



UL 758

Underwriters Laboratories Inc.
Standard for Safety

Appliance Wiring Material



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UL Standard for Safety for Appliance Wiring Material, UL 758

Second Edition, Dated April 24, 2006

Summary of Topics

The revisions for UL 758 are being issued to:

Define method for determining the equivalent AWG size for rectangular conductors in 5.1.1;

Addition of exemption for expendable components in 7.2.4 and 20.2;

Addition of ASTM D 471 oil as standard test liquid in 15.1;

Clarification of the form of the samples for the deformation test in 19.1;

Corrections to deformation test in Table 19.1;

Modification to the durability of ink-print test in 26.1;

Clarification of dielectric method I sample preparation in 28.5;

Addition of test temperatures in the capacitance and relative permittivity test temperatures in 37.1 and 37.2;

Clarification of bending tests for silicone insulation covered with a braid in Table 7.2 and Table 7.3;

Editorial revision to correct conversion in Table 13.1 and Table 13.2;

Deletion of reference to form of material in 7.2.4, 13.2.1, and 20.2;

Relocation of conductor construction to 5.7.4;

Revision to 7.2.2, 7.2.4, 14.3, 16.1 to relocate test method reference.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The revised requirements are substantially in accordance with Proposal(s) on this subject dated February 26, 2010.

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The following table lists the future effective dates with the corresponding reference.

Future Effective Date	Reference
October 1, 2015	Paragraphs 5.1.1, 5.3.2, 5.6.1, 8.4, 13.3.2, 13.3.3, 18.1, 19.1, 22.1, 26.1, 34.1, 35.1, 37.1, 37.2, 48.2(b), (d), (e), (f); Tables 7.1, 8.2, 13.1, 13.2, 19.1

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UL 758

Standard for Appliance Wiring Material

First Edition – July, 2000

Second Edition

April 24, 2006

This ANSI/UL Standard for Safety consists of the Second Edition including revisions through July 15, 2010.

The most recent designation of ANSI/UL 758 as an American National Standard (ANSI) occurred on July 15, 2010. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or effective date information.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <http://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.

1.5.1 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 the Standard for Flexible Materials Interconnect Constructions, UL 796F.

1.5.1 added September 3, 2008

1.6 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.

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

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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.

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 Tables 3.1 – 3.7 serve as indices to requirements for construction details and basic test methods for typical AWM constructions.

Table 3.1
Single or multiple conductor with extruded insulation

Table 3.1 revised December 11, 2009

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 47, and Markings on Tag, Reel or Carton, Section 48
Basic tests:	Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14. Conductor Corrosion Test, Section 18 Deformation Test (Thermoplastics and Class XL Only), Section 19. # Flexibility Test of Insulation, Covering, and Jacket, Section 20. Heat Shock Test (Thermoplastic Materials Only), Section 21. Cold Bend Test, Section 22. Durability of Ink-Print Test, Section 26 Crush Resistance Test, Section 27. Dielectric Test, Method I, Section 28. Dielectric Test, Method II, Section 29. Dielectric Test, Method III, Section 30. Horizontal Flame Test for Internal Wiring, Section 39.
Elective tests/ratings:	See Table 3.7

Table 3.2
Single conductor with other-than-extruded insulation

Table 3.2 revised December 11, 2009

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 47, and Markings on Tag, Reel or Carton, Section 48
Basic tests:	Conductor Corrosion Test, Section 18. # Flexibility Test of Insulation, Covering, and Jacket, Section 20. Cold Bend Test, Section 22. Durability of Ink-Print Test, Section 26 Dielectric Test, Method I, Section 28. Dielectric Test, Method II, Section 29. Horizontal Flame Test for Internal Wiring, Section 39.
Elective tests/ratings:	See Table 3.7.

Table 3.3
Parallel cable with extruded integral insulation and jacket

Table 3.3 revised December 11, 2009

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 47, and Markings on Tag, Reel or Carton, Section 48
Basic tests:	Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14. Conductor Corrosion Test, Section 18. Deformation Test (Thermoplastics and Class XL Only), Section 19. # Flexibility Test of Insulation, Covering, and Jacket, Section 20. Heat Shock Test (Thermoplastic Materials Only), Section 21. Cold Bend Test, Section 22. Durability of Ink-Print Test, Section 26 Dielectric Test, Method I, Section 28. Dielectric Test, Method II, Section 29. Dielectric Test, Method III, Section 30. Horizontal Flame Test for Internal Wiring, Section 39. Cable Flame Test, Section 40.
Elective tests/ratings:	See Table 3.7.

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Table 3.4
Multiple-conductor cable using non-integral jacket

Table 3.4 revised December 11, 2009

Conductors:	
Material	See Conductor, Section 5
Size	See Conductor, Section 5
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 47, and Markings on Tag, Reel, or Carton, Section 48
Basic tests: Insulated conductors tested in accordance with Tables 3.1, 3.2, 3.3, or 3.5. Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14 – Test jacket only. Deformation Test (Thermoplastics and Class XL Only), Section 19. # Flexibility Test of Insulation, Covering, and Jacket, Section 20 Heat Shock Test (Thermoplastic Materials Only), Section 21 Cold Bend Test, Section 22. Durability of Ink-Print Test, Section 26 Horizontal Flame Test for Internal Wiring, Section 39. Cable Flame Test, Section 40.	
Elective tests/ratings:	See Table 3.7.

Table 3.5
Bonded or laminated flat ribbon cable

Table 3.5 revised December 11, 2009

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 47, and Markings on Tag, Reel, or Carton, Section 48
Basic tests: Physical Properties of Insulation and Jacket, 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 of Insulation, Covering, and Jacket, Section 20. Heat Shock Test (Thermoplastic Materials Only), Section 21.	

Table 3.5 Continued

Cold Bend Test, Section 22.	
Durability of Ink-Print Test, Section 26	
Delamination Test (Laminated Constructions Only), Section 23.	
Dielectric Test, Method I, Section 28.	
Dielectric Test, Method II, Section 29	
Dielectric Test, Method III, Section 30.	
Horizontal Flame Test for Internal Wiring, Section 39.	
Elective tests/ratings:	See Table 3.7.

Table 3.6
High voltage DC wire with extruded insulation

Table 3.6 revised December 11, 2009

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
Markings:	See Surface Marking of AWM, Section 47, and Markings on Tag, Reel, or Carton, Section 48
Basic tests:	
Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14.	
Conductor Corrosion Test, Section 18.	
Deformation Test (Thermoplastics and Class XL Only), Section 19.	
# Flexibility Test of Insulation, Covering, and Jacket, Section 20.	
Heat Shock Test (Thermoplastic Materials Only), Section 21.	
Shrinkback Test – Special Rating TV Wires Only, Section 24.	
Ozone Resistance Test – Special Rating TV Use Wires Only, Section 25.	
Durability of Ink-Print Test, Section 26	
High-Voltage DC Wire Dielectric Voltage-Withstand Test, Method I, Section 31.	
High-Voltage DC Wire Dielectric Voltage-Withstand Test, Method II, Section 32.	
High-Voltage Cut-Through Test, Special Rated TV Wire Only, Section 33.	
Horizontal Flame Test for Internal Wiring, Section 39.	
VW-1 Flame Test (required for TV wire), Section 41.	
Elective tests/ratings:	See Table 3.7.

Table 3.7
Elective tests and ratings

Table 3.7 revised September 3, 2008

Flame tests:	VW-1 Flame Test, Section 41. FT-1 Flame Test, Section 42. FT-2 Flame Test, Section 43.
Mechanical test:	Crush Resistance Test, Section 27.
Sunlight resistance test:	Physical Properties of Insulation and Jacket, Sunlight Resistance, Section 17.
Oil and gasoline resistance tests:	Physical Properties of Insulation and Jacket, Oil Immersion Aging, Section 15. Physical Properties of Gasoline Resistant Insulation and Jacket, Section 16.
Wet ratings tests:	Temperature Correction Factor (Wet Rated AWM), Section 36. Capacitance and Relative Permittivity Tests (Wet Rated AWM), Section 37. Short Term Insulation-Resistance Test in Water at Room Temperature (Wet Rated AWM), Section 34, required for all wet rated wires. Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 35, at 50°C required for wires rated 60°C wet. Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 35, at 75°C required for wires rated 75°C wet. Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 35, at 90°C required for wires rated 90°C wet. Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 35, 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.

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. A tinsel conductor consists of a number of strands, twisted together, each strand being composed of one or more flattened wires of copper or copper alloy, helically wound on a polymeric thread. 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) 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. The size of a tinsel 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:

$$\text{average width (mils)} \times \text{average thickness (mils)} \times 1.273$$

The AWG size can then be determined using Table 20.1 in UL 1581.

Effective date for revised 5.1.1 changed from October 1, 2014 to October 1, 2015

Table 5.1
Conductor dimensions

Table 5.1 revised April 24, 2006

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
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

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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)
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

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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)
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
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
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

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.

5.2 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 5.2. The metal shall comply with the applicable ASTM specification, when specified, as indicated in Table 5.2.

Table 5.2
Conductor – metal specifications

Table 5.2 revised September 3, 2008

Conductor metal	ASTM reference for the metal	Temperature limit for the metal, °C (°F)	Other limits
Copper, uncoated, each strand less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 3	150 (302)	
Copper, uncoated, each strand at least 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 3	200 (392)	
Copper, tin-coated, each strand less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 33	150 (302)	
Copper, tin-coated, each strand at least 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 33	200 (392)	
Copper, lead-base-alloy coated, each strand less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 189	150 (302)	
Copper, lead-base alloy coated, each strand at least 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 189	200 (392)	
Copper, uncoated or tin coated, each strand less than 0.015 inch (0.38 mm) in diameter, overcoated with tin	ANSI/ASTM B 286	150 (302)	For use where flexibility is not a concern.
Copper, uncoated or tin coated, each strand at least 0.015 inch (0.38 mm) in diameter, overcoated with tin	ANSI/ASTM B 286	200 (392)	For use where flexibility is not a concern.
Copper, silver-coated	ANSI/ASTM B 298	200 (392)	
Copper, nickel-coated	ANSI/ASTM B 355	250 (482)	
Copper, nickel-coated, Type A, 27 percent minimum nickel coated copper	ANSI/ASTM B 355	550 (1022)	
Copper alloy, hard-drawn, less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 105	150 (302)	May be uncoated or provided with a tin, or lead-base-alloy coating
Copper alloy, hard-drawn, each strand at least 0.015 inch (0.38 mm) in diameter	ANSI/ASTM B 105	200 (392)	May be uncoated or provided with a tin, lead-base-alloy, silver, or nickel coating

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Table 5.2 Continued on Next Page

Table 5.2 Continued

Conductor metal	ASTM reference for the metal	Temperature limit for the metal, °C (°F)	Other limits
Copper alloy, annealed, less than 0.015 inch (0.38 mm) diameter	ASTM B 566	150 (302)	High-strength copper-alloy (minimum tensile strength 55,000 psi or 379 MN/m ² or 37.9 kN/cm ² or 38.7 kgf/mm ²), 85 percent IACS ^a minimum conductivity, 6 percent minimum elongation. May be uncoated or provided with a tin, or lead based alloy coating
Copper alloy, annealed, at least 0.015 inch (0.38 mm) diameter		200 (392)	High-strength copper alloy (minimum tensile strength 55,000 psi or 379 MN/m ² or 37.9 kN/cm ² or 38.7 kN/cm ² or 38.7 kgf/mm ²), 85 percent IACS ^a minimum conductivity, 6 percent minimum elongation. May be uncoated or provided with a tin, or lead based alloy coating
Copper alloy, annealed or hard-drawn, silver-coated		200 (392)	
Copper alloy, annealed, or hard-drawn, nickel-coated		250 (482)	
Copper-clad aluminum, annealed or hard-drawn, 6530 circular mils or 3.31 mm ² (12 AWG) and larger		90 (194)	Class 10A
Copper-clad steel less than 0.015 inch (0.38 mm) in diameter		150 (302)	Minimum conductivity of 30 percent IACS ^a
Copper-clad steel at least 0.015 inch (0.38 mm) in diameter		200 (392)	Minimum conductivity of 30 percent IACS ^a
Copper-clad steel, silver-coated		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		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		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	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	ANSI/ASTM B 609	90 (194)	
Stainless steel		250 (482)	

Table 5.2 Continued

Conductor metal	ASTM reference for the metal	Temperature limit for the metal, °C (°F)	Other limits
Nickel-plated iron Nickel, alloy		250 (482) 550 (1022)	Tensile strength 50,000 – 80,000 psi or 345 – 552 MN/m ² or 34.5 – 55.2 kN/cm ² or 35.1 – 56.2 kgf/mm ² ; elongation at least 35 percent; nominal volume resistivity 66 ohm circular mil/foot at 20°C (68°F) or 0.110 ohm mm ² /m at 20°C (68°F)
Nickel-chromium-iron		550 (1022)	
NOTE – "Copper, tin coated" mentioned in this table refers to copper strands of a conductor that are coated with tin before they are twisted. "Copper, overcoated with tin" mentioned in this table refers to copper strands that are twisted and then coated with tin.			
^a IACS – International Annealed Copper Standard			

5.3 Size and cross-sectional area

5.3.1 The size of a conductor shall not be less than indicated in Table 5.1 when measured in accordance with Conductor Diameter, Section 200 of UL 1581.

5.3.2 *Effective date for deleted 5.3.2 changed from October 1, 2014 to October 1, 2015.*

5.3.3 The cross-sectional area of a stranded conductor shall not be less than indicated in Table 5.1 when determined by either of the following:

- The sum of the areas of its component round strands.
- The weight method outlined in UL 1581, for a round compact-stranded aluminum conductor or a round compressed-stranded copper or aluminum conductor.

5.3.4 The determination of conductor resistance described in 5.6.1 – 5.6.3 may be used as an alternative method for determining conductor cross-sectional area of AWG-sized conductors. Conductors of Insulated Cables, IEC 60228, shall be used for metric-sized conductors, and shall be used as the referee method of determining conductor size.

5.4 Metal coating

5.4.1 When the insulation adjacent to a copper or copper-clad aluminum 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 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 D-C 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; and the Standard Specification for Fine-Wire Bunch-Stranded and Rope-Lay Bunch-Stranded Copper Conductors for Use as Electrical Conductors, ASTM B738 for conductors smaller than 30 AWG. Compliance of the DC conductor resistance shall be determined in accordance with Section 220 of UL 1581.

Exception: The DC conductor resistance of tinsel conductor shall not exceed the maximum value indicated on the tag, reel, or carton [see Exception to 42.2(d)].

Effective date for 5.6.1 changed from October 1, 2014 to October 1, 2015

5.6.2 For conductors having a conductivity other than 100 percent as noted in Table 5.2, 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 mm²) solid 40-percent-conductivity copper-clad steel conductor:

a) $R[12 \text{ AWG copper-clad steel at } 20^{\circ}\text{C (68}^{\circ}\text{F)}] = R(12 \text{ AWG copper at } 20^{\circ}\text{C}) \times 100/40 = R(12 \text{ AWG copper at } 20^{\circ}\text{C or } 68^{\circ}\text{F}) \times 2.5.$

b) $R[12 \text{ AWG copper at } 20^{\circ}\text{C (68}^{\circ}\text{F)}] = 1.62 \text{ ohms/1000 feet or } 5.31 \text{ ohms/kilometer.}$

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c) $R[12 \text{ AWG copper-clad at } 20^{\circ}\text{C (68}^{\circ}\text{F)}] = 1.62 \times 2.5 = 4.05 \text{ ohms/1000 feet or } 5.31 \times 2.5 = 13.28 \text{ ohms-kilometer.}$

5.6.2 revised September 3, 2008

5.6.3 Special alloy copper conductors having a conductivity of not less than 80 percent of stranded 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 80 percent of the 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 – 5.7.7.

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 conductors, Table 5.3. The American Wire Gauge (AWG) sizes shown in Table 5.3 represent conductors of intermediate nominal area.

5.7.3 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.

5.7.4 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 5.3. The direction of lay of the strands in a single-bunch bunch-stranded conductor shall be left-hand. 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 5.7.6 or 5.7.7 as applicable. The direction of lay of the outer layer shall be left-hand in all cases.

5.7.4 revised July 15, 2010

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Table 5.3
Maximum lay of single-bunch, bunch stranded copper conductors

AWG size	Inches	(mm)
28 or higher	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
10	2.5	64
8	3.0	76
6	3.5	89
4	4.0	102

5.7.5 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). 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) 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.

5.7.5 revised April 24, 2006

5.7.6 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. 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

5.7.7 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.

- 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.

5.7.7 revised September 3, 2008

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.

6 Optical Fiber Member(s)

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

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 Tables 7.2, and 7.3, or any of the materials described in Specific Materials, Table 7.1. Specimens shall be tested in accordance with the Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14, or shall be evaluated in accordance with Long-Term Aging, Section 481 of UL 1581.

Revised 7.2.1 effective October 24, 2007

7.2.2 Solid single-layer and multi-layered extruded insulation made from materials which are not described in Tables 7.1, or 7.2, and 7.3, shall also be subjected to Flexibility Test After Air Oven Conditioning, Section 20, and Dielectric Test Method I and II, Sections 28 and 29 respectively, 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.

7.2.2 revised July 15, 2010

Table 7.1
Index to insulations and jackets

Effective date for Table 7.1 changed from October 1, 2014 to October 1, 2015

Materials	Temperature rating	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	75	50.34	Insulation only
CPE	75	50.30	Jacket
CPE	90	50.23	—
CPE	105	50.33	—
ECTFE	150	50.63	—
EP	90	50.55	Insulation only. Covering required, or not subject to mechanical abuse.
EP	105	50.55	Insulation only. Covering required, or not subject to mechanical abuse.
EPCV	90	50.62	—
EPDM	60	50.24	—
EPDM	75	50.54	—
EPDM	90	50.52	—
EPDM	90	50.52	—
EPDM	125	50.56	—
ETFE	150	50.63	—
ETFE	200	50.64	—
FEP	150	50.73	—
FEP	200	50.70	—
FRPE	90	50.134	—
HDFRPE	75	50.133	—
HDPE	75	50.136	—
LDHRPE	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	—
NBR/PVC	75	50.97	—
NBR/PVC	90	50.23	—
Neoprene	60	50.120	—
Neoprene	60	50.122	—
Neoprene	75	50.123	—
Neoprene	90	50.125	—
PFA	200	50.137	—
PFA	250	50.137	—
PP	60	50.139	—
PP	75	50.139	—
PTFE	250	50.219	—

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Table 7.1 Continued on Next Page

Table 7.1 Continued

Materials	Temperature rating	Applicable table of physical properties in UL 1581	Notes
PVC	60	50.182	—
PVC	75	50.182	—
PVC	90	50.182	—
PVC	105	50.182	—
PVDF	125	50.185	—
PVDF	150	50.185	—

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Table 7.1 Continued

Materials	Temperature rating	Applicable table of physical properties in UL 1581	Notes
SBR/NR	60	50.195	—
SBR/NR	75	50.199	—
SR	150	50.210	Insulation only. Covering required, or not subject to mechanical abuse.
SR	200	50.210	Insulation only. Covering required, or not subject to mechanical abuse.
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	—
TPES	75	50.226	—
TPES	80	50.226	—
TPU	60	50.227	—
TPU	75	50.227	—
TPU	80	50.227	—
XL	75	50.231	—
XL	90	50.231	—
XL	105	50.245	—
XLPO	105	50.233	—
XLPO	125	50.232	—
XLPO	150	50.232	—

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

Table 7.2 revised July 15, 2010

Polymer designation	Dry temperature rating, °C (°F)	Polymer type/test speed, inches (mm)	Physical properties, unaged	
			Minimum average	
			Elongation, percent	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 jacket	80 (176)	Thermoplastic/20 ±1 inch (508 ±25 mm) per minute	100	3000 (2.11)

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Table 7.2 Continued on Next Page

Table 7.2 Continued

Polymer designation	Dry temperature rating, °C (°F)	Polymer type/test speed, inches (mm)	Physical properties, unaged	
			Minimum average	
			Elongation, percent	Tensile strength, psi (kgf/mm ²)
^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 Table 50.210 and Paragraph 1560.1 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 and jackets

Table 7.3 revised July 15, 2010

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 jacket	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 Table 50.210 and Paragraph 1560.1 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 of Insulation, Covering, and Jacket, Section 20.

7.2.3 revised December 11, 2009

7.2.4 Foamed and foam/skin insulation and non-extruded insulations made from materials which are not described in Tables 7.2 and 7.3 or Section 50 of UL 1581, shall be subjected to Flexibility Test, Section 20, after 150 days of aging 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.

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Exception No. 1: If the generic temperature rating of the material used (regardless of form) is equal to that described in Table 7.1 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 a polymeric varnish or finish and rated 300°C or above will be as indicated in Table 14.1.

7.2.4 revised July 15, 2010

7.2.5 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.

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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.

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).

7.3.3 For wires with extruded insulation which do not have a restricted use, the thicknesses shown in Tables 7.4 – 7.6 apply. Thinner thicknesses or non-extruded insulation may be evaluated for unrestricted use by subjecting the wires to the Crush Resistance Test, Section 26. Wires with extruded insulation that are intended to be used in a jacketed cable are not required to comply with either the thicknesses shown in Tables 7.4 – 7.6 or with the Crush Resistance Test.

7.3.4 The requirements for the wires noted in Tables 7.4 and 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 extruded, non-fluoropolymer insulation materials^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	0.006 (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 – 0.01	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
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 (0.15)	0.005 (0.13)	0.030 (0.76)	0.027 (0.69)	0.030 (0.76)	0.027 (0.69)	0.030 (0.76)	0.027 (0.69)	b	b
9, 8	6.0	b	b	b	b	0.030 (0.76)	0.027 (0.69)	0.045 (1.14)	0.041 (1.04)	–	–
7, 6	10.0	b	b	b	b	0.045 (1.14)	0.041 (1.04)	0.060 (1.52)	0.054 (1.37)	–	–
5 – 2	16.0 – 25.0	b	b	b	b	0.045 (1.14)	0.041 (1.04)	0.060 (1.52)	0.054 (1.37)	–	–
1 – 4/0	35.0 – 95.0	b	b	b	b	0.060 (1.52)	0.041 (1.04)	0.080 (2.03)	0.072 (1.83)	–	–
250 – 500 kcmil	120 – 240	b	b	b	b	0.060 (1.52)	0.041 (1.04)	0.095 (2.41)	0.086 (2.18)	–	–

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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
501 – 1000 kcmil	300 – 500	b	b	b	b	0.060 (1.52)	0.041 (1.04)	0.110 (2.79)	0.099 (2.51)	–	–
1001 – 2000 kcmil	630 – 1000	b	b	b	b	0.060 (1.52)	0.041 (1.04)	0.125 (3.18)	0.112 (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. Please see Table 5.1, Conductor Dimensions, for equivalence between English and metric conductor sizes.

^b See 7.3.4.

Table 7.5
Thickness requirements for extruded, fluoropolymer insulation materials (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 (0.13)	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
30 – 25	0.05 – 0.1	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
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 – 4.20	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)	–	–

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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
								(1.52)	(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 7.3.4.											

Table 7.6
Thickness requirements for PVC insulation with a nylon covering^a

Table 7.6 revised April 24, 2006

Conductor size, AWG	Conductor size, mm ²	Wires rated 300 volts			Wires rated 600, 1000 volts		
		PVC wall thickness, inch (mm)		Nylon wall thickness, inch (mm)	PVC wall thickness, inch (mm)		Nylon wall thickness, inch (mm)
		Avg	Min	Min	Avg	Min	Min
24 – 19	0.50	0.009 (0.23)	0.008 (0.20)	0.002 (0.05)	0.015 (0.38)	0.013 (0.33)	0.004 (0.10)
18 – 15	1.00 – 1.5	0.009 (0.23)	0.008 (0.20)	0.002 (0.05)	0.015 (0.38)	0.013 (0.33)	0.004 (0.10)
14 – 12	2.5	0.012 (0.30)	0.011 (0.28)	0.002 (0.05)	0.015 (0.38)	0.013 (0.33)	0.004 (0.10)
11, 10	4.0	0.015 (0.38)	0.013 (0.33)	0.003 (0.08)	0.020 (0.51)	0.018 (0.56)	0.004 (0.10)
9, 8	6.0	0.015 (0.38)	0.013 (0.33)	0.003 (0.08)	0.030 (0.76)	0.027 (0.69)	0.005 (0.13)
7, 6	10.0	0.030 (0.76)	0.027 (0.69)	0.005 (0.13)	0.030 (0.76)	0.027 (0.69)	0.005 (0.13)
5 – 2	16.0 – 25.0	0.040 (1.02)	0.036 (0.91)	0.006 (0.15)	0.040 (1.02)	0.036 (0.91)	0.006 (0.15)
1 – 4/0	35.0 – 95.0	0.050 (1.27)	0.045 (1.14)	0.007 (0.18)	0.050 (1.27)	0.045 (1.14)	0.007 (0.18)
^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.							

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 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. The requirements in Section 14 and Section 20 of UL 758 shall not apply.

Effective date for 8.4 changed from October 1, 2014 to October 1, 2015

Table 8.2
Extruded Nylon Coverings

Effective date for Table 8.2 changed from October 1, 2014 to October 1, 2015

Conductor size, AWG	Conductor size, mm ²	300 V Nylon wall thickness, inch (mm), maximum	600, 1000 V Nylon wall thickness, inch (mm), maximum
24 – 12	0.50 – 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	127 – 253	0.010 (0.25)	0.010 (0.25)
501 – 1000	279 – 507	0.011 (0.28)	0.011 (0.28)

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.

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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.

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.

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 47.3 and 48.2(k).

11.5 revised April 24, 2006

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. 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.

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 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 12.4.

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

12.4 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.

Revised 12.4 effective October 24, 2007

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12.5 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.

Added 12.5 effective October 24, 2007

12.6 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.)

Added 12.6 effective October 24, 2007

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 Tables 7.2 and 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). 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 Tables 7.2 and 7.3 or any of the materials described in Specific Materials, Section 50 of UL 1581. The jacket thickness shall comply with Tables 13.1 – 13.3, and the cable shall comply with the requirements of the Cable Flame Test, Section 40.

13.2 Materials

13.2.1 An overall jacket shall be solid and shall use one of the jacket materials indicated in Tables 7.2 and 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 Long-Term Aging, Section 481 of UL 1581. 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 Table 7.1 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.

13.2.1 revised July 15, 2010

13.2.2 Jackets made from materials which are not described in Tables 7.2 and 7.3, or Section 50 of UL 1581, shall also be subjected to Flexibility Test, Section 20.

13.2.2 revised December 11, 2009

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 In some cases, the use of a jacket that is other than indicated in Tables 13.1 – 13.3 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.

Effective date for 13.3.2 changed from October 1, 2014 to October 1, 2015

13.3.3 Investigation of mechanical and physical characteristics of a construction using a jacket that is thinner than described in Tables 13.1 – 13.3 shall show the construction to be comparable in performance to the constructions currently intended for the application and described in Tables 13.1 – 13.3. Crush, impact, abrasion, and other tests may be used to compare the performance of the thinner construction to the constructions described in Tables 13.1 – 13.3.

Effective date for 13.3.3 changed from October 1, 2014 to October 1, 2015

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

Effective date for revised Table 13.1 changed from October 1, 2014 to October 1, 2015

		Calculated diameter of round assembly under jacket or calculated equivalent diameter ^b of flat assembly under jacket				
		0 – 0.400 inch	0.401 – 0.700 inch	0.701 – 1.000 inch	1.001 – 1.500 inches	1.501 – 2.500 inches
		(0 – 10.16 mm)	(10.17 – 17.78 mm)	(17.79 – 25.40 mm)	(25.41 – 38.10 mm)	(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	0.020 inch (0.51 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 $1.1284 \times (TW)^{\frac{1}{2}}$ 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

Effective date for revised Table 13.2 changed from October 1, 2014 to October 1, 2015

		Calculated diameter of round assembly under jacket or calculated equivalent diameter ^b of flat assembly under jacket					
		0 – 0.250 inch	0.251 – 0.350 inch	0.351 – 0.500 inch	0.501 – 0.700 inch	0.701 – 1.500 inches	1.501 – 2.500 inches
		(0 – 6.36 mm)	(6.37 – 8.91 mm)	(8.92 – 12.72 mm)	(12.73 – 17.80 mm)	(17.81 – 38.10 mm)	(38.11 – 63.50 mm)
30 – 600 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)
	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.							

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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	0.251 – 0.350 inch	0.351 – 0.500 inch	0.501 – 0.700 inch	0.701 – 1.500 inches	1.501 – 2.500 inches
	(0 – 6.36 mm)	(6.37 – 8.91 mm)	(8.92 – 12.72 mm)	(12.73 – 17.80 mm)	(17.81 – 38.10 mm)	(38.11 – 63.50 mm)
^b The equivalent diameter of a flat assembly is to be calculated as $1.1284 \times (TW)^{\frac{1}{2}}$ in which T is the thickness of the assembly under the jacket and W is the width of the assembly under the jacket.						

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Table 13.3

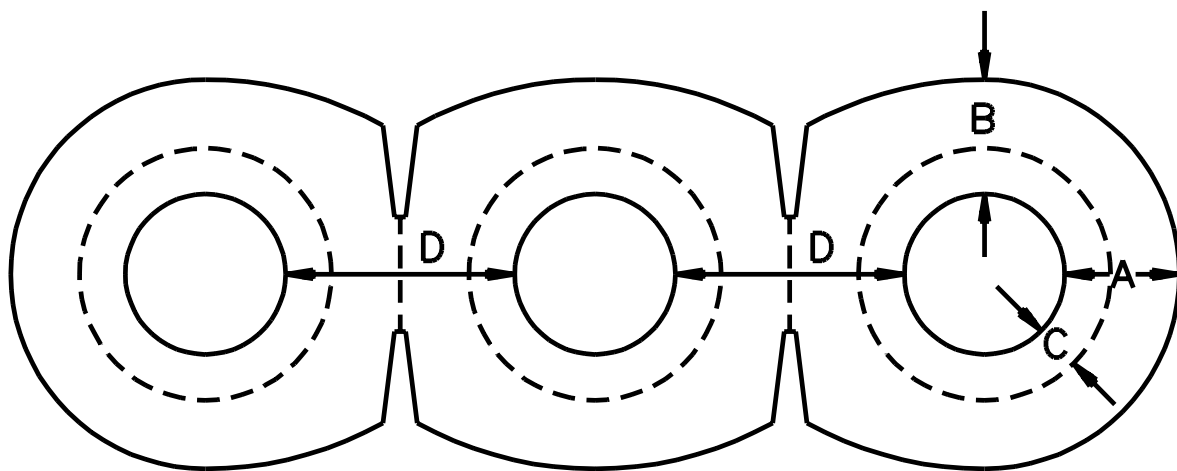
Thickness of integral insulation (solid) and jacket on 2-, 3-, or 4-conductor flat, parallel cable and distance between conductors for cables rated 125 – 600 volts, or less than 125 volts

Table 13.3 revised April 24, 2006

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 Figures 13.2 and 13.3)		Minimum thickness at any point before separation measured outside point P or X (defined in Figures 13.2 and 13.3)		Minimum thickness at any point after separation		Minimum distance between copper conductors	
	(Information only - not a requirement), A ^a ,		B ^a ,		C ^a ,		D ^a ,	
	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
22 – 12 AWG rated 125 – 600 volts	0.030	0.76	0.027	0.69	0.013	0.33	0.047	1.19
24 – 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.

Figure 13.1
Integral flat cable

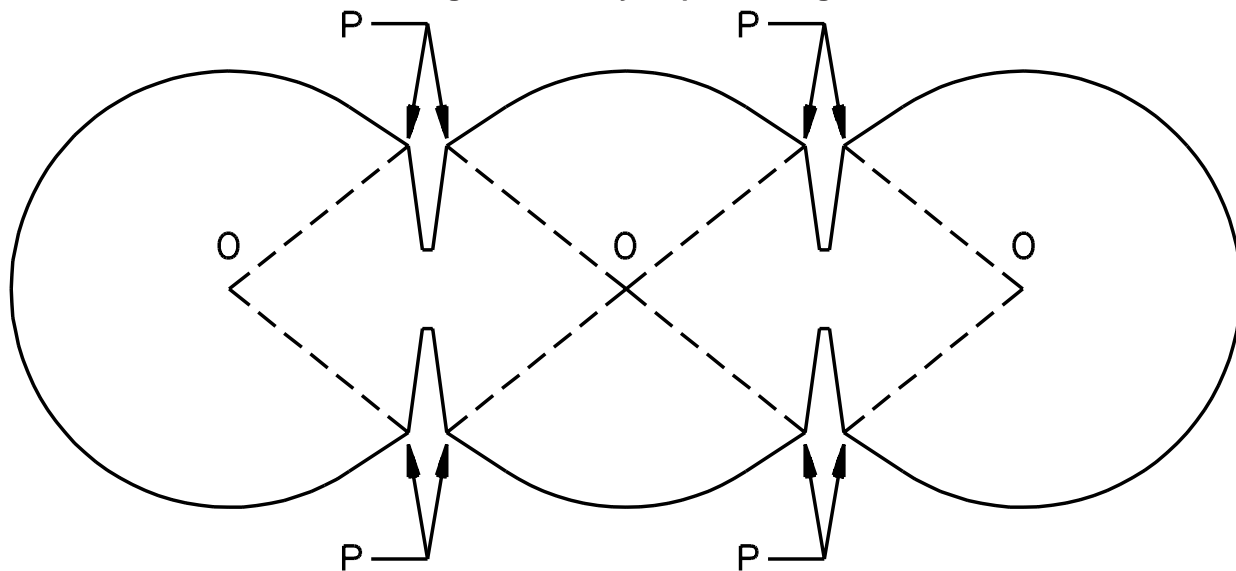


SB0636-2

NOTE – See Table 13.3 for dimensions A – D

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Figure 13.2
Definitions of regions of valley slopes in integral flat cables

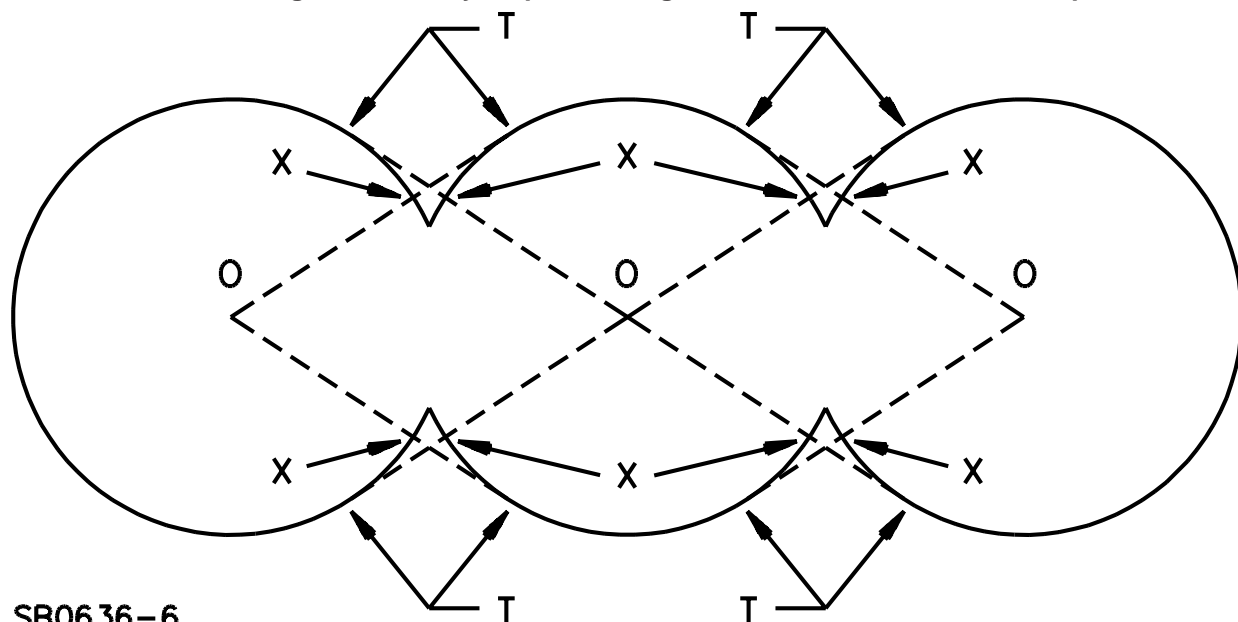


SB0636-5

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.

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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.

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PERFORMANCE

TESTS FOR THERMAL AND CHEMICAL PROPERTIES

14 Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged

14.1 Except for foamed and foamed/skin insulations, the physical properties (tensile strength, elongation, and elongation recovery (when specified in Section 50 of UL 1581) of both unaged and oven aged specimens of insulation, covering, and jacket shall be in accordance with Tables 7.2 and 7.3, or any of the materials described in Specific Materials, Section 50 of UL 1581. Foamed and foamed/skin insulations are to be evaluated in accordance with the Flexibility Test of Insulation, Covering, and Jacket, Section 20. 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 Long-Term Aging, Section 481 of UL 1581 shall be applied.

14.1 revised December 11, 2009

Table 14.1
Aging conditions for insulation and jackets

Dry temperature rating,		Air oven conditioning		
		Oven temperature,		Time, days
°C	(°F)	°C ±2	(°F ±3)	
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 greater than 250°C (482°F), 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 are to 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 larger than 0.200 inches in core diameter shall be tested die-cut. When testing is to be conducted in accordance with Long-Term Aging, Section 481 of UL 1581, six specimens shall be tested.

14.2 revised April 24, 2006

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.

14.3 revised July 15, 2010

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.

14.5 revised April 24, 2006

15 Physical Properties of Insulation and Jacket, Oil Immersion Aging

15.1 Five specimens of oil resistant insulation and jacket are to be conditioned in IRM 902 oil in accordance with 480.6 and 480.7 of Accelerated Aging, Section 480 of 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.

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 and elongation with the nylon removed.

15.1 revised July 15, 2010

Table 15.1
Physical properties, oil aged, of insulation and jacket

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

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Table 15.1 Continued on Next Page

Table 15.1 Continued

Polymer designation	Oil temperature rating, °C (°F)	Physical properties, oil aged			
		Oil conditioning		Minimum percent of unaged values	
		Oil temperature, °C \pm 2 (°F \pm 3)	Time, hours	Elongation, percent	Tensile strength, percent
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
All other thermosets	80 (176)	80 (176)	1440	65	65
	60 (140)	100 (212)	96	50	50
	80 (176)	80 (176)	1440	65	65

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

16 Physical Properties of Gasoline Resistant Insulation and Jacket

16.1 Five specimens each of gasoline resistant insulation 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 Standard Test Method for Rubber Property-Effect of Liquids, ASTM D 471) for 30 days at $23 \pm 1^\circ\text{C}$ ($73.4 \pm 1.8^\circ\text{F}$).

16.1 revised July 15, 2010

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

17 Physical Properties of Insulation and Jacket, Sunlight Resistance

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

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

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 the physical properties requirements for the specific material and its associated temperature rating in Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14. 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.

Effective date for 18.1 changed from October 1, 2014 to October 1, 2015

18.2 After air oven conditioning, the test specimen is to be cooled to room temperature. Once at room temperature, the insulation is to be removed from the bare copper 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 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), 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 are to be tested in the same manner as jackets. Bonded or separable (rippable) flat cable constructions are to be separated and tested in the same manner as insulation. Foamed insulation material which is intended to be the outermost layer of the wire construction shall be tested.

Effective date for revised 19.1 changed from October 1, 2014 to October 1, 2015

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

Effective date for revised Table 19.1 changed from October 1, 2014 to October 1, 2015

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	30 – 21 20 – 12 10 – 7 6 – 1 1/0 – 4/0	250 400 ^a 500 1600 2000	2.45 3.92 ^a 4.90 15.72 19.61	100.0 ±1.0 (212.0 ±1.8)	50
	Any separable jacket	–	2000 ^b	19.61 ^b	100.0 ±1.0 (212.0 ±1.8)	50
PVC, SRPVC, TPES, mPPE, nylon, THV, TPU, other materials not shown in this table	Insulation or integral insulation and jacket	30 – 21 20 – 12 10 – 7 6 – 1 1/0 – 4/0	250 400 ^a 500 1600 2000	2.45 3.93 ^a 4.90 9.80 19.61	121.0 ±1.0 (249.8 ±1.8)	50
	Any separable jacket	–	2000 ^b	19.61 ^b	121.0 ±1.0 (249.8 ±1.8)	50
TPE	Insulation	30 – 21 20 – 12 10 – 7 6 – 1 1/0 – 4/0	250 400 ^a 500 1600 2000	2.45 3.92 ^a 4.90 15.72 19.61	150.0 ±1.0 (302.0 ±1.8)	50
	Any separable jacket	–	2000 ^b	19.61 ^b	150.0 ±1.0 (302.0 ±1.8)	50
XLPO XL	Insulation or integral insulation and jacket	30 – 21 20 – 12 10 – 7 6 – 1 1/0 – 4/0	250 400 ^a 500 1600 2000	2.45 3.92 ^a 4.90 15.72 19.61	121.0 ±1.0 (249.8 ±1.8)	50
	Any separable jacket	–	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 identical to the load assigned to the conductor size (AWG) specified in this table.

20 Flexibility Test of Insulation, Covering, and Jacket

20.1 One specimen each of insulation, covering, and jacket is to be conditioned in an air oven for the same time and temperature as described in the physical properties requirements for the specific material and its associated temperature rating. For wires meeting the requirements in Tables 3.2 and 3.5 where the intended use is in a location where not subjected to movement or mechanical abuse after installation, specimens shall be tested in the unaged condition only.

20.1 revised December 11, 2009

20.2 Foamed, foamed-skinned materials, and other forms of materials which are not described in Tables 7.2 and 7.3 or Section 50 of UL 1581 shall be aged for 150 days at the temperature described in 481.3 of UL 1581.

Exception No. 1: If the generic temperature rating of the material used (regardless of form) is equal to that described in Table 7.1 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 polymeric varnish or finish and rated 300°C or above will be as indicated in Table 14.1.

20.2 revised July 15, 2010

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

20.4 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) 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. For wires meeting the requirements in Tables 3.2 and 3.5 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 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.

20.4 revised December 11, 2009

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20.5 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 Heat Shock Test (Thermoplastic Materials Only)

21.1 One specimen is to be wound as described in 20.3 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 21.1 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.

Table 21.1
Air temperature for heat-shock test

Revised Table 21.1 effective October 24, 2007

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)
	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)

21.2 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, jacket, or both are then to be visually examined for cracking either on the surface or internally.

21.3 Upon visual examination, the insulation, jacket, or both, shall not show cracks either on the surface or internally.

22 Cold Bend Test

22.1 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 $10 \pm 2^{\circ}\text{C}$ ($14 \pm 3.6^{\circ}\text{F}$) 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 $-50^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (-4 , -22 , -40 , or $-58^{\circ}\text{F} \pm 3.6^{\circ}\text{F}$), 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 for minimum 180 degrees. Insulated conductors as well as the finished cable are to be tested separately.

Effective date for 22.1 changed from October 1, 2014 to October 1, 2015

22.2 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 22.1. 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 for a minimum of 180 degrees.

Table 22.1
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

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

23 Delamination Test

23.1 One 12-inch specimen of laminated flat cable in any color and thickness of insulation is to be used for this test. The specimens are to be aged in an air oven for the same time and temperature as described in Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14. After the conditioning, unaged and aged samples are to be held for two weeks in air at 32°C (80°F) and 85 percent relative humidity. After two weeks, the specimens are to be examined for delamination.

24 Shrinkback Test – Special Rating TV Wires Only

24.1 One specimen of finished high-voltage DC rated TV use wire is to be tested in accordance with the method described in 24.2 – 24.5. Finished insulated conductors composed of multiple layers of insulation are to be tested only as a finished cable.

24.2 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.

24.3 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 24.1.

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Table 24.1
Shrinkback test conditioning temperatures

Table 24.1 revised April 24, 2006

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)

24.4 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.

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

25 Ozone Resistance Test – Special Rating TV Use Wires Only

25.1 A specimen of finished high-voltage DC rated TV use wire is to be tested in accordance with the method described in 25.2 – 25.8. Finished insulated conductors composed of multiple layers of insulation are to be tested only as a finished cable.

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

25.3 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.

25.4 Each specimen is to be wrapped a single turn around a mandrel having a diameter as indicated in Table 25.1. 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.

Table 25.1
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

25.5 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.

25.6 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 $25 \pm 0.2^{\circ}\text{C}$ ($77 \pm 0.36^{\circ}\text{F}$) for a period of 3 hours. Care is to be taken not to touch the specimen during the transfer to the ozone chamber.

25.7 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.

25.8 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.

26 Durability of Ink-Print Test

26.1 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 Standard for Wire and Cable Test Methods, UL 2556. One specimen shall be conditioned in a forced-circulation air oven at $60^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for 168 hours. The other specimen shall be maintained at ROOM TEMPERATURE for a minimum of 24 hours.

Effective date for revised 26.1 changed from October 1, 2014 to October 1, 2015

TESTS FOR MECHANICAL PROPERTIES

27 Crush Resistance Test

27.1 All insulated conductors which do not have a restricted use must either comply with:

- a) The requirements in Tables 7.4, 7.5, or 7.6 or
- b) The crush test described in this section.

27.2 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.

27.2 revised April 24, 2006

27.3 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.

27.4 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 $24 \pm 8.0^\circ\text{C}$ ($75 \pm 14.4^\circ\text{F}$) 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.

27.5 After the short circuit occurs, the machine is to be reversed and the plates separated. The specimen is to be turned end for end, rotated 90 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 27.1.

Table 27.1
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)

27.6 Specimens shall exhibit average crush values in accordance with Table 27.1.

TESTS FOR ELECTRICAL PROPERTIES

28 Dielectric Test, Method I

28.1 Specimens of finished wire are to be tested in accordance with the method described in 28.2 – 28.9. 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.

28.2 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.

28.3 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 in tests for Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14.

28.4 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.

28.5 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. For wires meeting the requirements in Tables 3.2 and 3.5 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 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.

28.5 revised July 15, 2010

28.6 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.

28.7 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 28.1 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.

28.7 revised December 11, 2009

Table 28.1
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 – 10,000	All	2 times the rated voltage + 1000 V AC or V DC
3 kV DC and higher	All	2 times the rated voltage + 1000 V DC

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

28.8 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.

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

- Unaged and oven aged samples shall withstand the test voltage in Table 28.1 without breakdown for 60 seconds and
- The average dielectric breakdown value of oven aged samples shall not be less than 50 percent of the average breakdown value of unaged samples.

29 Dielectric Test, Method II

29.1 Specimens of finished wire are to be tested in accordance with the method described in 29.2 – 29.7. 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.

29.2 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 specified in tests for Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14.

Effective date for 29.2 changed from November 1, 2006 to May 1, 2008

29.3 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.

29.4 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.

29.5 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 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. 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.

29.6 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 28.1 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.

29.7 Unaged and oven aged specimens shall withstand the test voltage specified in Table 28.1 without breakdown for 60 seconds.

30 Dielectric Test, Method III

30.1 A specimen of finished wire is to be tested in accordance with the method described in 30.2 – 30.6. 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.

30.2 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.

30.3 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.

30.4 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.

30.5 After a minimum of 24 hours immersion in water, the voltage is to be increased from zero to the test potential specified in Table 28.1 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.

30.6 The specimen shall withstand the test voltage specified in Table 28.1 without breakdown for 60 seconds.

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

31.1 Specimens of finished high-voltage DC rated wire are to be tested in accordance with the method described in 31.2 – 31.6 before and after conditioning in an air oven for the same time and temperature as described in the physical properties requirements for the specific material and its associated temperature rating. 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.

31.1 revised April 24, 2006

31.2 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.

31.3 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 31.1. The end of each resulting helix is to be twisted loosely together or fastened together with tape to prevent unwinding.

Table 31.1
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

31.4 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.

31.5 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.

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

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

32.1 Specimens of finished high-voltage DC use wire are to be tested in accordance with the method described in 32.2 – 32.6. 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 an air oven aged condition. The oven aged sample are to be conditioned in a circulating air oven for the same time and temperature as in Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14.

32.1 revised April 24, 2006

32.2 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 31.1. The ends of the specimen are to be twisted loosely together or fastened together with tape to prevent unwinding.

32.3 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.

32.4 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.

32.5 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.

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

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

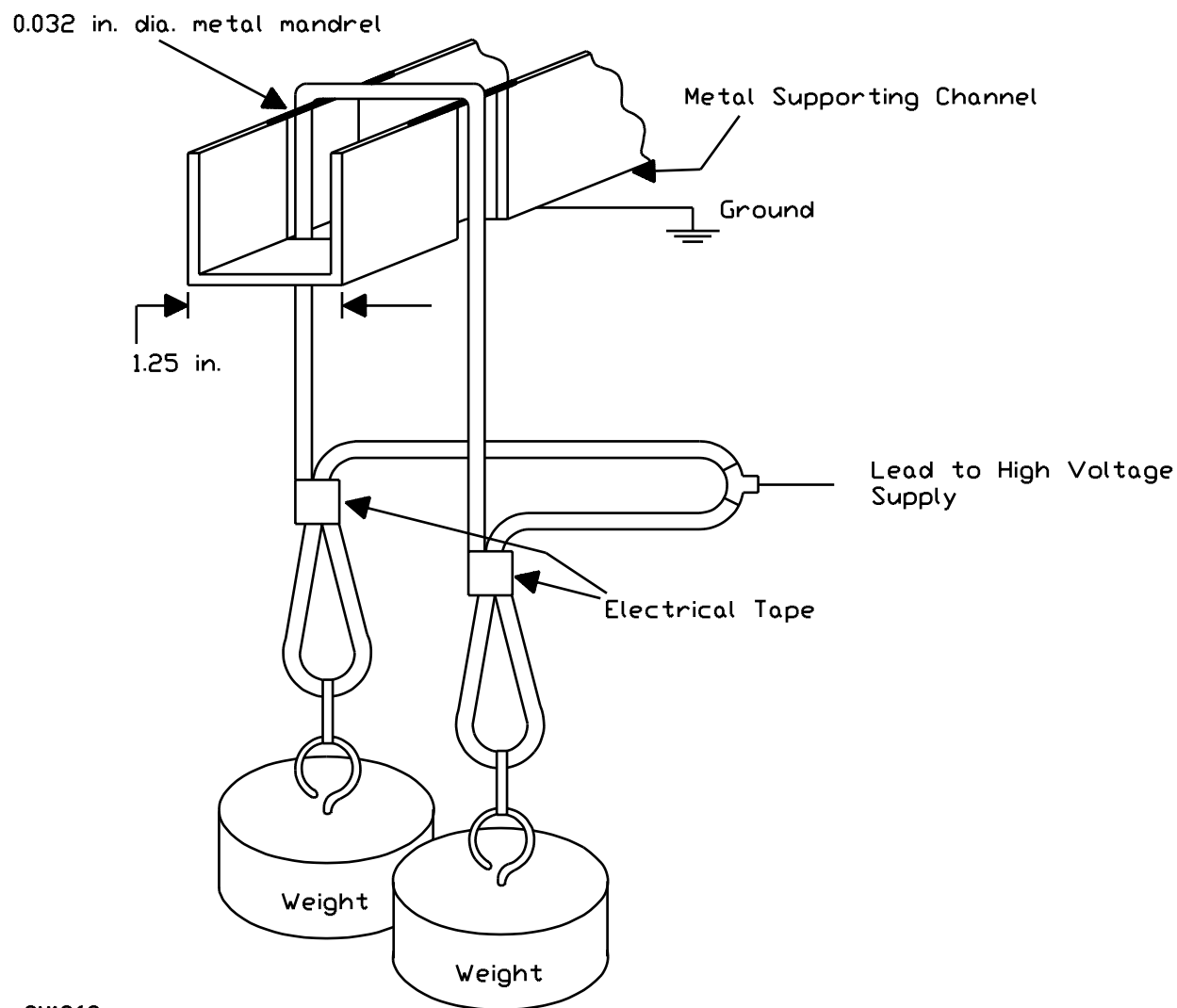
33.1 Specimens of finished high-voltage DC rated TV use wire are to be tested in accordance with the method described in 33.2 – 33.7. Insulated conductors composed of multiple layers of insulation are to be tested only as a finished cable. Insulated conductors, insulated flat cables or the insulated 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.

33.1 revised April 24, 2006

33.2 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.

33.3 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 33.1.

Figure 33.1
Apparatus for the TV wire high-voltage cut-through test



SM1268

33.4 The wire specimen with the hanging weights positioned over the upturned U-shaped channel is to be placed in a circulating air oven with a temperature the same as the rated temperature of the wire.

33.5 The dielectric tester is to 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 other way be connected to the specimen while it is at the specified temperature in the circulating air oven.

33.6 With the sample and upturned U-shaped channel in the oven set at the rated temperature of the wire, the positive test lead of the dielectric tester is to be connected to the conductor of the test specimen as one electrode and the negative test lead is to be connected to the upturned U-shaped metal channel as the other electrode. The channel is to be grounded to the air oven. The voltage is to be increased from zero to 1.5 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 specimens withstand the test voltage without breakdown for a period of seven hours.

34 Short Term Insulation-Resistance Test in Water at Room Temperature (Wet Rated AWM)

34.1 The finished insulated conductor (any jacket, shield, and covering removed) shall have an insulation resistance value of greater than 2.5 megohms based on 1000 feet (0.75 megohm based on one kilometer) of conductor. The PTFE and ETFE insulation shall result in the full range of sizes of finished wire having an insulation resistance not less than 1000 megohms based on 1000 conductor feet or 304 megohms based on a conductor kilometer. The test is to be conducted in accordance with Insulation-Resistance Test in Water, Section 920 of UL 1581.

Effective date for 34.1 changed from October 1, 2014 to October 1, 2015

35 Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM)

35.1 The finished wire that is rated for water resistance shall have an insulation resistance in tap water that is not less than indicated in the applicable formulas specified below at any time during immersion. The PTFE and ETFE insulation shall result in the full range of sizes of finished wire having an insulation resistance in tap water at an elevated temperature of not less than 100 megohms based on 1000 conductor feet or 30.4 megohms based on a conductor kilometer. The tap water is to have a temperature of either $50 \pm 1.0^{\circ}\text{C}$ ($122 \pm 1.8^{\circ}\text{F}$) or $75 \pm 1.0^{\circ}\text{C}$ ($167 \pm 1.8^{\circ}\text{F}$) or $90 \pm 1.0^{\circ}\text{C}$ ($194 \pm 1.8^{\circ}\text{F}$), or $100 \pm 1.0^{\circ}\text{C}$ ($212 \pm 1.8^{\circ}\text{F}$). The period of immersion is:

- a) 12 weeks or more when the insulation resistance throughout the last six weeks of the period is greater than 10 megohms based on 1000 conductor feet (3 megohms based on a conductor kilometer),

- b) 24 – 36 weeks when the insulation resistance is less than 10 megohms based on 1000 conductor feet and more than the value indicated in the applicable formulas below (3 megohms based on a conductor kilometer and more than the value indicated in the applicable formulas).

A sinusoidal rms 50 or 60 Hz potential equal to the voltage rating of the insulation is to be applied at all times other than while readings of insulation resistance are being taken. See 35.4 for the requirement covering the maximum rate of decrease of the insulation resistance.

Effective date for 35.1 changed from October 1, 2014 to October 1, 2015

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35.2 For PVC and thermosets, insulation-resistance values are to be calculated by using one of the following formulas, whichever is applicable:

a) (English):

$$IR_{50^{\circ}\text{C}} = K_{15.6^{\circ}\text{C}} \times 6.63 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

in which:

IR at 50°C (122°F) or 75°C (167°F) is the insulation resistance in megohms based on 1000 conductor feet for wire rated for exposure to water at 60°C (140°F) or 75°C, respectively;

K is the constant for the insulation material at 15.6°C (60.0°F) in megohms based on 1000 conductor feet;

6.63 x 10⁻⁴ is the multiplier required for reducing K for PVC at 15.6°C (60.0°F) to its value at the test temperature of 50°C (122°F) or 75°C (167°F); or

6.37 x 10⁻⁵ is the multiplier required for reducing K for the thermoset materials specified at 15.6°C (60°F) to its value at the test temperature specified;

D is the diameter over the insulation in inches; and

d is the diameter of the metal conductor in inches;

b) (Metric)

$$IR_{50^{\circ}\text{C}} = K_{15.6^{\circ}\text{C}} \times 2.02 \times 10^{-4} \times \log_{10} \frac{D}{d}$$

in which:

IR at 50°C (122°F) or 75°C (167°F) is the insulation resistance in megohms based on a conductor kilometer for wire – rated for exposure to water at 60°C (140°F) or 75°C, respectively;

K is the constant for the insulation material at 15.6°C (60.0°F) in megohms based on 304.8 conductor meters;

2.02 x 10⁻⁴ is the multiplier required for reducing K for PVC at 15.6°C (60.0°F) to its value at the test temperature of 50.0°C (122.0°F) or 75.0°C (167.0°F); or

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1.94×10^{-5} is the multiplier required for reducing K for the thermoset materials specified at 15.6°C (60.0°F) to its value at the test temperature specified;

D is the diameter over the insulation in mm; and

d is the diameter of the metal conductor in mm.

35.2.1 The minimum Insulation Resistance Constant (K) at 15.6°C (60°F) when calculated per 36.7 will be equal to or greater than:

500 MΩ-1000 ft. (150 GΩ-m) for PVC

1000 MΩ-1000 ft. (300 GΩ-m) for thermoset materials (except XLPVDF)

250 MΩ-1000 ft. (80 GΩ-m) for XLPVDF

35.2.1 added September 3, 2008

35.2.2 The minimum insulation-resistance value at the temperature of interest is to be calculated using the formula below:

a) (English):

$$IR_t = (K_{15.6^\circ\text{C}} / M) \times \log_{10}(D/d)$$

in which:

t is the test temperature of 60°C (140°F), 75°C (167°F), 90°C (194°F), or 100°C (212°F) respectively;

IR_t is the minimum insulation resistance in megohms based on 1000 conductor feet for wire rated for exposure to water at the test temperature t ;

M is the correction factor for reducing K at the test temperature of 60°C (140°F), 75°C (167°F), 90°C (194°F), or 100°C (212°F), respectively, as determined by the Temperature Correction Factor, Section 36, of this specification;

K is the insulation resistance constant at 15.6°C (60.0°F) in megohms based on 1000 conductor feet as specified in 35.2.1, above;

D is the diameter over the insulation of the wire being tested in inches; and

d is the diameter of the metal conductor of the wire being tested in inches;

b) (Metric)

$$IR_t = [K_{15.6^\circ\text{C}} / (M \times 3.281)] \times \log_{10}(D/d)$$

in which:

t is the test temperature of 60°C (140°F), 75°C (167°F), 90°C (194°F), or 100°C (212°F) respectively;

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IR_t is the minimum insulation resistance in gigohms based on a conductor meter for wire rated for exposure to water at the test temperature t ;

M is the correction factor for reducing K at the test temperature of 60°C (140°F), 75°C (167°F), 90°C (194°F), or 100°C (212°F), respectively, as determined by the Temperature Correction Factor, Section 36, of this specification;

K is the insulation resistance constant at 15.6°C (60.0°F) in megohms based on 304.8 conductor meters as specified in 35.2.1, above;

D is the diameter over the insulation of the wire being tested in mm; and

d is the diameter of the metal conductor of the wire being tested in mm.

35.2.2 added September 3, 2008

35.3 The extended immersion at 50 ±1°C (122 ±1.8°F) or 75 ±1°C (167 ±1.8°F) is the accelerated test for wire that is rated for exposure to water at 60°C (140°F) or 75°C. Although these wires are rated for such exposure to water, it is not expected that the wires during service are exposed simultaneously to a temperature of 60°C or 75°C and water for long periods of time.

35.4 For every continuous period of 3 weeks during the latter half of the 12-week or 24 – 36-week immersion, a smooth curve drawn covering the entire immersion period and showing the average of the measured readings of insulation resistance shall not decrease at a rate exceeding:

- a) 4 percent per week when the individual insulation-resistance readings are at least either 10 megohms based on 1000 conductor feet (3 megohms based on a conductor kilometer).
- b) 2 percent per week when the individual insulation-resistance readings are greater than the calculated insulation resistance in accordance with 35.5 but are less than either 10 megohms based on 1000 conductor feet (3 megohms based on a conductor kilometer).

35.5 To determine whether or not the insulation complies with the requirements in this section, finished wire is to be tested according to the following method. The ends of each specimen are to be brought well away from the tank, and the temperature of the water is to be maintained at the specified temperature ±1°C (±1.8°F). A coil that shows a greater percent decrease in insulation resistance during the extended immersion than specified in 35.4 may be tested for additional 1-week immersion periods and the coil is to be evaluated based on the last 12 weeks of immersion.

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

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36 Temperature Correction Factor (Wet Rated AWM)

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

36.1 revised April 24, 2006

36.2 The two specimens are to be immersed in a water bath equipped with heating, cooling, and circulating facilities. The ends of the specimens are to extend at least 24 inches (600 mm) above the surface of the water to reduce electrical leakage. The specimens are to be left in the water at room temperature for 16 hours before adjusting the bath temperature to 10°C (50°F) or before transferring the specimens to a 10°C bath.

36.3 The DC resistance of the metal conductor is to be measured at applicable intervals of time until the temperature remains unchanged for at least five minutes. The insulation is to be determined as being at the temperature of the bath as indicated on the bath thermometer.

36.4 Each of the two specimens is to be exposed, in accordance with 36.3, to successive water temperatures of 10, 16.1, 22.2, 27.8, and 35°C (50, 61, 72, 82, and 95°F) and returning, 27.8, 22.2, 16.1, and 10°C (82, 72, 61, and 50°F). Insulation resistance readings are to be taken at each temperature after equilibrium has been established.

36.5 The two sets of readings (four readings in all taken at the same temperature) are to be averaged for the two specimens. These four average values and the average of the single readings at 35°C (95°F) are to be plotted on semilog paper. A continuous curve (usually a straight line) is to be drawn through the five points. The value of insulation resistance at 15.6°C (60°F) is then to be read from the graph.

36.6 The resistivity coefficient – for a 0.55°C (1.0°F) change in temperature – is to be calculated to two decimal places by dividing the insulation resistance at 15.6°C (60.0°F) as read from the graph by the insulation resistance at 16.1°C (61.0°F). The resulting insulation resistance at 15.6°C is then to be adjusted using the value in Table 36.1 corresponding to the calculated resistivity coefficient.

Table 36.1
Multiplying factor M^a for adjusting insulation resistance to 60.0°F (15.6°C)

Temperature		Resistivity coefficient C for 1.0°F (0.55°C)									
°F	(°C)	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
40	4.4	0.55	0.46	0.38	0.31	0.26	0.22	0.18	0.15	0.12	0.10
41	5.0	0.57	0.48	0.40	0.33	0.28	0.23	0.19	0.16	0.14	0.12
42	5.6	0.59	0.49	0.42	0.35	0.30	0.25	0.21	0.18	0.15	0.13
43	6.1	0.60	0.51	0.44	0.37	0.32	0.27	0.23	0.20	0.17	0.15
44	6.7	0.62	0.53	0.46	0.39	0.34	0.29	0.25	0.22	0.19	0.16
45	7.2	0.64	0.56	0.48	0.42	0.36	0.32	0.28	0.24	0.21	0.18
46	7.8	0.66	0.58	0.50	0.44	0.39	0.34	0.30	0.26	0.23	0.20
47	8.3	0.68	0.60	0.53	0.47	0.42	0.37	0.33	0.29	0.26	0.23
48	8.9	0.70	0.62	0.56	0.50	0.44	0.40	0.36	0.32	0.29	0.26
49	9.4	0.72	0.65	0.59	0.53	0.48	0.42	0.39	0.35	0.32	0.29
50	10.0	0.74	0.68	0.61	0.56	0.51	0.46	0.42	0.39	0.35	0.32
51	10.6	0.77	0.70	0.64	0.59	0.54	0.50	0.46	0.42	0.39	0.36
52	11.1	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.43	0.40

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Table 36.1 Continued on Next Page

Table 36.1 Continued

Temperature		Resistivity coefficient C for 1.0°F (0.55°C)									
°F	(°C)	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
53	11.7	0.81	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45
54	12.2	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.54	0.51
55	12.8	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.59	0.57
56	13.3	0.89	0.86	0.82	0.79	0.76	0.74	0.71	0.68	0.66	0.64
57	13.9	0.92	0.89	0.86	0.84	0.82	0.79	0.77	0.75	0.73	0.71
58	14.4	0.94	0.93	0.91	0.89	0.87	0.86	0.84	0.83	0.81	0.80
59	15.0	0.97	0.95	0.94	0.95	0.94	0.93	0.92	0.91	0.90	0.89
60	15.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
62	16.7	1.06	1.08	1.10	1.12	1.14	1.17	1.19	1.21	1.23	1.25
63	17.2	1.09	1.12	1.16	1.19	1.23	1.26	1.30	1.33	1.37	1.40
64	17.8	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.46	1.52	1.57
65	18.3	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.61	1.69	1.76
66	18.9	1.19	1.27	1.34	1.42	1.50	1.59	1.68	1.77	1.87	1.97
67	19.4	1.23	1.32	1.41	1.50	1.61	1.71	1.83	1.95	2.08	2.21
68	20.0	1.27	1.37	1.48	1.59	1.72	1.85	1.99	2.14	2.20	2.48
69	20.6	1.30	1.42	1.55	1.69	1.84	2.00	2.17	2.36	2.56	2.77
70	21.1	1.34	1.48	1.63	1.79	1.97	2.16	2.37	2.59	2.84	3.11
71	21.7	1.38	1.54	1.71	1.90	2.10	2.33	2.58	2.85	3.15	3.48
72	22.2	1.43	1.60	1.80	2.01	2.25	2.52	2.81	3.14	3.50	3.90
73	22.8	1.47	1.67	1.89	2.13	2.41	2.72	3.07	3.45	3.88	4.36
74	23.3	1.51	1.73	1.98	2.26	2.58	2.94	3.34	3.80	4.31	4.89
75	23.9	1.56	1.80	2.08	2.40	2.76	3.17	3.64	4.18	4.78	5.47
76	24.4	1.60	1.87	2.18	2.54	2.95	3.43	3.97	4.59	5.31	6.13
77	25.0	1.65	1.95	2.29	2.69	3.16	3.70	4.33	5.05	5.90	6.87
78	25.6	1.70	2.03	2.41	2.85	3.38	4.00	4.72	5.56	6.54	7.69
79	26.1	1.75	2.11	2.53	3.03	3.62	4.32	5.14	6.12	7.26	8.61
80	26.7	1.81	2.19	2.65	3.21	3.87	4.66	5.60	6.73	8.06	9.65
81	27.2	1.86	2.28	2.79	3.40	4.14	5.03	6.11	7.40	8.95	10.8
82	27.8	1.92	2.37	2.93	3.60	4.43	5.44	6.66	8.14	9.93	12.1
83	28.3	1.97	2.46	3.07	3.82	4.74	5.87	7.26	8.95	11.0	13.6
84	28.9	2.03	2.56	3.23	4.05	5.07	6.34	7.91	9.85	12.2	15.2
85	29.4	2.09	2.67	3.39	4.29	5.43	6.85	8.62	10.8	13.6	17.0

^a Calculated from the formula $M = C^{(t+60)}$

in which

C is determined as described in the Test Procedure for Determining the Multiplying-Factor Column for Adjusting Insulation Resistance, Section 59 of the Standard for Medium-Voltage Power Cables, UL 1072; and

t is the temperature of the cable in °F.

36.7 The Insulation Resistance constant *K*, in megohms based on 1000 ft., at a temperature of 15.6°C (60°F) is to be calculated from the formula:

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$$K_{15.6\text{ }^{\circ}\text{C}} = \frac{L \times IR}{1000 \times \log_{10} \frac{D}{d}}$$

in which:

IR is the insulation resistance in megohms at 15.6°C (60.0°F) as determined in 36.5;

L is the length of circuit conductor being tested in feet or meters;

D is the measured diameter over the insulation; and

d is the measured diameter under the insulation.

36.7 added September 3, 2008

37 Capacitance and Relative Permittivity Tests (Wet Rated AWM)

37.1 The insulation (jacket, shield, and other coverings removed) on a wire rated for 60°C (140°F) water resistance is to have the following inductive capacity and capacitance values when specimens are tested with 1000 Hz sinusoidal current in tap water in accordance with Capacitance and Relative Permittivity Test, Section 1020 of UL 1581 at a test temperature of 30.0 ±1°C (86.0 ±1.8°F):

- a) The specific inductive capacity (relative permittivity or dielectric constant) determined after immersion of the specimens for 24 hours shall be 10 or less.
- b) The capacitance determined after immersion for 14 days shall not be more than 10 percent higher than the capacitance after the 24-hour immersion.
- c) The capacitance determined after immersion for 14 days shall not be more than 5 percent higher than the capacitance determined after immersion for 7 days.

Revised 37.1 effective October 1, 2015

37.2 The insulation (jacket, shield, and other coverings removed) on a wire rated for 75°C (167°F), 90°C (194°F), or 100°C (212°F) water resistance shall have the following specific inductive capacity and capacitance values when specimens are tested with 1000 Hz sinusoidal current in accordance with Capacitance and Relative Permittivity Test, Section 1020 of UL 1581 at a test temperature of 75°C ±1°F (167 ±1.8°F), 90°C (194 ±1.8°F), or 100°C (212 ±1.8°F):

- a) The specific inductive capacity (relative permittivity or dielectric constant) determined after immersion of the specimens for 24 hours shall be 10 or less.
- b) The capacitance determined after immersion for 14 days shall not be more than 10 percent higher than the capacitance after the 24-hour immersion.
- c) The capacitance determined after immersion for 14 days shall not be more than 5 percent higher than the capacitance determined after immersion for 7 days.

Revised 37.2 effective October 1, 2015

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38 Stability Factor (Wet Rated AWM)

38.1 Specimens of the thermoset insulated wire that are immersed continuously in tap water for 14 days at a temperature of $75 \pm 1^\circ\text{C}$ ($167 \pm 1.8^\circ\text{F}$) for materials rated 75°C , or $90 \pm 1^\circ\text{C}$ ($194 \pm 1.8^\circ\text{F}$) for materials rated 90°C , shall comply with one of the following requirements when tested in accordance with the stability factor test in UL 1581:

- a) The stability factor (the numerical difference between the percentage power factors measured with a 60 Hz current at average stresses of 80 and 40 volts per mil or 3150 and 1575 volts per millimeter) determined after the fourteenth day of immersion shall be 1.0 or less, or
- b) The stability factor determined after the first day subtracted from the stability factor determined after the fourteenth day shall be 0.5 or less.

TESTS FOR FLAME PROPERTIES

39 Horizontal Flame Test for Internal Wiring

39.1 Three specimens of the finished insulated conductor and finished cable used for internal wiring, are to be evaluated in accordance with the Horizontal-Specimen Appliance-Wire Flame Test, Section 1090 of UL 1581.

40 Cable Flame Test

40.1 Three specimens of the finished cable for external use, are to be evaluated in accordance with Cable Flame Test, Section 1061 of UL 1581.

41 VW-1 Flame Test

41.1 Three specimens each of the finished insulated conductor and finished cable are to be tested in accordance with the VW-1 (Vertical-Specimen) Flame Test, Section 1080 of UL 1581.

41.2 Flame Rating VW-1 applies to the complete finished wire or cable. Insulated conductors in a finished cable are not determined to be rated VW-1 unless specifically noted on the tag markings.

42 FT-1 Flame Test

42.1 Three specimens each of the finished insulated conductor and finished cable are to be tested in accordance with Vertical Flame and FT-1 Tests, Section 1060 of UL 1581.

42.2 Flame Rating FT-1 applies to the complete finished wire or cable. Insulated conductors in a finished cable are not determined to be rated FT-1 unless specifically noted on the tag markings.

43 FT-2 Flame Test

43.1 Three specimens each of the finished insulated conductor and finished cable are to be tested in accordance with Horizontal-Specimen/FT-2 Flame Test, Section 1100 of UL 1581.

43.2 Flame Rating FT-2 applies to the complete finished wire or cable. Insulated conductors in a finished cable are not determined to be rated FT-2 unless specifically noted on the tag markings.

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MANUFACTURING AND PRODUCTION TESTS

44 Test for Continuity of Conductors

44.1 Each circuit conductor and grounding conductor shall be continuous throughout the entire length of finished cable. Finished cable is to be tested for continuity of each 10 AWG, or smaller conductor by the cable manufacturer at the cable factory. Only those cables where the conductors have undergone further processing after spark testing must undergo this test.

44.1 revised April 24, 2006

44.2 To determine whether or not a cable is continuous, each of the conductors (one at a time) is to be connected in series with a lamp, buzzer, bell or other indicator and a power supply. A conductor is continuous from end-to-end of the finished cable when the lamp lights, bell or buzzer sounds, or another indicator signal is activated.

44.3 For the factory production continuity testing of a cable, the manufacturer may elect to substitute a continuous eddy-current procedure complying with 44.4 and 44.5 for the test specified in 44.2.

44.4 The eddy-current test arrangement is to include equipment that complies with each of the following:

- a) The equipment is to apply current at one or several frequencies in the range of 1 – 125 kHz to a test coil for the purpose of inducing eddy currents in the conductors moving through the coil at production speed.
- b) The equipment is to detect the variation in impedance of the test coil caused by each break in one or more of the conductors.
- c) The equipment is to provide a visual indication to the operator.

44.5 The longitudinal axis of the cable is to be coincident with the electrical center of the test coil. The cable is to have little or no vibration as it passes through the test coil and is to clear the coil by a distance not greater than 1/2 inch or 13 mm. Variations in the speed of the cable through the test coil are to be limited to plus 50 percent and minus whatever percentage (50 percent maximum) keeps the signal amplitude from falling below the level at which a break can be detected. Separate calibration, balance, and adjustments for sensitivity, maximum signal-to-noise ratio, and maximum rejection of signals indicating gradual variations in diameter and other slow changes are to be made for each size, type of stranding, and conductor material. Calibration without any cable in the test coil is to be made at least daily to check whether the equipment is functioning. The temperature along the length of the cable being tested may vary from the temperature at which the equipment was calibrated, and so forth, for that size, type of stranding, and conductor material provided that the variations are gradual without hot or cold spots that cause false signals.

45 Spark Test

45.1 The spark test shall be performed by the manufacturer as a routine test at the factory on 100 percent of the finished wire in accordance with the Spark Test – Method, Section 900, and Spark Tests for Power-Limited Circuit Cable and for Cable for Power-Limited Fire-Alarm Circuits, Section 910 of UL 1581, and the method described in 45.2. The potential shall be 10 times the voltage rating of the wire, up to 1000 volts, with a minimum potential of 1500 volts. If the rated voltage is not specified, the potential shall be 3000 volts. For wire rated more than 1000 volts, the potential shall be two times the rated voltage with a minimum potential of 10,000 volts. The test potential for wire rated for direct current is specified in Table 45.1. Insulated conductors or the insulated conductors of a jacketed cable shall be tested. In the case of a jacketed cable, the insulated conductors shall be tested prior to the application of the overall jacket or covering.

45.2 The spark test shall be performed at a point in the production operation just prior to the wire being cut into shipping lengths.

45.3 Any faults shall be cut out or repaired. The insulation at points of repair shall be resparked. For 30-volt rated wire only, an insulated conductor that averages one fault maximum per 3000 feet (915 m) in any reel length of single insulated conductor complies with the intent of this requirement.

45.4 Wires rated 300 volts that comply with the requirements of Table 3.2 shall be spark tested at 1500 volts. Wires rated for 600 volts that comply with the requirements of Table 3.2 shall be spark tested at 2000 volts.

Table 45.1
Spark test potentials

Voltage rating	AWG sizes	Spark test potential
3 kV DC	All	7.5 kV DC or 3 kV AC
5 kV DC	All	12.5 kV DC or 5 kV AC
6 kV DC	All	15 kV DC or 6 kV AC
10 kV DC	All	25 kV DC or 10 kV AC
15 kV DC	All	37.5 kV DC or 12.5 kV AC
20 kV DC	All	50 kV DC or 15 kV AC
25 kV DC	All	62.5 kV DC or 17.5 kV AC
30 kV DC	All	75 kV DC or 20 kV AC
35 kV DC	All	87.5 kV DC or 22.5 kV AC
40 kV DC	All	100 kV DC or 25 kV AC
50 kV DC	All	125 kV DC or 30 kV AC
60 kV DC	All	150 kV DC or 35 kV AC

46 Production-Line Dielectric Test

46.1 The dielectric test shall be performed by the manufacturer on 100 percent of production where a metallic shield is placed over insulated conductors.

46.2 The insulation on the individual wires in the finished assembly shall be capable of withstanding at room temperature the test potential, without breakdown, stated in Table 28.1 applied between all interconnected conductors and all the interconnected shields. The test potential is to be supplied from a suitable 2 kVA or larger test transformer. The test potential is to be gradually increased from zero until the required test voltage is reached and is to be held at that value for one minute.

46.2 revised April 24, 2006

MARKINGS

47 Surface Marking of AWM

47.1 Surface marking is not required for appliance wiring material.

47.2 When surface marking referencing "AWM" is used, the marking shall contain the following elements:

a) Wire/cable designation: "AWM."

b) Name of the organization responsible for the AWM, trade name, other applicable mark, or file number. When the organization responsible for the AWM produces AWM in more than one location, an additional distinctive marking shall be provided that identifies the specific manufacturing location of the AWM.

Other markings such as wire size, number of conductors, and similar data, are determined to be in compliance with this requirement when they are not confusing or misleading.

47.3 For a cable that contains a conductive polymeric shield, the jacket or marker tape shall be marked "Conductive Shield," "Contains Polymeric Conductive Shield," or equivalent.

47.3 revised April 24, 2006

48 Markings on Tag, Reel, or Carton

48.1 Markings on the tag, reel, or carton are required for appliance wiring material (AWM). The markings shall be present on the smallest shipping unit of AWM. For AWM that is respooled from a single reel or spool to several smaller reels or spools, the tag information shall be duplicated and accompany the respooled wires on the smallest shipping unit.

48.2 Markings on the tag, reel, or carton shall contain the following elements:

a) Wire/cable designation: "AWM."

b) Statement that describes the intended use of the AWM [location of the wire (internal or external), the equipment in which the wire is intended to be used, and conditions to which the wire is exposed (i.e. gasoline, oil, gas vapor)], the temperature rating, and the minimum voltage rating of any insulated conductor used in the cable. Wires or cables meeting the requirements for -20, -30, -40, or -50°C as described in 22.1 shall be allowed to be marked at -20, -30, -40, or -50°C respectively.

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c) Name of the organization responsible for the AWM, trade name, other applicable mark or file number. When the organization responsible for the AWM produces AWM in more than one location, an additional distinctive marking shall be provided that identifies the specific manufacturing location of the AWM.

d) Size and quantity of conductors. The quantity and "AWG" or metric size in mm² of the conductors in a wire or cable shall be provided. Single conductor cables do not require the quantity of conductors. For a cable containing a mixture of sizes of individual or paired conductors, the size and quantity of each size conductor shall be provided (Example: 2/18 AWG and 4/24 AWG).

Exception: For AWM employing tinsel conductor, the words "Tinsel conductor" shall be marked and the size of the tinsel conductor shall be identified by its maximum DC resistance at a particular temperature (Example: Maximum ____ ohm/feet at ____ °C).

e) Conductor material.

Exception: Conductor material marking is not required for unalloyed copper which is at least 97 percent unalloyed copper as referenced in IACS (International Annealed Copper Standard.)

f) The conductivity of the conductor in percent of unalloyed copper. Reference IACS (International Annealed Copper Standard).

Exception: Not applicable for minimum 97 percent IACS unalloyed copper, or 61 percent IACS aluminum, or tinsel conductor.

g) Insulation and jacket material and average wall thickness (example: Insulation SRPVC 0.009 inch; Jacket: PVC 0.030 inch). If more than one jacket is required, all materials and thicknesses shall be marked.

h) Date of manufacture by month and year. As an option, the date code may be printed on the cable.

i) For a cable that contains one or more optical fibers, the following statement or equivalent:

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

j) For a cable that contains one or more optical fiber members, or group of such members, having a metal or other electrically conductive part, the following statement or equivalent:

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

k) For a cable that contains a conductive polymeric shield, the following wording or equivalent shall be included on the tag: "Conductive shield" or "Contains Polymeric Conductive Shield."

In addition to the markings noted above, a cable that contains other markings complies with the intent of this requirement as long as they are not confusing or misleading.

Effective date for 48.2 (b), (d), (e), and (f) changed from October 1, 2014 to October 1, 2015

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49 Multiple Markings

49.1 In addition to complying with the requirements for one of the cable types in these requirements, a cable may comply with the requirements for one or more of the following:

- a) One or more of the types described in the National Electrical Code (NEC) (example: Type CM communications cable, Type SJT flexible cord, Type MTW machine tool wire).
- b) One or more of the Canadian wire types (example: Type TR-64 radio lead wire, Type TEW equipment wire, etc.) for Canadian Electrical Code (CEC) types.
- c) One or more of the European wire types (example: HO5VV-F cord).
- d) One or more of the Military Specification (Mil Spec) wire designations (example: RG-59/U coaxial cable).

49.2 A cable that complies with the multiple requirements as specified in 49.1 may be constructed so the identifiers for the additional wire types, as well as the voltage, temperature, and other required associated designations, are marked on the surface and tag, reel, or carton of the product. The sequence of the markings is not specified; however, each rating and associated designation:

- a) Shall be clearly tied to the specific cable type to which it applies.
- b) Shall be clearly separated from all of the other cables types and varieties indicated.

49.3 On a cable surface marking, the types and varieties and their associated designations shall be separated from one another by the word "or," a long dash, or a minimum 1/4 inch wide space.

49.4 On a cable tag, reel, or carton marking, types and varieties and their associated designations shall be separated from one another by being placed in separate statements. Each statement shall end in a period and shall appear together with its applicable designations.

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**Superseded requirements for
the Standard for
Appliance Wiring Material**

UL 758, Second Edition

The requirements shown are the current requirements that have been superseded by requirements in revisions issued for this Standard. To retain the current requirements, do not discard the following requirements until the future effective dates are reached.

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) 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.

5.3.2 Tinsel conductors may be used when they have been successfully evaluated for the particular use. Tinsel conductor requirements, including maximum temperature use, size, and construction, shall be in accordance with the requirements in the Standard for Flexible Cord and Fixture Wire, UL 62.

5.6.1 Conductor resistance shall be equal to or less than the maximum resistance values according to D-C 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; and the Standard Specification for Fine-Wire Bunch-Stranded and Rope-Lay Bunch-Stranded Copper Conductors for Use as Electrical Conductors, ASTM B738 for conductors smaller than 30 AWG.

**Table 7.1
Index to insulations and jackets**

Materials	Temperature rating	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	75	50.30	Insulation only
CPE	75	50.34	Jacket
CPE	90	50.23	–
CPE	105	50.33	–
ECTFE	150	50.63	–
EP	90	50.55	Insulation only. Covering required, or not subject to mechanical abuse.
EP	105	50.55	Insulation only. Covering required, or not subject to mechanical abuse.
EPCV	90	50.62	–
EPDM	60	50.24	–
EPDM	75	50.54	–
EPDM	90	50.52	–
ETFE	150	50.63	–
ETFE	200	50.64	–

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Table 7.1 Continued

Materials	Temperature rating	Applicable table of physical properties in UL 1581	Notes
FEP	150	50.73	–
FEP	200	50.70	–
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	–
NBR/PVC	75	50.97	–
NBR/PVC	90	50.23	–
Neoprene	60	50.120	–
Neoprene	60	50.122	–
Neoprene	75	50.123	–
Neoprene	90	50.125	–
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	–
PVDF	125	50.185	–
PVDF	150	50.185	–
SBR/NR	60	50.195	–
SBR/NR	75	50.199	–
SR	150	50.210	Insulation only. Covering required, or not subject to mechanical abuse.
SR	200	50.210	Insulation only. Covering required, or not subject to mechanical abuse.
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	–
TPES	75	50.226	–
TPES	80	50.226	–
TPU	60	50.227	–
TPU	75	50.227	–

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Table 7.1 Continued

Materials	Temperature rating	Applicable table of physical properties in UL 1581	Notes
TPU	80	50.227	–
XL	75	50.231	–
XL	90	50.231	–
XL	105	50.245	–
XLPO	105	50.233	–
XLPO	125	50.232	–
XLPO	150	50.232	–

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.

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	0.401 – 0.700 inch	0.701 – 1.00 inch	1.01 – 1.500 inches	1.501 – 2.500 inches
		(0 – 10.16 mm)	(10.17 – 17.78 mm)	(17.79 – 25.40 mm)	(25.41 – 38.10 mm)	(38.11 1 – 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)		N/A
	Minimum thickness at any point	0.020 inch (0.51 mm)	0.024 inch (0.61 mm)	0.036 inch (0.91 mm)		N/A
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)		N/A
	Minimum thickness at any point	0.004 inch (0.01 mm)	0.004 inch (0.01 mm)	0.008 inch (0.02 mm)		N/A
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 $1.1284 \times (TW)^{\frac{1}{2}}$ 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	0.251 – 0.350 inch	0.351 – 0.500 inch	0.501 – 0.700 inch	0.701 – 1.500 inches	1.501 – 2.500 inches
		(0 – 6.36 mm)	(6.37 – 8.91 mm)	(8.92 – 12.72 mm)	(12.73 – 17.80 mm)	(17.81 – 38.10 mm)	(38.11 – 63.50 mm)
30 – 600 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)	N/A
	Minimum thickness at any point	0.006 inch (0.46 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)	N/A
^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.							

13.3.2 In some cases, the use of a jacket that is other than indicated in Tables 13.1 – 13.3 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. Crush, impact, abrasion, and other tests may be necessary to evaluate jackets thinner than indicated in Tables 13.1 – 13.3.

18.1 Only bare 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 the physical properties requirements for the specific material and its associated temperature rating in Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14. 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.

19.1 Only thermoplastic elastomer (TPE), thermoplastics (except for fluoropolymers) 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 are to be tested in the same manner as jackets. Bonded constructions are to be separated and tested in the same manner as insulation. Foamed insulation material which is intended to be the outermost layer of the wire construction shall be tested.

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, mPPE-PE	Insulation	30 – 21 20 – 12 10 – 7	250 400 ^a 500	2.45 3.92 ^a 4.90	100.0 ±1.0 (212.0 ±1.8)	50
	Any separable jacket	–	2000 ^b	19.61 ^b	100.0 ±1.0 (212.0 ±1.8)	50
PVC, SRPVC, PU, TPES, mPPE,	Insulation or integral insulation and jacket	30 – 21 20 – 12 10 – 7 6 – 1 1/0 – 4/0	250 400 ^a 500 1600 2000	2.45 3.93 ^a 4.90 9.80 19.61	121.0 ±1.0 (249.8 ±1.8)	50
	Any separable jacket	–	2000 ^b	19.61 ^b	121.0 ±1.0 (249.8 ±1.8)	50
TPE	Insulation	30 – 21 20 – 12 10 – 7	250 400 ^a 500	2.45 3.92 ^a 4.90	150.0 ±1.0 (302.0 ±1.8)	50
	Any separable jacket	–	2000 ^b	19.61 ^b	150.0 ±1.0 (302.0 ±1.8)	50
XLPO XL	Insulation or integral insulation and jacket	30 – 21 20 – 12 10 – 7 6 – 1 1/0 – 4/0	250 400 ^a 500 1600 2000	2.45 3.92 ^a 4.90 9.30 19.61	121.0 ±1.0 (249.8 ±1.8)	50
	Any separable jacket	–	2000 ^b	19.61 ^b	121.0 ±1.0 (249.8 ±1.8)	50

^a For wall thickness less than 30 mils, 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 conductor or solid steel 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 identical to the load assigned to the conductor size (AWG) specified in this table.

22.1 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. 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 for minimum 180 degrees. Insulated conductors as well as the finished cable are to be tested separately.

26.1 Printing on the surface of the finished wire shall remain legible after being subjected to the test described in the Durability of Indelible-Ink Printing Test, Section 1690 of UL 1581.

34.1 The finished insulated conductor (any jacket, shield, and covering removed) shall have an insulation resistance value of greater than 2.5 megohms based on 1000 feet (0.75 megohm based on one kilometer) of conductor. The test is to be conducted in accordance with Insulation-Resistance Test in Water, Section 920 of UL 1581.

35.1 The finished wire that is rated for water resistance shall have an insulation resistance in tap water that is not less than indicated in the applicable formulas specified below at any time during immersion. The tap water is to have a temperature of either $50 \pm 1.0^{\circ}\text{C}$ ($122 \pm 1.8^{\circ}\text{F}$) or $75 \pm 1.0^{\circ}\text{C}$ ($167 \pm 1.8^{\circ}\text{F}$) or $90 \pm 1.0^{\circ}\text{C}$ ($194 \pm 1.8^{\circ}\text{F}$), or $100 \pm 1.0^{\circ}\text{C}$ ($212 \pm 1.8^{\circ}\text{F}$). The period of immersion is:

- a) 12 weeks or more when the insulation resistance throughout the last six weeks of the period is greater than 10 megohms based on 1000 conductor feet (3 megohms based on a conductor kilometer),
- b) 24 – 36 weeks when the insulation resistance is less than 10 megohms based on 1000 conductor feet and more than the value indicated in the applicable formulas below (3 megohms based on a conductor kilometer and more than the value indicated in the applicable formulas).

A sinusoidal rms 50 or 60 Hz potential equal to the voltage rating of the insulation is to be applied at all times other than while readings of insulation resistance are being taken. See 36.4 for the requirement covering the maximum rate of decrease of the insulation resistance.

37.1 The insulation (jacket, shield, and other coverings removed) on a wire rated for 60°C (140°F) water resistance is to have the following inductive capacity and capacitance values when specimens are tested with 1000 Hz sinusoidal current in tap water in accordance with Capacitance and Relative Permittivity Test, Section 1020 of UL 1581:

- a) The specific inductive capacity (relative permittivity or dielectric constant) determined after immersion of the specimens for 24 hours shall be 10 or less.
- b) The capacitance determined after immersion for 14 days shall not be more than 10 percent higher than the capacitance after the 24-hour immersion.
- c) The capacitance determined after immersion for 14 days shall not be more than 5 percent higher than the capacitance determined after immersion for 7 days.

37.2 The insulation (jacket, shield, and other coverings removed) on a wire rated for 75°C (167°F) water resistance shall have the following specific inductive capacity and capacitance values when specimens are tested with 1000 Hz sinusoidal current in accordance with Capacitance and Relative Permittivity Test, Section 1020 of UL 1581:

- a) The specific inductive capacity (relative permittivity or dielectric constant) determined after immersion of the specimens for 24 hours shall be 10 or less.
- b) The capacitance determined after immersion for 14 days shall not be more than 10 percent higher than the capacitance after the 24-hour immersion.
- c) The capacitance determined after immersion for 14 days shall not be more than 5 percent higher than the capacitance determined after immersion for 7 days.

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48.2 Markings on the tag, reel, or carton shall contain the following elements:

- a) Wire/cable designation: "AWM."
- b) Statement that describes the intended use of the AWM [location of the wire (internal or external), the equipment in which the wire is intended to be used, and conditions to which the wire is exposed (i.e. gasoline, oil, gas vapor)], the temperature rating, and the minimum voltage rating of any insulated conductor used in the cable.
- c) Name of the organization responsible for the AWM, trade name, other applicable mark or file number. When the organization responsible for the AWM produces AWM in more than one location, an additional distinctive marking shall be provided that identifies the specific manufacturing location of the AWM.
- d) Size and quantity of conductors. The quantity and "AWG" or metric size in mm² of the conductors in a wire or cable shall be provided. Single conductor cables do not require the quantity of conductors. For a cable containing a mixture of sizes of individual or paired conductors, the size and quantity of each size conductor shall be provided (Example: 2/18 AWG and 4/24 AWG).
- e) Conductor material.

Exception: Conductor material marking is not required for unalloyed copper.

- f) The conductivity of the conductor in percent of unalloyed copper. Reference IACS (International Annealed Copper Standard).

Exception: Not applicable for unalloyed copper or 61 percent IACS aluminum.

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g) Insulation and jacket material and average wall thickness (example: Insulation SRPVC 0.009 inch; Jacket: PVC 0.030 inch). If more than one jacket is required, all materials and thicknesses shall be marked.

h) Date of manufacture by month and year. As an option, the date code may be printed on the cable.

i) For a cable that contains one or more optical fibers, the following statement or equivalent:

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

j) For a cable that contains one or more optical fiber members, or group of such members, having a metal or other electrically conductive part, the following statement or equivalent:

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

k) For a cable that contains a conductive polymeric shield, the following wording or equivalent shall be included on the tag: "Conductive shield" or "Contains Polymeric Conductive Shield."

In addition to the markings noted above, a cable that contains other markings complies with the intent of this requirement as long as they are not confusing or misleading.

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