jacket of a jacketed cable are to be tested. Laminated constructions employing flat conductors are to be tested in the same manner as jackets. Bonded or separable (rippable), laminated constructions employing round conductors, or other types of non-separable flat cable constructions are to be separated and tested in the same manner as insulation. For non-separable flat cable construction, the individual insulated conductors may be separated using a razor blade or other cutting tool. Foamed insulation material which is intended to be the outermost layer of the wire construction shall be tested.

Exception: The deformation test is not required for single conductor with other-than-extruded insulation described in Table 3.2 and the non-extruded covering described in Table 3.8.

Table 19.1
Load, temperature, and decrease in thickness for deformation test

Material	Sample	Size of conductor, AWG	Load		Test temperature, °C (°F)	Maximum decrease in thickness, percent
			gf	N		
HDFRPE, LDFRPE, LDPE, HDPE, PP, FRPE mPPE-PE	Insulation	50 – 31	150	1.47	100.0±1.0	50
		30 – 21	250	2.45	(212.0±1.8)	
		20 – 12	400[a]	3.92[a]		
		11 – 7	500	4.90		
		6 – 1	1600	15.72		
		1/0 – 4/0	2000	19.61		
	Any separable jacket or insulation over conductors larger than 4/0 AWG	–	2000[b]	19.61[b]	100.0 ±1.0 (212.0 ±1.8)	50

Table 19.1 Continued on Next Page

Table 19.1 Continued

Material	Sample	Size of conductor, AWG	Load gf	Load N	Test temperature, °C (°F)	Maximum decrease in thickness, percent
PVC, SRPVC, TPES, mPPE, nylon, THV, TPU, other materials not shown in this table	Insulation or integral insulation and jacket	50 – 31	150	1.47	121.0 ±1.0	50
		30 – 21	250	2.45	(249.8 ±1.8)	
		20 – 12	400[a]	3.93[a]		
		11 – 7	500	4.90		
		6 – 1	1600	15.72		
		1/0 – 4/0	2000	19.61		
	Any separable jacket or insulation over conductors larger than 4/0 AWG	–	2000[b]	19.61[b]	121.0 ±1.0 (249.8 ±1.8)	50
TPE	Insulation	50 – 31	150	1.47	150.0 ±1.0	50
		30 – 21	250	2.45	(302.0 ±1.8)	
		20 – 12	400[a]	3.92[a]		
		10 – 7	500	4.90		
		6 – 1	1600	15.72		
		1/0 – 4/0	2000	19.61		
	Any separable jacket or insulation over conductors larger than 4/0 AWG	–	2000[b]	19.61[b]	150.0 ±1.0 (302.0 ±1.8)	50
XLPO XL XLFRPE	Insulation or integral insulation and jacket	50 – 31	150	1.47	121.0 ±1.0	50
		30 – 21	250	2.45	(249.8 ±1.8)	
		20 – 12	400[a]	3.92[a]		
		10 – 7	500	4.90		
		6 – 1	1600	15.72		
		1/0 – 4/0	2000	19.61		
	Any separable jacket or insulation over conductors larger than 4/0 AWG	–	2000[b]	19.61[b]	121.0 ±1.0 (249.8 ±1.8)	50

[a] For wall thickness less than 30 mils average, test at 250 gf (2.45 N).

[b] A jacket is to be tested in tubular form when it is too small in diameter to yield flat specimens having a width equal to or exceeding the diameter of the presser foot of the deformation apparatus. In this case, a solid metal rod having a diameter that is neither too loose nor tight in the jacket is to be inserted into the jacket. The load applied shall be based on the size of the solid metal rod and identical to the load assigned to the conductor size (AWG) specified in this table.

20 Flexibility Test of Nylon Covering

20.1 One specimen of wires employing extruded nylon covering described in the Exception to 8.4 shall be subjected to the Flexibility at Room Temperature After Aging Test in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83. For conductors smaller than 14 AWG, the Flexing Test of Nylon Jacket on Types TFN and TFFN in the Standard for Fixture Wire, UL 66, shall apply. The conditioning shall be at 121°C for 7 days for 90°C or lower ratings. The conditioning shall be 136°C for 7 days for 105°C rating.

20.2 When a mandrel specified in the Standard for Fixture Wire, UL 66 or the Standard for Thermoplastic-Insulated Wires and Cables, UL 83 is not available, it shall be permitted to use a mandrel with a smaller diameter. However, in the event of non-compliant results, the sample shall be re-tested using the mandrel size specified in UL 66 or UL 83.

21 Flexibility Test

21.1 One specimen each of insulation, buffer used as the outermost layer in a wire or cable construction covering, and jacket is to be conditioned in an air oven for the same time and temperature as described in Table 7.1, Table 7.2, and Table 7.3 for the specific material and its associated temperature rating.

Exception: Insulation composed of fiberglass with a polymeric coating is to be conditioned in an air oven for the same time and temperature as described in the physical properties requirements for the polymeric coating material and its associated temperature rating.

21.2 Materials, buffer which is used as the outermost layer, and other forms of materials which are not described in Table 7.1, Table 7.2 and Table 7.3 shall be aged for 150 days at the temperature described in the test Dry temperature rating of new materials (long-term aging test) in the Standard for Wire and Cable Test Methods, UL 2556.

Exception No. 1: For foamed, foam-skinned materials, and non-extruded forms of materials, if the generic temperature rating of the material used (regardless of form) is equal to that described in the table, Relative thermal indices based upon past field-test performance and chemical structure, of the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, the aging time and the aging temperature will be as indicated in Table 14.1.

Exception No. 2: The aging time and the aging temperature for composite insulation consisting of mica tape and glass fiber braid with or without polymeric varnish or finish and rated 300°C or above will be as indicated in Table 14.1.

Exception No. 3: For insulation composed of fiberglass without a polymeric coating, the oven aging condition in accordance with Table 14.1 is to be used.

Exception No. 4: For covering composed of fiberglass with or without a polymeric coating, the oven aging condition in accordance with Table 14.1 is to be used.

Exception No. 5: The aging condition for Polyimide (PI) tape that is evaluated for use at 200°C or lower is 7 days at 232±2°C.

21.3 After air oven conditioning, specimens are to be cooled to room temperature in still air for a period of 16 – 96 hours.

21.4 Specimens of round wire or cable are to be wound for six adjacent times onto a mandrel having a diameter twice the diameter of the finished wire or cable. Care is to be taken so an axial twist is not imparted on the specimen. Flat cables and cables greater than 0.625 inch (15.9 mm) in diameter are to be wrapped in a U-bend in which the specimen is in contact with a mandrel having a diameter of twice the minor axis diameter of the specimen for minimum 180 degrees.

Exception No. 1: For wires meeting the requirements in Table 3.2, Table 3.5 (laminated flat cables only), and Table 3.8 where the intended use is in a location where not subjected to movement or mechanical abuse after installation, the mandrel diameter shall be three (3) times the diameter of the finished wire, or *three (3) times the minor axis diameter of the specimen for flat cable, or, 0.19 in (4.8 mm), whichever is larger. Only unaged specimens shall be wrapped around a mandrel. Aged specimens shall be tested in a straight form.*

Exception No. 2: The finished cable composed entirely of optical-fiber members that complies with the requirements of Table 3.7 shall be tested with a mandrel having a diameter three times (3X) the diameter or the minor axis diameter (for flat cables) of the specimen.

21.5 When a mandrel specified above is not available, it shall be permitted to use a mandrel with a smaller diameter. However, in the event of non-compliant results, the sample shall be re-tested using the mandrel size specified in 21.4.

21.6 Specimens are then to be visually examined for cracking on the outer surface. The visual examination is to be made without magnification. Upon examination, the specimens are not to show evidence of cracking.

21.7 After the temperature rating of a new material described in 21.2 has been established with complying test results based on 150 days long term oven aging, a short-term air oven aging test shall be developed. The material shall be subjected to the flexibility test using the same test method described in 21.1 – 21.6 above. The temperature and duration for the oven aging shall be from the test parameters listed in the Table 14.1 for the temperature rating of the material.

22 Heat Shock Test (Thermoplastic Materials Only)

22.1 One specimen is to be wound as described in 21.4 onto a mandrel having a diameter twice the diameter of the finished wire or cable. Care is to be taken so an axial twist is not imparted on the specimen. Flat cables and cables greater than 0.625 inch (15.9 mm) are to be wrapped in a U-bend in which the specimen is in contact with a mandrel having a diameter of twice the minor axis diameter of the specimen for minimum 180 degrees. The specimens are held in position by heat resistant tape or some other effective means and then conditioned in a circulating air oven for 1 hour at the temperature specified in Table 22.1 with respect to the specific material and its associated temperature rating. Insulated conductors as well as finished jacketed cables are to be tested separately. Only thermoplastic materials are required to be tested.

Exception No. 1: The heat shock test is not required for single conductor and other-than-extruded insulation described in Table 3.2 and the non-extruded covering described in Table 3.8.

Exception No. 2: The finished cable composed entirely of optical-fiber members that complies with the requirements of Table 3.7 shall be tested with a mandrel having a diameter three times (3X) the diameter or the minor axis diameter (for flat cables) of the specimen.

Table 22.1
Air temperature for heat-shock test

Material	Temperature rating of wire, °C (°F)	Air oven temperature, ±1.0°C (±1.8°F)
FRPE – Flame retardant polyethylene or PE – Polyethylene	60 (140), 75 (167), and 80 (176)	100.0 (212.0)
TPE – Thermoplastic elastomer	60 (140), 80 (176), 90 (194) and 105 (221)	150.0 (302.0)
All other materials	60 (140), 75 (167), 80 (176), and 90 (194)	121.0 (249.8)

Table 22.1 Continued on Next Page

Table 22.1 Continued

Material	Temperature rating of wire, °C (°F)	Air oven temperature, ±1.0°C (±1.8°F)
	105 (221)	136.0 (276.8)
	125 (257)	158.0 (316.4)
	150 (302)	180.0 (356.0)
	200 (392)	232.0 (482.0)
	250 (482)	280.0 (536.0)

22.2 When a mandrel specified above is not available, it shall be permitted to use a mandrel with a smaller diameter. However, in the event of non-compliant results, the sample shall be re-tested using the mandrel size specified in 22.1.

22.3 Specimens after air oven conditioning are to be cooled to room temperature in still air for a period of 30 minutes or longer. The insulation, buffer, and jacket are then to be visually examined for cracking either on the surface or internally.

22.4 Upon visual examination, the insulation, buffer, and jacket shall not show cracks either on the surface or internally.

23 Cold Bend Test

23.1 One specimen of finished wire or cable and a mandrel having a diameter twice the diameter of the finished wire or cable are to be conditioned in a cold chamber for 4 hours at minus 10 ±2°C (14 ±3.6°F) in accordance with Cold Bend Test, Section 580, of UL 1581. Wires or cables marked for use at −20, −30, −40, or −50°C, shall be tested at −20, −30, −40, or −50°C ±2°C (−4, −22, −40, or −58°F ±3.6°F), respectively. Flat cables are to be wrapped in a U-bend in which the specimen is in contact with a mandrel having a diameter of twice the minor axis diameter of the specimen. Insulated conductors as well as the finished cable are to be tested separately.

Exception: The finished cable composed entirely of optical-fiber members that complies with the requirements of Table 3.7 shall be tested with a mandrel having a diameter three times (3X) the diameter or the minor axis diameter (for flat cables) of the specimen.

23.2 After cold chamber conditioning, specimens are to be wound around the mandrel at a uniform rate of 3 seconds per turn. The number of turns around the mandrel shall be in accordance with Table 23.1. Flat cables are to be wrapped in a U-bend in which the specimen is in contact with a mandrel for a minimum of 180 degrees.

Exception: The Cold Bend Test is not required for a high voltage DC wire described in Table 3.6 and Table 3.6A.

Table 23.1
Cold bend test specifications

Overall diameter of wire or cable	Number of turns of specimen around mandrel
Less than or equal to 0.625 inch (16 mm)	6 adjacent turns, tightly around mandrel
Greater than 0.625 inch (16 mm), flat cables	U-bend, in which specimen is in contact with mandrel for a minimum of 180 degrees

23.3 When a mandrel specified above is not available, it shall be permitted to use a mandrel with a smaller diameter. However, in the event of non-compliant results, the sample shall be re-tested using the mandrel size specified in 23.2.

23.4 Specimens are to then be examined for cracking on the outer surface. Specimens shall not show evidence of cracking.

24 Delamination Test

24.1 One 12-inch specimen of laminated flat cable in any color and thickness of laminated insulation, laminated shield, and laminated covering, is to be used for this test.The specimens are to be aged in an air oven for the time and temperature as described in Table 7.1, Table 7.2, and Table 7.3 for the specific material and its associated temperature rating. When the material is not specified, aging in accordance with Table 14.1 is to be used. After the conditioning, unaged and aged samples are to be held for two weeks in air at 32 ±2°C (80 ±3°F) and 85 ±5 percent relative humidity. After two weeks, the specimens are to be examined for delamination. No delamination shall occur between any layers of the cable.

25 Shrinkback Test – Special Rating TV Wires Only

25.1 One specimen of finished high-voltage DC rated TV use wire is to be tested in accordance with the method described in 25.2 – 25.5. Finished insulated conductors composed of multiple layers of insulation are to be tested only as a finished cable.

25.2 One 12-inch (305-mm) length specimen of the finished wire is to be cut so that the insulation and conductor are flush at both ends.

25.3 The specimen is to then be straightened by hand and placed on felt bed or a layer of preheated talc or glass beads in a circulating air oven for a period of 18 hours at the temperature specified in Table 25.1.

Table 25.1
Shrinkback test conditioning temperatures

Temperature rating of wire, °C (°F)	Oven conditioning temperature, ±2°C (±3°F)
60 (140), 75 (167), 80 (176), and 90 (194)	121 (250)[a]
105 (221)	136 (277)
125 (257)	158 (317)
150 (302)	180 (356)
200 (392)	250 (482)
250 (482)	300 (572)

[a] Test temperatures for LDPE, HDPE, LDFRPE, and HDFRPE rated 60, 75, and 80°C are to be 100 ±2°C (212 ±3°F)

25.4 At the end of the conditioning period, the specimen is to be removed from the oven and felt bed or a layer of talc or glass beads and cooled to room temperature for 1 hour. When insulation shrinkage occurs, the conductor is exposed on one or both ends of the specimen. The insulation shrinkback, as indicated by the length of the exposed conductor, is to be measured with a caliper or scale and recorded.

25.5 Insulation shrinkback at either end of the specimen shall not be greater than 0.12 inch (3.0 mm).

26 Ozone Resistance Test – Special Rating TV Use Wires Only

26.1 A specimen of finished high-voltage DC rated TV use wire is to be tested in accordance with the method described in 26.2 – 26.9. Finished insulated conductors composed of multiple layers of insulation are to be tested only as a finished cable.

26.2 Two appropriate lengths of the test specimen, 4 – 8 inches (102 – 203 mm), are to be tested.

26.3 The test apparatus is to consist of a device for generating a controlled amount of ozone with a means of circulating ozonized air under controlled conditions of temperature and humidity through a chamber containing the test specimens and a mandrel. A means for determining the percentage ozone concentration, temperature and humidity shall be provided. See the Standard Test Methods for Crosslinked Insulations and Jackets for Wire and Cable, ASTM D470, for specific information concerning the test apparatus.

26.4 Each specimen is to be wrapped a single turn around a mandrel having a diameter as indicated in Table 26.1. At the point where the test specimen crosses over itself, tape or twine is to be used to bind the specimen in place around the mandrel. One specimen is to be wrapped around the mandrel in a plane of existing curvature of the specimen. The second specimen is to be wrapped around the mandrel opposite to the plane of existing curvature of the specimen.

26.5 When a mandrel specified above is not available, it shall be permitted to use a mandrel with a smaller diameter. However, in the event of non-compliant results, the sample shall be re-tested using the mandrel size specified in 26.4.

Table 26.1
Ozone resistance test mandrel sizes

Outside diameter of wire	Mandrel diameter
0 – 0.500 inch (0 – 12.70 mm)	4 x cable outside diameter
0.501 – 0.750 inch (12.71 – 19.10 mm)	5 x cable outside diameter
0.751 – 1.250 inches (19.11 – 32.00 mm)	6 x cable outside diameter
1.251 – 1.750 inches (32.01 – 44.50 mm)	8 x cable outside diameter
1.751 inches and larger (44.51 mm and larger)	10 x cable outside diameter

26.6 Once the specimens are secured to the mandrel, the surface of each specimen is to be wiped with a clean cloth to remove dirt, sweat, or oil. The specimens secured to the mandrel are to then be placed in a desiccator for 30 – 45 minutes to remove surface moisture.

26.7 Immediately after removing the specimens from the desiccator, the specimens secured to the mandrel are to be placed in the ozone chamber with an ozone concentration of 0.010 – 0.015 percent and a temperature of 25 ±0.2°C (77 ±0.36°F) for a period of 3 hours. Care is to be taken not to touch the specimen during the transfer to the ozone chamber.

26.8 At the end of the conditioning period, the specimen and mandrel are to be removed from the ozone chamber. With the specimens remaining secured to the mandrel, the specimens are to be examined for cracks at the bent portion. Any cracks or other damage in the bent portion of the specimen are to be recorded. The visual examination is to be made without use of any equipment other than the examiners normal corrective lenses, when required.

26.9 Compliance is determined by examination and the insulation shall show no cracking or surface checking at the bent portion of the specimen. Areas of the sample outside of the 180-degree area of bend are to be ignored.

27 Durability of Ink-Print Test

27.1 Printing on the surface of the finished wire shall remain legible after being subjected to the test described in the Durability of ink printing in the Standard for Wire and Cable Test Methods, UL 2556. One specimen shall be conditioned in a forced-circulation air oven at 60°C ±2°C for 168 hours. The other specimen shall be maintained at ROOM TEMPERATURE for a minimum of 24 hours.

TESTS FOR MECHANICAL PROPERTIES

28 Crush Resistance Test

28.1 All solid, extruded insulated conductors which do not have a restricted use must either comply with:

a) The requirements in Table 7.4 or Table 7.5,

b) The crush test described in this section.

28.2 All foamed, foamed/skinned or non-extruded insulated conductors which do not have a restricted use shall comply with the crush test described in this section.

28.3 Five specimens of finished 20 – 14 AWG wire are to be tested in accordance with the method described below. Insulated conductors or the insulated conductors from a jacketed cable are to be tested. In the case of a jacketed cable, the insulated conductors are to be removed and tested independently of the jacket. Testing of an insulated single with a solid conductor represents identical constructions using a stranded conductor. Testing of a single conductor represents multiple conductors. Flat cable is to be tested flat-wise only.

28.4 The insulated conductors are to be individually straightened with the fingers after all coverings other than a skin have been removed. Specimens 7 inches (180 mm) long are to be cut from the straight insulated specimens. Each of the five specimens is to be tested separately by being crushed twice between 2-inch (50-mm) wide flat, horizontal steel plates in a compression machine whose jaws close at a rate of 0.2 ±0.02 in/min (5.0 ±0.5 mm/min). The edges of the plates are not to be sharp. The length of each specimen is to be parallel to the 2-inch dimension of the plates, 1 inch (25 mm) of the specimen is to extend the plates at one end of the specimen and 4 inches (100 mm) of the specimen is to extend outside the plates at the other end.

28.5 The plates are to be electrically connected together, to the metal of the testing machine and to earth ground. The specimens, apparatus and the surrounding air are to be in thermal equilibrium with one another at a temperature of 24 ±8.0°C (75 ±14.4°F) throughout the test. The machine is to be started and the specimen is to be subjected to the increasing force of the plates moving towards one another until a short occurs between the conductor in the specimen and one or both of the earth grounded plates. The maximum force exerted on the specimen before the short circuit occurs is to be recorded as the crushing force for that end of the specimen.

28.6 After the short circuit occurs, the machine is to be reversed and the plates separated. The specimen is to be turned end for end, rotated 90 degrees, reinserted between the plates from the end opposite the one originally inserted and crushed. The two crushing forces are to be averaged for each specimen. The average of all ten of the crushing forces obtained for the five specimens is compared to the values in Table Table 28.1.

Table 28.1
Crush test requirements

Voltage rating of wire	Minimum average crush force
30 – 90 Volts	300 lbf (1334 N or 136 kgf)
125 – 300 Volts	600 lbf (2668 N or 272 kgf)
600 Volts or greater	1000 lbf (4446 N or 453 kgf)

28.7 Specimens shall exhibit average crush values in accordance with Table 28.1.

TESTS FOR ELECTRICAL PROPERTIES

29 Dielectric Test, Method I

29.1 Specimens of finished wire are to be tested in accordance with the method described in 29.2 – 29.10. Insulated conductors, insulated flat cables or the insulated conductors of a jacketed cable are to be tested. In the case of a jacketed cable, the insulated conductors are to be removed and tested independently of the jacketed cable.

29.2 Six lengths of insulated wire or insulated conductors removed from a jacketed cable are to be tested for each specimen of wire to be evaluated. Each sample is to measure 24 inches (610 mm) in length. Three of the samples are to be tested in an unaged condition. The other three samples are to be tested after air oven conditioning.

29.3 The three straight samples intended for oven aging are to be conditioned in a circulating air oven for the same time and temperature as specified for the specific insulation material in 21.2 and Table 7.1, Table 7.2, and Table 7.3. When the material is not specified, aging in accordance with Table 14.1 is to be used.

Exception No. 1: Insulation composed of fiberglass with a polymeric coating is to be conditioned in an air oven for the same time and temperature as described in the physical properties requirements for the polymeric coating material and its associated temperature rating.

Exception No. 2: For insulation composed of fiberglass without a polymeric coating, the oven aging condition in accordance with Table 14.1 is to be used.

Exception No. 3: The aging condition for Polyimide (PI) tape that is evaluated for use at 200°C or lower is 7 days at 232±2°C.

29.4 After air oven conditioning, the three specimens are to be cooled to room temperature in still air for a period of 16 – 96 hours before testing. After the cooling period, both the unaged and oven conditioned samples are to be tested. The center 12 inches (305 mm) of each sample is to be wrapped with metal foil.

29.5 Except for flat cables, the foil-wrapped center section of each sample is to then be wrapped closely for six complete turns around a metal mandrel having a diameter of two times the outside diameter of the specimen or 0.19 inch (5 mm), whichever is larger. The end of each resulting helix is to be twisted loosely together or fastened together with tape to prevent unwinding. Specimens of flat cables are to be wrapped in a U-bend in which the specimen is in contact with a mandrel having a diameter of twice the minor axis diameter of the specimen or 0.19 inch (5 mm), whichever is larger.

Exception: For wires meeting the requirements in Table 3.2 and Table 3.5 (laminated flat cables only) where the intended use is in a location where not subjected to movement or mechanical abuse after installation, the mandrel diameter shall be three times (3X) the diameter of the finished wire or 0.19 in (5 *mm), whichever is larger. Only unaged specimens shall be wrapped around a mandrel. Aged specimens shall be tested in a straight form.*

29.6 When a mandrel specified above is not available, it shall be permitted to use a mandrel with a smaller diameter. However, in the event of non-compliant results, the sample shall be re-tested using the mandrel size specified in 29.5.

29.7 The dielectric tester is to supply a 50 or 60 Hz continuously variable output from zero to at least five times the voltage rating of the wire specimen being tested. With a specimen in the circuit, the output potential is to have a crest factor (peak voltage divided by the 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 whose response time does not introduce a lagging error greater than one percent of full scale at the specified rate of increase in voltage. The overall accuracy shall not introduce an error greater than five percent. The maximum current output of the tester's transformer shall be enough for testing samples to dielectric breakdown without tripping of the circuit breaker by the charging unit.

29.8 One test lead of a dielectric tester is to be connected to the conductor of the test specimen as one electrode and the other connected to the metal mandrel as the other electrode. In the case of straight specimens, one electrode shall be connected to the conductor of the test specimen and the other to the foil. The voltage is to be increased from zero to the test potential specified in Table 29.1 at a rate not exceeding 500 volts per second. When this level is reached without breakdown, the voltage is to be held constant at this level for 60 seconds.

Table 29.1
Dielectric voltage-withstand test potentials

Voltage rating, V AC	Conductor sizes, AWG	Dielectric test potential, V AC
30	All	500
60, 90	All	1000
125, 150	All	1500
250[a]	All	2000
300, voltage not specified[a]	All	2000
600	2 and smaller	2000
600	1 – 4/0	2500
600	250 – 500 kcmil	3000
600	500 – 1000 kcmil	3500
600	1100 – 2000 kcmil	4000
1000 – 20,000	All	2 times the rated voltage + 1000 V AC or DC
600V DC	All	2000 V DC or AC
Over 600V or less than 3kV DC	All	2 times the rated voltage + 1000 V DC or AC

[a] 250 V and 300 V AC wires complying with Table 3.2 are to be tested at 1500 V.

29.9 After 60 seconds at the specified test voltage, the test potential is to be increased at a rate not exceeding 500 volts per second until dielectric breakdown occurs. The dielectric breakdown values are to be recorded separately for unaged specimens and oven aged specimens. The average of the dielectric breakdown values are to be calculated and recorded separately for unaged specimens and oven aged specimens.

29.10 Samples of both unaged and oven aged specimens shall comply with the following:

a) Unaged and oven aged samples shall withstand the test voltage in Table 29.1 without breakdown for 60 seconds and

b) The average dielectric breakdown value of oven aged samples shall not be less than 50 percent of the average breakdown value of unaged samples.

30 Dielectric Test, Method II

30.1 Specimens of finished wire are to be tested in accordance with the method described in 30.2 – 30.7. Insulated conductors, insulated flat cables, or the insulated conductors of a jacketed cable are to be tested. In the case of a jacketed cable, the insulated conductors are to be removed and tested independently of the jacketed cable.

30.2 Six lengths of insulated wire or insulated conductors removed from a jacketed cable are to be tested. Each sample is to measure 24 inches (610 mm) in length. Three of the samples are to be tested in an unaged condition. The three straight samples intended for oven aging are to be conditioned in a circulating air oven for the same time and temperature as for the specific insulation material described in 21.2 and Table 7.1, Table 7.2, and Table 7.3. When the material is not specified, aging in accordance with Table 14.1 is to be used.

Exception No. 1: Insulation composed of fiberglass with a polymeric coating is to be conditioned in an air oven for the same time and temperature as described in the physical properties requirements for the polymeric coating material and its associated temperature rating.

Exception No. 2: For insulation composed of fiberglass without a polymeric coating, the oven aging condition in accordance with Table 14.1 is to be used.

Exception No. 3: The aging condition for Polyimide (PI) tape that is evaluated for use at 200°C or lower is 7 days at 232±2°C.

30.3 After air oven conditioning, the three specimens are to be cooled to room temperature in still air for a period of 16 – 96 hours before testing. After the cooling period, both the unaged and oven conditioned samples are to be tested. The center 12 inches (305 mm) section of each sample is to be wrapped with metal foil.

30.4 The unaged and oven conditioned foil wrapped samples are to be placed in an oven for one hour. The temperature of the oven is to be equal to the temperature rating of the specimen being tested.

30.5 The dielectric tester is to supply a 50 or 60 Hz continuously variable output from zero to at least five times the voltage rating of the wire specimen being tested. With a specimen in the circuit, the output potential is to have an crest factor (peak voltage divided by the 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 whose response time does not introduce a lagging error greater than one percent of full scale at the specified rate of increase in voltage. The overall accuracy shall not introduce an error greater than five percent. The maximum current output of the tester's transformer is to be enough for testing samples to the specified dielectric withstand value without tripping of the circuit breaker by the charging unit. The test leads of the dielectric tester are to pass through an opening into the circulating air oven or in some other way be connected to the specimen while it is at the specified temperature in the circulating air oven.

30.6 One test lead of the dielectric tester is to be connected to the conductor of the test specimen and the other test lead connected to the foil. While the samples are in the oven at the rated temperature, the voltage is to be increased from zero to the test potential specified in Table 29.1 at a rate not exceeding 500 volts per second. When this level is reached without breakdown, the voltage is to be held constant at this level for 60 seconds and then returned to zero. The rate of decreasing the test voltage is not specified.

30.7 Unaged and oven aged specimens shall withstand the test voltage specified in Table 29.1 without breakdown for 60 seconds.

31 Dielectric Test, Method III

31.1 A specimen of finished wire is to be tested in accordance with the method described in 31.2 – 31.6. An insulated conductor or an insulated conductor from a jacketed cable is to be tested. In the case of a jacketed cable, the insulated conductor is to be tested prior to application of the jacket or are to be carefully removed and tested independently of the jacketed cable.

31.2 A single specimen 25 feet (7.6 m) in length of insulated wire or insulated conductors removed from a jacketed cable is to be immersed in a tank of tap water at room temperature for 24 hours or longer. The sample is to be immersed in the water tank so that 20 feet (6.1 m) of the sample is immersed leaving a length of 2.5 feet (0.76 m) of the sample out of the water on each end.

31.3 One test lead of the dielectric tester is to be connected to the conductor of the test specimen and the other test lead connected to a metal plate or disc in the water tank. The negative test lead may be connected directly to the water tank when the water tank is metallic.

31.4 The dielectric tester is to supply a test potential that is 50 or 60 Hz, continuously variable output from zero to at least five times the voltage rating of the wire specimen being tested. With a specimen in the circuit, the output potential is to have a crest factor (peak voltage divided by the 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 whose response time does not introduce a lagging error greater than one percent of full scale at the specified rate of increase in voltage. The overall accuracy shall not introduce an error greater than five percent. The maximum current output of the tester's transformer is to be enough for testing samples to the specified dielectric withstand value without tripping of the circuit breaker by the charging unit.

31.5 After a minimum of 24 hours immersion in water, the voltage is to be increased from zero to the test potential specified in Table 29.1 at a rate not exceeding 500 volts per second. When this level is reached without breakdown, the voltage is to be held constant at this level for a period of 60 seconds and then returned to zero. There is no specified rate at which the test voltage is to be decreased.

31.6 The specimen shall withstand the test voltage specified in Table 29.1 without breakdown for 60 seconds.

32 High-Voltage DC Wire Dielectric Voltage-Withstand Test, Method I

32.1 Specimens of finished high-voltage DC rated wire are to be tested in accordance with the method described in 32.2 – 32.7 before and after conditioning in an air oven for the same time and temperature as described in 21.2 and Table 7.1, Table 7.2, and Table 7.3. When the material is not specified, aging in accordance with Table 14.1 is to be used. Finished insulated conductors composed of multiple layers of insulation are to be tested only as a finished cable. Insulated conductors, insulated flat cables or the insulated conductors of a jacketed cable are to be tested. In the case of a jacketed cable, the insulated conductors are to be removed and tested independently of the jacketed cable.

32.2 One specimen of the finished wire 5 feet (1.5 m) in length is to be conditioned in a humidity chamber for 24 hours (6 hours when conducted at the factory) at a minimum temperature of 30°C (86°F) and a relative humidity of at least 80 percent.

32.3 Immediately after removal from the humidity chamber, any surface moisture is to be wiped off carefully with a clean, dry cloth. The wire is to then be wrapped for nine close turns around a metal mandrel with a diameter in accordance with Table 32.1. The end of each resulting helix is to be twisted loosely together or fastened together with tape to prevent unwinding.

32.4 When a mandrel specified above is not available, it shall be permitted to use a mandrel with a smaller diameter. However, in the event of non-compliant results, the sample shall be re-tested using the mandrel size specified in 32.3.

Table 32.1
High-voltage DC wire dielectric voltage-withstand test mandrel sizes Methods I and II

Overall diameter of finished wire,		Mandrel diameter,	
inch	(mm)	inch	(mm)
0 – 0.150	0 – 3.81	0.50	12.7
0.151 – 0.200	3.84 – 5.08	0.75	19.1
0.201 or larger	5.11 or larger	1.00	25.4

32.5 The dielectric tester shall supply a DC test potential that is continuously variable with an output from zero to at least the test voltage of the wire specimen being tested. The output voltage is to be monitored continuously by a voltmeter. The overall accuracy shall not introduce an error greater than five percent. The maximum current output of the tester's transformer is to be enough for testing samples to dielectric breakdown without tripping of the circuit breaker by the charging unit.

32.6 One test lead of the dielectric tester is to be connected to the conductor of the test specimen as one electrode and the other connected to the metal mandrel as the other electrode. The voltage is to be increased from zero to two times the DC voltage rating of the specimen at a rate not exceeding 500 volts per second. When this level is reached without breakdown, the voltage is to be held constant at this level for a period of 30 minutes and then returned to zero at the same rate.

32.7 Compliance is determined when specimens withstand the test voltage without breakdown for 30 minutes.

33 High-Voltage DC Wire Dielectric Voltage-Withstand Test, Method II

33.1 Specimens of finished high-voltage DC rated wire are to be tested in accordance with the method described in 33.2 – 33.7. Insulated conductors composed of multiple layers of insulation are to be tested only as a finished cable. Insulated conductors, insulated flat cables or the insulated conductors of a jacketed cable are to be tested. In the case of a jacketed cable, the insulated conductors are to be removed and tested independently of the jacketed cable. Specimens are to be tested in an unaged condition and in air oven aged condition. The oven aged specimen is to be conditioned in a circulating air oven for the same time and temperature for the specific insulation material described in 21.2 and Table 7.1, Table 7.2, and Table 7.3. After air oven conditioning, the specimen is to be cooled to room temperature in still air for a period of 16 – 96 hours before testing. When the material is not specified, aging in accordance with Table 14.1 is to be used.

33.2 One unaged specimen and one oven aged specimen are to be prepared as follows: A specimen 5 feet (1.5 m) in length is to be wrapped for nine close turns around a metal mandrel in accordance with Table 32.1. The ends of the specimen are to be twisted loosely together or fastened together with tape to prevent unwinding.

33.3 When a mandrel specified above is not available, it shall be permitted to use a mandrel with a smaller diameter. However, in the event of non-compliant results, the sample shall be re-tested using the mandrel size specified in 33.2.

33.4 The wrapped wire specimens and the metal mandrels are to be placed in a circulating air oven set at a temperature which is identical to the rated temperature of the wire.

33.5 The dielectric tester shall supply a DC test potential that is continuously variable with an output from zero to at least the test voltage of the wire specimen being tested. The output voltage is to be monitored continuously by a voltmeter. The overall accuracy shall not introduce an error greater than five percent. The maximum current output of the tester's transformer is to be enough for testing samples to dielectric breakdown without tripping of the circuit breaker by the charging unit. The test leads of the dielectric tester are to pass through an opening into the circulating air oven or in some way be connected to the specimen while it is at the specified temperature in the circulating air oven.

33.6 With the sample and metal mandrel in the oven, one test lead of the dielectric tester is to be connected to the conductor of the test specimen as one electrode and the other connected to the metal mandrel as the other electrode. The voltage is to be increased from zero to 1.25 times the DC voltage rating of the specimen at a rate not exceeding 500 volts per second. When this level is reached without breakdown, the voltage is to be held constant at this level for a period of seven hours and then returned to zero at the same rate.

33.7 Compliance is determined when unaged and oven aged specimens withstand the test voltage without breakdown for a period of seven hours.

34 High-Voltage Cut-Through Test, Special Rated TV Wire Only

34.1 Specimens of finished high-voltage DC rated TV use wire are to be tested in accordance with the method described in 34.2 – 34.7. Insulated conductors composed of multiple layers of insulation are to be tested only as a finished cable. Insulated conductors, insulated flat cables or the insulated conductors of a jacketed cable are to be tested. In the case of a jacketed cable, the insulated conductors are to be removed and tested independently of the jacketed cable.

34.2 One specimen of the finished wire at least 12 inches (305 mm) long is to have a weight attached to each end. The weight is to be 1 lbf (4.5 N or 0.45 kgf) for wire sizes 20 AWG or smaller and 2 lbf (8.9 N or 0.91 kgf) for wire sizes 19 AWG or larger. One end of the specimen is to be stripped of insulation so that a dielectric tester test lead is capable of being attached to the specimen's conductor.

34.3 The center portion of the test specimen is to be hung so that it fits snugly over an upturned U-shaped metal channel. The upturned U-shaped metal channel is to be elevated and supported in a horizontal position by a stand or some other equivalent holding device that enables the weights to hang freely on either side of the channel. The upturned edges of the U-shaped channel are to be rounded and have a radius of 0.015 inch (0.38 mm) or have drill rods with a diameter of 0.032 inch (0.8 mm) fastened in place along the upturned edge of the channel. See Figure 34.1.