

UL 758

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Appliance Wiring Material

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

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Page	Date
1-66	July 14, 2000

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1

UL 758

Standard for Appliance Wiring Material

First Edition

July 14, 2000

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

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

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FOREWORD

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

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

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

D. A product employing materials or having forms of construction which conflict with specific requirements of the Standard cannot be judged to comply with the Standard. A product employing materials or having forms of construction not addressed by this Standard may be examined and tested according to the intent of the requirements and, if found to meet the intent of this Standard, may be judged to comply with the Standard.

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

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

INTRODUCTION

1 Scope

1 effective July 14, 2005

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

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

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

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

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

1.6 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.

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

2 General

2 effective July 14, 2005

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
W60C (60°C Wet)	0.030	0.76	PVC insulation rated for use in Type TW thermoplastic-insulated wire
W60C or W75C (60°C or 75°C Wet)	0.030	0.76	PVC insulated rated for use in Types THW or THHW thermoplastic-insulated wire
W60C or W75C (60°C or 75°C Wet)	0.015	0.38	PVC insulation rated for use in Type THWN thermoplastic-insulated wire
W60C, W75C or W90C (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.

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 Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

CONSTRUCTION

3 General

3 effective July 14, 2005

3.1 A coding system and definitions for each rating and use parameter used to help determine the acceptability of an AWM for a specific end-product use are located in Tables 3.1 and 3.2 respectively.

**Table 3.1
Rating and use codes^a**

Use rating	Mechanical rating	Dry location temperature rating ^f	Voltage rating ^d	Flame ratings ^e	Special ratings (one or more)
I – Internal wiring ^b	A – Not evaluated	Rating expressed in °C. Minimum temperature rating is 60°C.	Voltage rating expressed in volts (V), kilovolts (kV) or direct current kilovolts (kV DC). Minimum voltage rating is 30 V. OF – Cables containing optical fiber members only VM – Cables containing insulated conductors of mixed voltage ratings; see tag markings	H – Horizontal flame test	O60C – Oil 60°C
II – External wiring ^c	B – Normal handling			V – Vertical flame test	O75C – Oil 75°C
F – Further processing only in AWM cables	C – Special use, see tag markings			VW-1 – Vertical wire flame test	O80C – Oil 80°C
S – Special applications, see tag marking				FT1	W60C – Wet 60°C
				FT2	W75C – Wet 75°C
				NR	W90C – Wet 90°C G – Gasoline resistant SUN RES – Sunlight resistant. OFM – Cable contains optical fiber members in addition to electrical conductors. SHIELDED – (Not required). Marking for AWM using one or more shields.

Table 3.1 Continued on Next Page

Table 3.1 Continued

Use rating	Mechanical rating	Dry location temperature rating ^f	Voltage rating ^d	Flame ratings ^e	Special ratings (one or more)
					TAG – See tag markings.
<p>^a Example of code: "I B 80C 300V VW-1 O60C." ^b AWM Use Rating I may be used in Use Rating F applications. ^c AWM Use Rating II may be used in Use Rating I and Use Rating F applications. ^d Volts AC rms unless specified otherwise. Refer to Table 45.1 for applicable ratings. ^e One or more ratings may apply. ^f Refer to Table 7.3 for acceptable ratings.</p>					

Table 3.2
Ratings and use code definitions

Use ratings	
I	Internal wiring – Totally enclosed by equipment enclosure or equivalent. Not required to use a protective integral or nonintegral jacket. Flame Rating H is required. Also suitable for Use Rating F applications.
II	External wiring – Partially or totally exposed from the equipment. Includes interconnecting wires and cables. Required to use a protective integral or nonintegral jacket. Flame Rating V is required. Also suitable for Use Rating I and Use Rating F applications.
F	For further processing – Only intended to be processed into Use Rating I, II, or S appliance wiring material.
S	Wiring for special applications – Intended to be installed in a special application with the possibility of being evaluated for special ratings or waiving certain construction and performance requirements of general internal (I) or external (II) use AWM. Special applications use are required to be marked on the tag or spool of the finished AWM.
Mechanical ratings	
A	Not evaluated
B	Evaluated for normal handling (See 7.3.1.3).
C	Additional use; see tag marking
Dry temperature ratings	
__°C	The dry temperature rating is expressed in °C. Minimum dry temperature rating of AWM is 60°C. For AWM composed entirely of optical fiber members, cable coverings and jacket are evaluated for a temperature rating.
Voltage ratings	
OF	Composed entirely of optical fiber members.
__V, __kV, __kV DC	Voltage rating expressed in volts (V), kilovolts (kV) or direct current kilovolts (kV DC). Minimum operating AC voltage rating of all electrical AWM wires and cables is 30 volts. Peak AC voltages are limited to the effective DC voltage.
VM	Multiple conductor cables composed of conductors with mixed voltage ratings. See tag marking.
Flame ratings	
H	Horizontal
V	Vertical
VW-1	VW-1
FT1	FT-1
FT2	FT-2
NR	Not flame rated
Special ratings – not required (one or more may be used)	

Table 3.2 Continued on Next Page

Table 3.2 Continued

O60C	Oil rated for 60°C – Insulation is rated for exposure to oil at 60°C. When only the jacket or the insulation and jacket of jacketed cable is oil rated at 60°C, it must be noted on the spool or tag. In this case the code must also include Special Rating S.
O75C	Oil rated for 75°C – Insulation is rated for exposure to oil at 75°C. When only the jacket or the insulation and jacket of jacketed cable is oil rated at 75°C, it must be noted on the tag markings. In this case the code must also include Special Rating S.
O80C	Oil rated for 80°C – Insulation is rated for prolonged exposure to oil at 80°C. When only the jacket or the insulation and jacket of jacketed cable is oil rated at 80°C, it must be noted on the tag markings. In this case the code must also include Special Rating S.
W60C	Wet rated for 60°C – Insulation is rated for continuous immersion in water at 60°C.
W75C	Wet rated for 75°C – Insulation is rated for continuous immersion in water at 75°C.
W90C	Wet rated for 90°C – Insulation is rated for continuous immersion in water at 90°C.
G	Gasoline resistant – Finished AWM is rated for continuous immersion in gasoline at room temperature.
“SUN RES” or “SUNLIGHT RESISTANT”	Outermost insulation, covering, or jacket is rated for continuous exposure to sunlight.
OFM	Indicates that the AWM contains optical fibers members in addition to electrical conductors.
SHIELDED	Not required – Marking to indicate that a finished AWM contains one or more electrical shields.
Special ratings – not required unless otherwise specified (one or more may be used)	
TAG	<p>Special ratings. See tag for use, or intended applications. Indicates AWM evaluated for a specific voltage or use defined in the tag marking. It is possible that the specific use requires additional tests that are different than those outlined in this Standard, or waive tests outlined in the Standard, or both based on the end use application.</p> <p>Examples of special uses, ratings, and intended applications.</p> <ol style="list-style-type: none"> 1) “AWM similar to Type (insert Listed wire type and category: SVT Flexible Cord, CM Communications Cable, etc.) except (insert exception to requirements) – This Construction Was Evaluated to the Test Requirements in the UL Standard (insert UL Standard number and title: UL 62, Flexible Cord and Fixture Wire, etc.)” 2) “Telephone Handset Cord” – Flame Rating H is required, even though it is an external use cable. 3) “Hermetically-Sealed Wiring” – This construction waives all flame test requirements. 4) “Television High Voltage Wire” – Intended for insulation in television equipment. Flame rating VW-1 is required. 5) “X-Ray Cable” – This construction is permitted to use mixed voltage rated conductors under a common jacket.

3.2 Tables 3.3 – 3.9 serve as indices to requirements for construction details and basic test methods for typical AWM constructions.

Table 3.3
Single or multiple conductor with extruded insulation

Uses:	I, II, F, S
Ratings:	Table 3.1
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 46, and Markings on Tag, Reel or Carton, Section 47
<p>Basic tests:</p> <p>Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14</p> <p>Conductor Corrosion Test, Section 18</p> <p>Deformation Test (Thermoplastics and Class XL Only), Section 19</p> <p>Flexibility Test After Air Oven Conditioning, Section 20</p> <p>Heat Shock Test (Thermoplastic Materials Only), Section 21</p> <p>Cold Bend Test, Section 22</p> <p>Crush Resistance Test (Mechanical Abuse Rating B), Section 26</p> <p>Dielectric Test, Method I, Section 28</p> <p>Dielectric Test, Method II, Section 29</p> <p>Dielectric Test, Method III, Section 30</p> <p>Horizontal Flame Test for Use Rating I, Section 39</p> <p>Elective tests/ratings: See Table 3.9</p>	

Table 3.4
Single conductor with other-than-extruded insulation

Uses:	I, II, F, S
Ratings:	Table 3.1
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 46, and Markings on Tag, Reel or Carton, Section 47
<p>Basic tests:</p> <p>Conductor Corrosion Test, Section 18</p> <p>Flexibility Test After Air Oven Conditioning, Section 20</p> <p>Cold Bend Test, Section 22</p> <p>Conductor Resistance Test, Section 27</p> <p>Dielectric Test, Method I, Section 28</p> <p>Dielectric Test, Method II, Section 29</p> <p>Horizontal Flame Test for Use Rating I, Section 39</p>	

Table 3.4 Continued on Next Page

Table 3.4 Continued

Vertical Flame Test for Use Rating II, Section 40
Elective tests/ratings: See Table 3.9

**Table 3.5
Parallel cable with extruded integral insulation and jacket**

Uses:	I, II, S
Ratings:	Table 3.1
Conductors:	
Material	See Conductor, Section 5
Size	See Conductor, Section 5
Integral insulation and jacket:	
Material	See Insulation, Section 7
Thickness	See Insulation, Section 7
Markings:	See Surface Marking of AWM, Section 46, and Markings on Tag, Reel or Carton, Section 47
<p>Basic tests:</p> <p>Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14 – Test insulation only.</p> <p>Conductor Corrosion Test, Section 18</p> <p>Deformation Test (Thermoplastics and Class XL Only), Section 19</p> <p>Flexibility Test After Air Oven Conditioning, Section 20</p> <p>Heat Shock Test (Thermoplastic Materials Only), Section 21</p> <p>Cold Bend Test, Section 22</p> <p>Conductor Resistance Test, Section 27</p> <p>Dielectric Test, Method I, Section 28</p> <p>Dielectric Test, Method II, Section 29</p> <p>Dielectric Test, Method III, Section 30</p> <p>Horizontal Flame Test for Use Rating I, Section 39</p> <p>Vertical Flame Test for Use Rating II, Section 40</p> <p>Elective tests/ratings: See Table 3.9</p>	

**Table 3.6
Multiple-conductor cable using non-integral jacket**

Uses:	I, II, S
Ratings:	Table 3.1
Conductors:	
Material	See Conductor, Section 5
Size	See Conductor, Section 5
Insulated conductors:	<p>See Insulation, Section 7</p> <p>The voltage and temperature rating of the cable shall not exceed the lowest rating of either the insulated conductors or the fiber optic members.</p> <p>Cables designated mechanical Rating B shall use only insulated conductors that are designated mechanical Rating B.</p> <p>Cables with wet ratings W60C, W75C, and W90C shall use insulated conductors that comply with the applicable wet rating.</p> <p>Cables composed entirely of optical fiber members shall be designated with voltage Rating OF.</p>
Covering:	
Material	See Coverings, Section 8
Shield:	See Shield(s), Section 11

Table 3.6 Continued on Next Page

Table 3.6 Continued

Jacket:	
Material	See Overall Jacket, Section 13
Thickness	See Overall Jacket, Section 13
Markings:	See Surface Marking of AWM, Section 46, and Markings on Tag, Reel, or Carton, Section 47
Basic tests:	
Insulated conductors tested in accordance with Tables 3.3, 3.4, 3.5, or 3.7.	
Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14	
Deformation Test (Thermoplastics and Class XL Only), Section 19	
Flexibility Test After Air Oven Conditioning, Section 20	
Heat Shock Test (Thermoplastic Materials Only), Section 21	
Cold Bend Test, Section 22	
Horizontal Flame Test for Use Rating I, Section 39	
Vertical Flame Test for Use Rating II, Section 40	
Elective tests/ratings:	See Table 3.9

Table 3.7
Bonded or laminated flat ribbon cable

Uses:	I, F, S
Ratings:	Table 3.1
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 46, and Markings on Tag, Reel, or Carton, Section 47
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 After Air Oven Conditioning, Section 20	
Heat Shock Test (Thermoplastic Materials Only), Section 21	
Cold Bend Test, Section 22	
Delamination Test (Laminated Constructions Only), Section 23	
Conductor 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 Use Rating I, Section 39	
Elective tests/ratings:	See Table 3.9

**Table 3.8
High voltage DC wire with extruded insulation**

Uses:	I, II, F, S
Ratings:	Table 3.1
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 46, and Markings on Tag, Reel, or Carton, Section 47
<p>Basic tests:</p> <ul style="list-style-type: none"> Physical Properties of Insulation and Jacket, Unaged and Air Oven Aged, Section 14 – Test insulation only Conductor Corrosion Test, Section 18 Deformation Test (Thermoplastics and Class XL Only), Section 19 Flexibility Test After Air Oven Conditioning, Section 20 Heat Shock Test, Section 21 Shrinkback Test – Special Rating TV Wires Only, Section 24 Ozone Resistance Test – Special Rating TV Use Wires Only, Section 25 Conductor Resistance Test, Section 27 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 Use Rating I, Section 39 Vertical Flame Test for Use Rating II, Section 40 VW-1 Flame Test (required for TV wire), Section 41 <p>Elective tests/ratings: See Table 3.9</p>	

**Table 3.9
Elective tests and ratings**

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 (Mechanical Abuse Rating B), Section 26
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

Table 3.9 Continued on Next Page

Table 3.9 Continued

	<p>Capacitance and Relative Permittivity Tests (Wet Rated AWM), Section 37</p> <p>Short Term Insulation-Resistance Test in Water at Room Temperature (Wet Rated AWM), Section 34, required for all wet rated wires.</p> <p>Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 35, at 50°C required for wires rated W60C.</p> <p>Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 35, at 75°C required for wires rated W75C.</p> <p>Long Term Insulation-Resistance Test in Water at Elevated Temperature (Wet Rated AWM), Section 35, at 90°C required for wires rated W90C.</p>
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4 Materials

4 effective July 14, 2005

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 effective July 14, 2005

5.1 General

5.1.1 A conductor consisting of a single wire is designated as a solid conductor, while one consisting of a number of individual wires is designated as a stranded conductor. The American Wire Gauge (AWG) numbers, the kcmil (thousands of circular mils) sizes, and the square-millimeter sizes each signify a definite nominal total cross-sectional area (see Table 5.1) 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.

**Table 5.1
Conductor dimensions**

Size of conductor, AWG	Diameter of solid conductor				Cross-sectional area of stranded conductor			
	Nominal,		Minimum,		Nominal,		Minimum,	
	Mils	(mm)	Mils	(mm)	Cmils	(mm ²)	Cmils	(mm ²)
50	0.99	0.0251	0.98	0.025	0.980	0.000497	0.960	0.000486
49	1.11	0.0282	1.10	0.028	1.23	0.000624	1.21	0.000613
48	1.24	0.0315	1.23	0.031	1.54	0.000768	1.51	0.000765
47	1.40	0.0356	1.39	0.035	1.96	0.000993	1.92	0.000973
46	1.57	0.0399	1.55	0.029	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	0.244	79.2	0.0401	77.6	0.0393
30	10.0	0.254	9.9	0.251	100	0.0507	98	0.0497
29	11.3	0.287	11.2	0.284	128	0.0647	125	0.0633
28	12.6	0.320	12.5	0.318	159	0.0804	156	0.0790
27	14.2	0.361	14.1	0.358	202	0.102	198	0.100
26	15.9	0.404	15.7	0.399	253	0.128	248	0.126
25	17.9	0.455	17.7	0.450	320	0.162	314	0.159
24	20.1	0.511	19.9	0.506	404	0.205	396	0.201
23	22.6	0.574	22.4	0.568	511	0.259	501	0.254
22	25.3	0.643	25.0	0.637	640	0.324	627	0.318
21	28.5	0.724	28.2	0.717	812	0.412	796	0.404
20	32.0	0.813	31.7	0.805	1020	0.519	1000	0.509
19	35.9	0.912	35.6	0.904	1290	0.653	1264	0.641
18	40.3	1.02	40.0	1.016	1620	0.823	1588	0.807
17	45.3	1.15	44.9	1.140	2050	1.04	2009	1.02
16	50.8	1.29	50.3	1.278	2580	1.31	2528	1.28
15	57.1	1.45	56.5	1.435	3260	1.65	3195	1.62
14	64.1	1.63	63.5	1.613	4110	2.08	4028	2.04
13	72.0	1.83	71	1.81	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	2.28	8230	4.17	8065	4.09
10	101.9	2.588	101	2.56	10380	5.261	10172	5.16
9	114.4	2.906	113	2.88	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	4.07	26240	13.30	25715	13.03

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)
5	181.9	4.620	180	4.57	33090	16.77	32428	16.43
4	204.3	5.189	202	5.14	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	7.27	83690	42.41	82016	41.56
1/0	324.9	8.252	322	8.17	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	10.30	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**

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, 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	450 (842)	
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
Copper alloy, annealed, less than 0.015 inch (0.38 mm) diameter		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), 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)	

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-clad aluminum, annealed or hard-drawn, 6530 circular mils or 3.31 mm ² (No. 12 AWG) and larger	ASTM B 566	90 (194)	Class 10A
Copper-clad steel less than 0.015 inch (0.38 mm) in diameter	ANSI/ASTM 452	150 (302)	Minimum conductivity of 30 percent IACS ^a
Copper-clad steel at least 0.015 inch (0.38 mm) in diameter	ANSI/ASTM 452	200 (392)	Minimum conductivity of 30 percent IACS ^a
Copper-clad steel, silver-coated	ANSI/ASTM 501	200 (392)	Minimum conductivity of 30 percent IACS ^a
Aluminum, 6,530 – 16,510 circular mils or 3.31 – 8.367 mm ² (Nos. 12 – 8 AWG), solid	ANSI/ASTM B800	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, 26,240 – 211,600 circular mils or 13.30 – 107.2 mm ² (Nos. 6 – 4/0 AWG), solid 1/2 or 3/4 hard; or Aluminum, 6530 circular mils or 3.31 mm ² (No. 12 AWG) and larger, stranded, 1/2, 3/4, or hard:		90 (194)	
Aluminum, 3/4 hard	ANSI/ASTM B 609	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
Aluminum, 1/2 hard	ANSI/ASTM B 609	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
Aluminum, hard	ANSI/ASTM B 609	90 (194)	
Stainless steel		250 (482)	
Nickel-plated iron		250 (482)	
Nickel, alloy		450 (842)	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		450 (842)	

^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 26, of UL 1581.

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 and construction, shall be in accordance with the requirements in the Standard for Flexible Cord and Fixture Wire, UL 62.

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:

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

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, 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, 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 The direct-current resistance of any length of insulated conductor in ohms per thousand conductor feet or in ohms per conductor kilometer shall not be higher than the maximum (nominal x 1.02) indicated in D-C Conductor Resistance, Section 30 of UL 1581 at 20°C (68°F) or at 25°C (77°F) when measured as described in the Conductor Resistance Test, Section 27.

5.6.2 For conductors that are in lengths other than those specified in 5.6.1, the resistance shall be calculated by referring to the latest issue of the applicable ASTM Standard referenced in Table 5.2.

5.6.3 For conductors having a conductivity other than 100 percent, 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 No. 12 AWG (6530 cmil or 3.31 mm²) solid 40-percent-conductivity copper-clad steel conductor:

a) $R[\text{No. 12 AWG copper-clad steel at } 20^{\circ}\text{C (68}^{\circ}\text{F)}] = R(\text{No. 12 AWG copper at } 20^{\circ}\text{C}) \times 100/40$
 $= R(\text{No. 12 AWG copper at } 20^{\circ}\text{C or } 68^{\circ}\text{F}) \times 2.5.$

b) $R[\text{No. 12 AWG copper at } 20^{\circ}\text{C (68}^{\circ}\text{F)}] = 1.62 \text{ ohms/1000 feet or } 5.31 \text{ ohms/1000 kilometer.}$

c) $R[\text{No. 12 AWG copper-clad at } 20^{\circ}\text{C (68}^{\circ}\text{F)}] = 1.62 \times 2.5 = 4.05 \text{ ohms/1000 feet or } 5.31 \times 2.5 = 13.28 \text{ ohms-kilometer.}$

5.6.4 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 – 5.7.6.

5.7.2 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.

5.7.3 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, Table 210.2 of UL 1581 other than compact stranding or single-bunch bunch-stranding shall comply with 5.7.5 or 5.7.6 as applicable. The direction of lay of the outer layer shall be left-hand in all cases.

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

5.7.4 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 reshaped 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 No. 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 No. 50 – 2 AWG conductor shall be 8.0 – 17.5 times the overall diameter of that layer.

5.7.5 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

5.7.6 Every stranded conductor covered in Percentage increase (k) in weight for type of strands, Table 210.2 of UL 1581 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 No. 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 No. 30 AWG or smaller conductors;
 - 2) 30 times the outside diameter of the conductor for No. 29 – No. 15 AWG conductors;
 - 3) 20 times the outside diameter of the conductor for No. 14 – No. 6 AWG conductors; and
 - 4) 16 times the outside diameter of the conductor for No. 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.

5.8 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 effective July 14, 2005

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 the 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 effective July 14, 2005

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.

7.2 Materials

7.2.1 Specimens of solid single layered extruded insulations and each layer of 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 7.1 and 7.2, or any of the materials described in Specific Materials, Section 50 of UL 1581. 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.

Table 7.1
Physical properties, unaged, of materials used for insulation and jacket

Polymer designation	Polymer type/test speed	Physical properties, unaged	
		Minimum average	
		Elongation, percent	Tensile strength, psi (Kgf/mm ²)
MFA – Methylfluoroalkoxy	Thermoplastic/20 ±2 inches per minute	200	2500 (1.76)
PU – Polyurethane	Thermoplastic/20 ±2 inches per minute	100	1500 (1.05)
TPES – Thermoplastic polyester	Thermoplastic/20 ±2 inches per minute	100	1500 (1.05)

Table 7.2
Physical properties, air oven aged, of insulation and jackets

Polymer designation	Dry temperature rating, °C (°F)	Physical properties, air oven aged			
		Air oven conditioning		Minimum percent of unaged values	
		Oven temperature, °C ±2 (°F ±3)	Time, days	Elongation, percent	Tensile strength, percent
MFA – Methylfluoroalkoxy	200 (392)	260 (500)	4	85	85
	250 (482)	287 (549)	7	85	85
	PU – Polyurethane	60 (140)	100 (212)	7	65 ^a
75 (167)		100 (212)	10	65 ^a	70
80 (176)		113 (235)	7	65 ^a	70
TPES – Thermoplastic polyester	60 (140)	100 (212)	7	65	70
	75 (167)	100 (212)	10	65	70
	80 (176)	113 (235)	7	65	70

^a 45 percent elongation for die-cut specimens complies with the intent of this requirement.

7.2.2 Foamed and foam/skin insulation and non-extruded insulations shall be evaluated in accordance with the Flexibility Test After Oven Conditioning, Section 20.

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

7.3 Thickness

7.3.1 Average thickness and minimum thickness at any point

7.3.1.1 Measurements from which the average thickness is to be determined shall be made in accordance with Thicknesses of Insulation on Thermoplastic- and Thermoset-Insulated Wires and Cable, Section 240 of UL 1581.

7.3.1.2 The minimum thickness at any point shall be at least 90 percent of the average thickness, rounded to the nearest 0.001 inch (0.025 mm).

7.3.1.3 For wires with extruded insulation with the mechanical abuse Rating B, the thicknesses shown in Tables 7.4 – 7.6 apply. Thinner thicknesses or non-extruded insulators may be evaluated for a B rating by subjecting the wires to the Crush Resistance Test (Mechanical Abuse Rating B), Section 26.

Table 7.3
Aging conditions for non-extruded 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

Table 7.4
Thickness requirements for extruded, non-fluoropolymer insulation materials

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,	
		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)	a	a
30 – 25	0.05 – 0.1	0.006 (0.15)	0.005 (0.13)	0.012 (0.30)	0.011 (0.28)	0.012 (0.30)	0.011 (0.28)	0.030 (0.76)	0.027 (0.69)	a	a
24 – 20	0.50	0.006 (0.15)	0.005 (0.13)	0.012 (0.30)	0.011 (0.28)	0.012 (0.28)	0.011 (0.28)	0.030 (0.76)	0.027 (0.69)	a	a
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)	a	a
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)	a	a
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)	a	a

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,	
		Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min
9, 8	6.0	a	a	a	a	0.030 (0.76)	0.027 (0.69)	0.045 (1.14)	0.041 (1.04)	–	–
7, 6	10.0	a	a	a	a	a	a	0.060 (1.52)	0.054 (1.37)	–	–
5 – 2	16.0 – 25.0	a	a	a	a	a	a	0.060 (1.52)	0.054 (1.37)	–	–
1 – 4/0	35.0 – 95.0	a	a	a	a	a	a	0.080 (2.03)	0.072 (1.83)	–	–
250 – 500 kcmil	–	a	a	a	a	a	a	0.095 (2.41)	0.086 (2.18)	–	–
501 – 1000 kcmil	–	a	a	a	a	a	a	0.110 (2.79)	0.099 (2.51)	–	–
1001 – 2000 kcmil	–	a	a	a	a	a	a	0.125 (3.18)	0.112 (2.84)	–	–

^a Use Rating S, special applications

Table 7.5
Thickness requirements for extruded, fluoropolymer insulation materials (ECTFE, ETFE, FEP, MFA, PFA, PTFE, PVDF)

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,	
		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)	a	a
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)	a	a
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)	a	a
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)	a	a
18 – 15	1.0 – 1.5	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)	a	a
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)	a	a
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)	0.020 (0.51)	0.018 (0.46)	a	a
9, 8	6.0	a	a	a	a	0.015	0.013	0.030	0.027	–	–

Table 7.5 Continued on Next Page

Table 7.5 Continued

Conductor size, AWG	Conductor size, mm ²	Minimum average wall thickness (Avg) and minimum wall thickness at any point (Min) of insulation,									
		Wires rated 30 volts, inch (mm)		Wires rated 60, 90, 125, and 150 volts, inch (mm)		Wires rated 300 volts, inch (mm)		Wires rated 600 – 1000 volts, inch (mm)		Wires rated over 1000 volts,	
		Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min
7, 6	10.0	a	a	a	a	(0.38) a	(0.33) a	(0.76) 0.030	(0.69) 0.027	–	–
5 – 2	16.0 – 25.0	a	a	a	a	a	a	(0.76) 0.030	(0.69) 0.027	–	–
1 – 4/0	35.0 – 95.0	a	a	a	a	a	a	(0.76) 0.045	(0.69) 0.041	–	–
250 – 500 kcmil	–	a	a	a	a	a	a	(1.14) 0.060	(1.04) 0.054	–	–
								(1.52) 0.060	(1.37) 0.054		

^a Use Rating S, special applications

Table 7.6
Thickness requirements for PVC insulation with a nylon jacket

Conductor size, AWG	Conductor size, mm ²	Wires rated 300 V PVC wall, inch (mm)		Nylon wall thickness, inch (mm)	Wires rated 600 V 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)

8 Coverings

8 effective July 14, 2005

8.1 Coverings or jackets over insulated conductors, groups of insulated conductors, or coaxial members are not prohibited unless the covering is required in order for the construction to comply with a flame rating or use rating, in which case it is required.

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, aramid paper	450 (842)
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.

9 Fillers

9 effective July 14, 2005

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

10 Binders

10 effective July 14, 2005

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 effective July 14, 2005

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 be black in color and 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 46.3 and 47.2(l).

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 for Use Rating F. 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 effective July 14, 2005

12.1 Except for cables marked "VM," all of the circuit conductors and insulated grounding conductors shall have the same voltage rating.

12.2 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.

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

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

12.5 The circuit conductors in a round cable shall be cabled with a length of lay that is uniform throughout the length of the cable. Grouping of the circuit conductors into pairs, triads, quads, and other precabled subassemblies is not required. The direction of lay may be changed throughout the length of the cable. The intervals are not required to be uniform. In a cable in which the lay is reversed:

a) Each area in which the lay is right- or left-hand for several (typically 10) complete twists (full 360-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 lay – 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. 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 is defined as a counterclockwise twist away from the observer).

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

Number of insulated conductors in cable	Maximum length of lay of insulated conductors and precabled groups ^a
2	30 times the finished insulated conductor diameter ^b
3	35 times the finished insulated conductor diameter ^b
4	40 times the finished insulated conductor diameter ^b
5 or more	15 times the calculated diameter of the overall assembly. In a multiple-layer cable, the length of lay of the conductors in each of the inner layers of the cable is not specified.
NOTE – Length of lay of insulated conductors in cables rated 30 volts is not specified.	
^a The length of lay of each conductor in a group shall comply with the same values as those that are required for a cable. The length of lay of each group in a cable shall comply with the same values as those that are required for a conductor.	
^b Conductor diameter is the measured diameter of the largest individual finished conductor in the cable.	

13 Overall Jacket

13 effective July 14, 2005

13.1 An overall jacket shall use one of the jacket materials indicated in Tables 7.1 and 7.2, or any of the jacket materials described in Specific Materials, Section 50 of UL 1581. Other 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.

13.2 A protective jacket is not required for internal use (Use Rating I) cables. When used, the jacket shall be of an integral or nonintegral construction. The jacket material shall be in accordance with Tables 7.1 and 7.2, 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.

13.3 A protective jacket is required for external use (Use Rating II) cables. The jacket shall be of an integral or nonintegral construction. The jacket material shall be in accordance with Tables 7.1 and 7.2, 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 Vertical Flame Test for Use Rating II, Section 40.

13.4 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 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.

Table 13.1
Thickness^a of nonintegral, non-fluoropolymer jackets for external use (Rating II) 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)	(38.111 – 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 $1.1284 \times (TW)^{1/2}$ 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 (Use Rating II) AWM cables

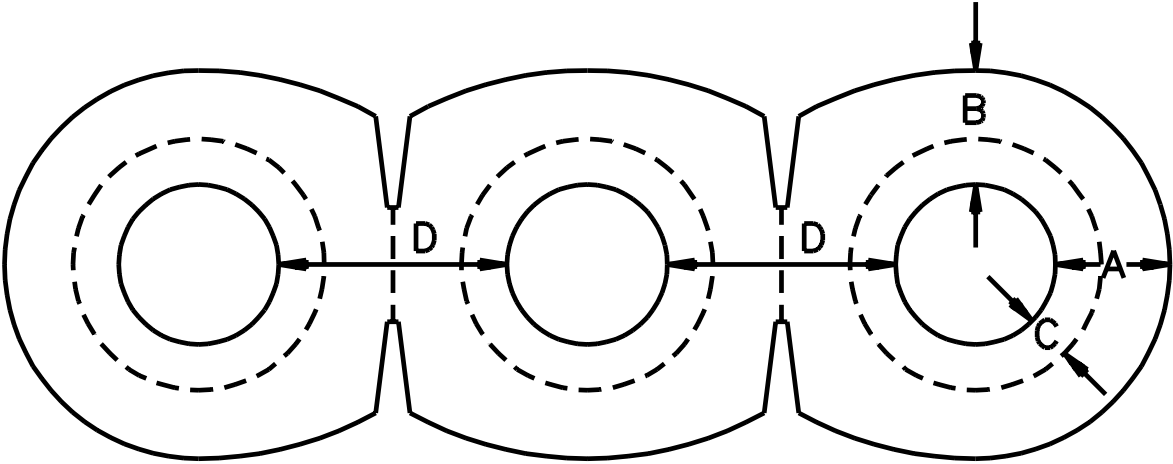
		Calculated diameter of round assembly under jacket or calculated equivalent diameter ^b of flat assembly under jacket					
		0 – 0.250 inch	0.251 – 0.350 inch	0.351 – 0.500 inch	0.501 – 0.700 inch	0.701 – 1.500 inches	1.501 – 2.500 inches
		(0 – 6.36 mm)	(6.37 – 8.91 mm)	(8.92 – 12.72 mm)	(12.73 – 17.80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

Table 13.3
Thickness of integral insulation (solid) and jacket on 2-, 3-, or 4-conductor flat, parallel cable and distance between conductors for 300-volt and 30-volt cables

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 , inch (mm)		B ^a , inch (mm)		C ^a , inch (mm)		D ^a , inch (mm)	
Nos. 22 – 12 AWG 300 or 600 volts	0.030	0.76	0.027	0.69	0.013	0.33	0.047	1.19
Nos. 24 – 12 AWG or 30 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.

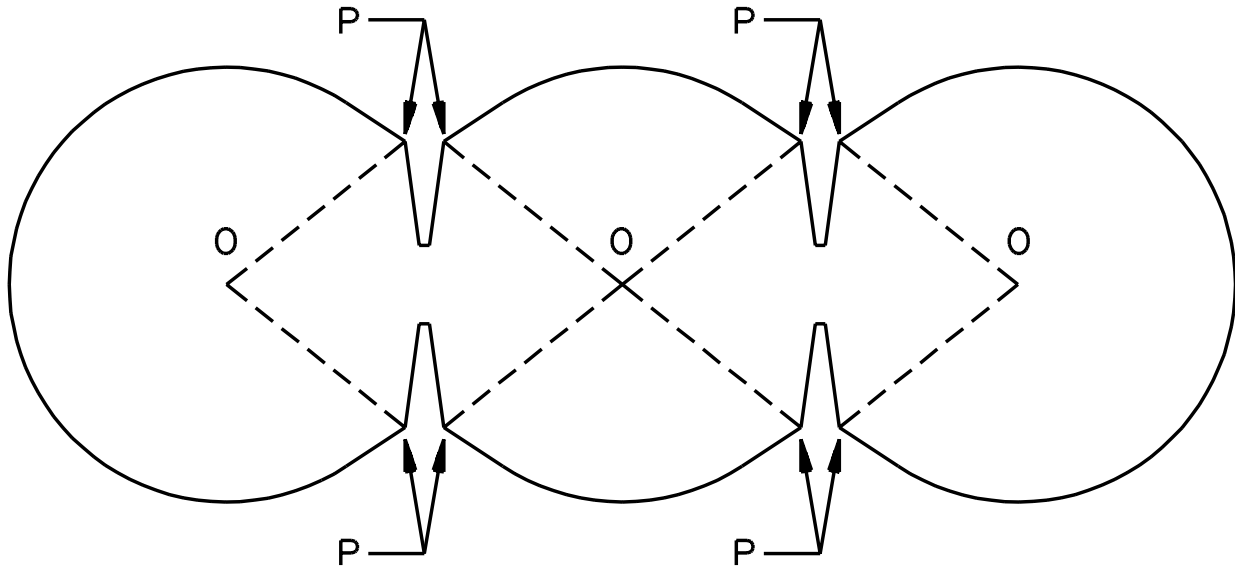
Figure 13.1
Integral flat cable



SB0636-2

NOTE - See Table 13.3 for dimensions A - D

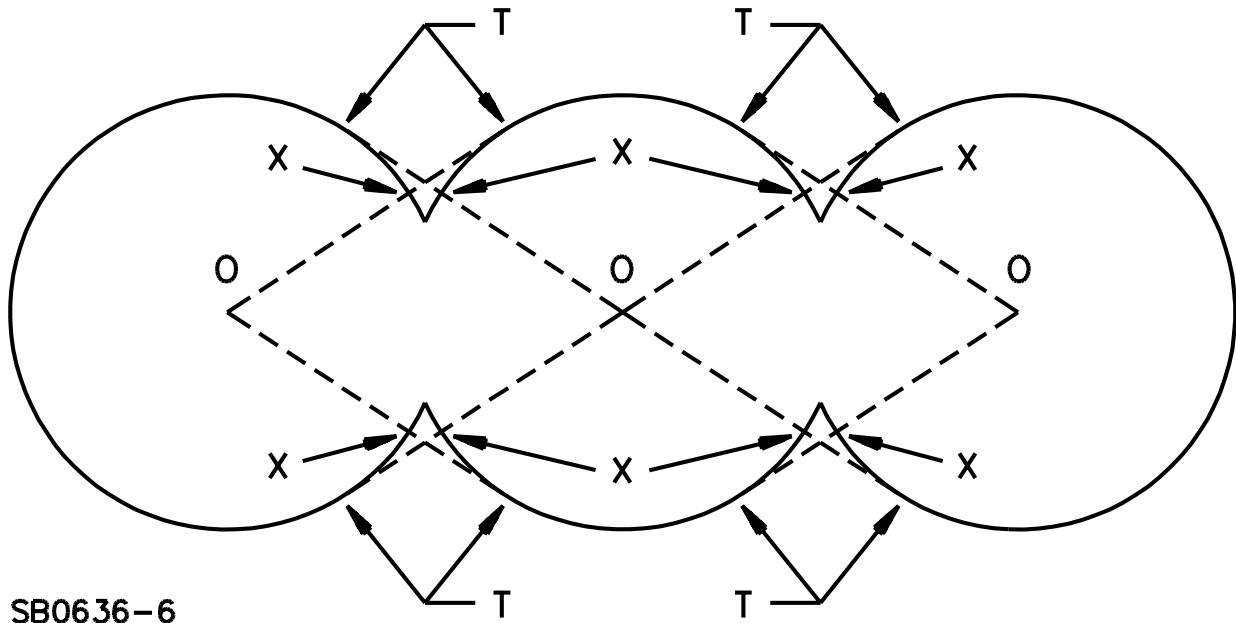
Figure 13.2
Definitions of regions of valley slopes in integral flat cables



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.

Figure 13.3
 Definition of regions of valley slopes in integral flat cables, without definite points



SB0636-6

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

PERFORMANCE

TESTS FOR THERMAL AND CHEMICAL PROPERTIES

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

14 effective July 14, 2005

14.1 Except for foamed and foamed/skin insulations, the physical properties (tensile strength and elongation) of both unaged and oven aged specimens of insulation, covering, and jacket shall be in accordance with Tables 7.1 and 7.2, 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 After Air Oven Conditioning, Section 20. For materials with a temperature rating other than that specified in Table 7.2 or for those materials not described in Section 50 of UL 1581, the aging conditions in Table 7.3 are to be used.

14.2 Specimens are to be tested in both unaged and air oven aged conditions. Tables 7.1 and 7.2, the tables in Specific Materials, Section 50, or Long-Term Aging, Section 481 of UL 1581 provide air oven conditioning requirements.

14.3 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.

14.4 The average of the maximum tensile strength and maximum elongation values are to be calculated and recorded separately for unaged specimens and oven aged specimens.

15 Physical Properties of Insulation and Jacket, Oil Immersion Aging

15 effective July 14, 2005

15.1 Specimens of oil resistant insulation and jacket are to be conditioned in accordance with 480.6 and 480.7 of Accelerated Aging, Section 480 of UL 1581 and Table 15.1.

Exception No. 1: Specimens of finished wire in 7 AWG and smaller sizes are to be bent at the center to form a narrow U² 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.

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
TPE – thermoplastic elastomer	60 (140)	60 (140)	168	75	75
XL – cross-linked thermosets	60 (140)	100 (212)	96	50	50

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 effective July 14, 2005

16.1 Specimens of gasoline resistant insulation and jacket are to be conditioned in a mixture of 17 percent water and 83 percent ASTM fuel C for 30 days at $23 \pm 1^\circ\text{C}$ ($73.4 \pm 1.8^\circ\text{F}$) in accordance with 480.9 of Accelerated Aging, Section 480 of UL 1581.

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 effective July 14, 2005

17.1 Specimens of sunlight resistant rating 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.

17.3 The "SUN RES" rating applies to the complete finished wire cable. Insulated conductors in a finished cable rated "SUN RES" are not evaluated for the "SUN RES" rating unless specifically noted on the shipping tag.

18 Conductor Corrosion Test

18 effective July 14, 2005

18.1 Only bare copper conductors without a metal coating are required to be tested. A specimen of an insulated conductor is to be tested in accordance with Conductor Corrosion, 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 7.3 is to be used. Insulated conductors in a jacketed cable are to be removed and tested independently of the finished cable.

18.2 After air oven conditioning, the test specimen is to be cooled to room temperature. Once at room temperature, the insulation 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 effective July 14, 2005

19.1 Only thermoplastic elastomer (TPE), thermoplastics (except for fluoropolymers), and XL materials are required to be tested. A specimen of finished wire is to be tested in accordance with Deformation, Section 560 of UL 1581, and Table 19.1 for the specific construction, wire size, material, and the specimen's associated temperature rating. Insulated conductors as well as the jacket of a jacketed cable are to 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		
Solid HDFRPE LDFRPE LDPE HDPE	Insulation	30 – 21	250	2.45	100.0 ±1.0	50
		20 – 12	400	3.92	(212.0 ±1.8)	
	Any separable jacket	–	2000 ^a	19.61	100.0 ±1.0 (212.0 ±1.8)	50
PVC or SRPVC	Insulation or integral insulation and jacket	30 – 21	250	2.45	121.0 ±1.0	50
		20 – 12	400	3.93	(249.8 ±1.8)	
		10 – 7	500	4.90		
		6 – 1	1600	9.80		
		1/0 – 4/0	2000	19.61		
	Any separable jacket	–	2000 ^a	19.61 ^a	121.0 ±1.0 (249.8 ±1.8)	50
TPE	Insulation	30 – 21	250	2.45	121.0 ±1.0	50
		20 – 12	400	3.92	(249.8 ±1.8)	
	Any separable jacket	–	2000 ^a	19.61 ^a	150.0 ±1.0 (302.0 ±1.8)	50
Solid XLPO Solid XL	Insulation or integral insulation and jacket	30 – 21	250	2.45	121.0 ±1.0	50
		20 – 12	400	3.92	(249.8 ±1.8)	
		10 – 7	500	4.90		
		6 – 1	1600	9.30		
		1/0 – 4/0	2000	19.61		
	Any separable jacket	–	2000 ^a	19.61 ^a	121.0 ±1.0 (249.8 ±1.8)	50

^aA 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. 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.

20 Flexibility Test After Air Oven Conditioning

20 effective July 14, 2005

20.1 An extruded specimen 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. Non-extruded specimens are to be subjected to the aging conditions specified in Table 7.3.

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

20.3 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. 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.

20.4 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 effective July 14, 2005

21.1 A 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. 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. The samples 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 jacket cables are to be tested separately. Only thermoplastic materials are required to be tested.

Table 21.1
Air temperature for heat-shock test

Material	Temperature rating of wire, °C (°F)	Air oven temperature, ±1.0°C (±1.8°F)
PE (polyethylene)	60 (140), 75 (167), and 80 (176)	100.0 (212.0)
TPE (thermoplastic elastomer)	90 (194) and 105 (221)	150.0 (302.0)
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 effective July 14, 2005

22.1 A 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, 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.

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 effective July 14, 2005

23.1 One 12-inch specimen of laminated flat cable in each 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 effective July 14, 2005

24.1 A 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 A 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.

Table 24.1
Shrinkback test conditioning temperatures

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

^a Test temperatures for LDPE, HDPE, FRLDPE, and FRHDPE 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 effective July 14, 2005

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 Method 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 0.0010 – 0.0015 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.

TESTS FOR MECHANICAL PROPERTIES

26 Crush Resistance Test (Mechanical Abuse Rating B)

26 effective July 14, 2005

26.1 All conductors with a mechanical abuse rating B 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.

26.2 Five specimens of finished 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.

26.3 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.

26.4 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.

26.5 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 26.1.

Table 26.1
Crush test requirements

Voltage rating of wire	Minimum average crush force
30 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)

26.6 Specimens shall exhibit average crush values in accordance with Table 26.1.

26.7 Mechanical abuse Rating B applies to the insulated conductor complying with the requirements or the complete finished jacketed cable using insulated conductors that comply with the requirements. In the case of a jacketed cable, only the insulated conductors are evaluated to qualify the complete finished cable for the mechanical abuse Rating B. All insulated conductors used in jacketed cables with the mechanical abuse Rating B must comply with the requirements of the test described in this section.

TESTS FOR ELECTRICAL PROPERTIES

27 Conductor Resistance Test

27 effective July 14, 2005

27.1 Resistance measurements are to be made by testing specimens in accordance with D-C Conductor Resistance, Section 220 of UL 1581. For temperatures other than 20 and 25°C (68 and 77°F), temperature factors for adjusting the DC resistance of conductors are to be made according to Factors for adjusting d-c resistance of conductors, Table 220.1 of UL 1581.

27.2 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; Table 27.1 in this Standard for conductors between 15 – 32 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 32 AWG.

Table 27.1
Maximum D-C resistance

Nominal conductor size, AWG	Solid conductor				Concentric-lay stranded conductor or bunch-stranded conductor			
	20°C (68°F)		25°C (77°F)		20°C (68°F)		25°C (77°F)	
	Ohms per 1000 ft.	Ohms per kilometer	Ohms per 1000 ft.	Ohms per kilometer	Ohms per 1000 ft.	Ohms per kilometer	Ohms per 1000 ft.	Ohms per kilometer
32	171.78	563.49	178.7	575.00	171.7	588.85	182.34	601.78
30	110.09	361.13	112.30	368.38	114.4	376.96	116.73	385.24
28	69.32	227.39	70.76	232.11	72.0	237.25	73.45	242.02
26	43.53	142.79	44.40	145.65	45.2	148.94	46.12	152.21
24	27.25	89.39	27.79	91.16	28.3	93.25	28.87	95.28
22	16.5	54.3	16.8	55.3	16.7	55.0	17.0	56.1
21	13.0	42.7	14.5	43.6	13.3	43.6	13.5	44.5
20	10.3	33.9	10.5	34.6	10.5	34.6	10.7	35.3
19	8.21	26.9	8.37	27.4	8.37	27.5	8.54	28.1
18	6.52	21.4	6.64	21.8	6.64	21.8	6.77	22.2
17	5.15	16.9	5.25	17.2	5.27	17.2	5.38	17.7
16	4.10	13.5	4.18	13.7	4.18	13.7	4.26	14.0

Table 27.1 Continued on Next Page

Table 27.1 Continued

Nominal conductor size, AWG	Solid conductor				Concentric-lay stranded conductor or bunch-stranded conductor			
	20°C (68°F)		25°C (77°F)		20°C (68°F)		25°C (77°F)	
	Ohms per 1000 ft.	Ohms per kilometer	Ohms per 1000 ft.	Ohms per kilometer	Ohms per 1000 ft.	Ohms per kilometer	Ohms per 1000 ft.	Ohms per kilometer
15	3.24	10.6	3.30	10.8	3.30	10.9	3.39	11.1
14	2.57	8.45	2.62	8.61	2.62	8.62	2.68	8.78
13	2.04	6.69	2.08	6.82	2.08	6.82	2.12	6.97
12	1.62	5.31	1.65	5.42	1.65	5.43	1.68	5.53
11	1.29	4.22	1.32	4.30	1.32	4.30	1.34	4.39
10	1.02	3.34	1.04	3.41	1.04	3.41	1.06	3.48

28 Dielectric Test, Method I

28 effective July 14, 2005

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 for 180 degrees minimum.

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. 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.

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	All	2000
300 ^a	All	2500
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 AC or DC

^a 300 V wires complying with Table 3.4 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:

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

29 Dielectric Test, Method II

29 effective July 14, 2005

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 remaining three samples are to be tested after air oven conditioning in accordance with Table 7.2, or Specific Materials, Section 50 of UL 1581. Non-extruded insulation is to be subjected to the aging conditions described in Table 7.3.

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 a circulating air 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 effective July 14, 2005

30.1 Specimens of finished wire are to be tested in accordance with the method described in 30.2 – 30.6. Insulated conductors 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 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 effective July 14, 2005

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. Finished insulated conductors composed of multiple layers of insulation are to be tested only as a finished cable.

31.2 A sample 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 effective July 14, 2005

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. 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.

32.2 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

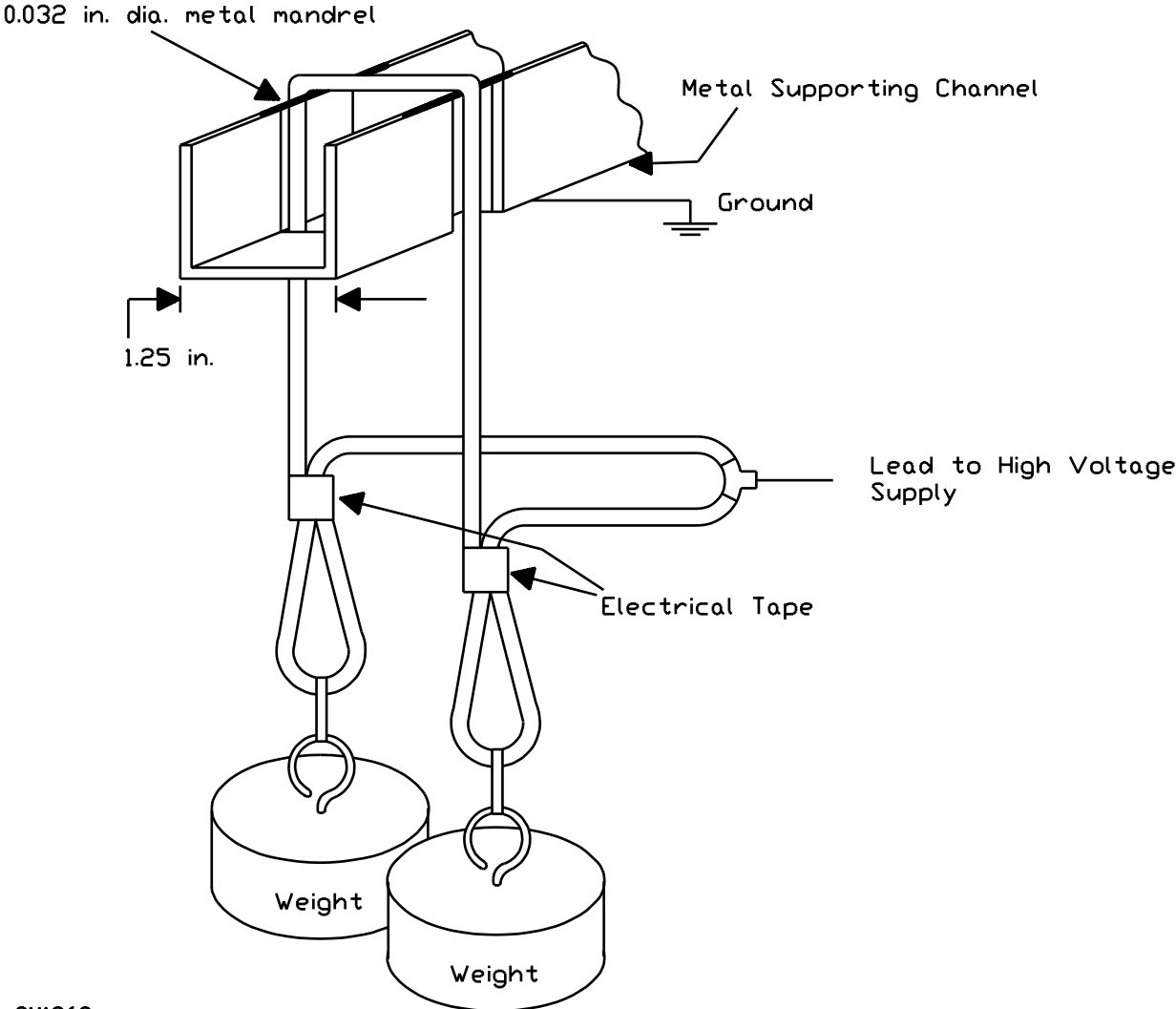
33 effective July 14, 2005

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.

33.2 A 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 effective July 14, 2005

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

35 effective July 14, 2005

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 $75 \pm 1.0^{\circ}\text{C}$ ($167 \pm 1.8^{\circ}\text{F}$). 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.

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):

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

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)

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

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

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.

35.3 The extended immersion at $50 \pm 1^\circ\text{C}$ ($122 \pm 1.8^\circ\text{F}$) or $75 \pm 1^\circ\text{C}$ ($167 \pm 1.8^\circ\text{F}$) 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 $\pm 1^\circ\text{C}$ ($\pm 1.8^\circ\text{F}$). 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 equipment and procedures used to conduct the insulation-resistance test shall be consistent with the equipment and procedures that are utilized by many manufacturers. However, the means used to achieve those objectives are not specified. A megohm bridge used for this purpose shall:

- a) Be of applicable range and calibration;
- b) Present readings that are accurate to 3 percent or less of full scale; and
- c) Have a 100 – 500-volt or higher open-circuit potential.

35.7 The center 50-foot (20-meter) sections of 55-foot (22-meter) coils of the insulated conductor are to be immersed in tap water at the specified temperature. The water temperature is to be maintained within 1°C (1.8°F) of being constant at any temperature in the range of $10.0 - 26.7^\circ\text{C}$ ($50 - 80^\circ\text{F}$) for the entire 6-hour or longer immersion period before the measurement of resistance. The ends of each coil are to extend 2.5 feet (1 m) away from the water.

36 Temperature Correction Factor (Wet Rated AWM)

36 effective July 14, 2005

36.1 Two specimens, conveniently of a No. 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.

36.2 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
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

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
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.

37 Capacitance and Relative Permittivity Tests (Wet Rated AWM)

37 effective July 14, 2005

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, 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, 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.

38 Stability Factor (Wet Rated AWM)

38 effective July 14, 2005

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 Use Rating I

39 effective July 14, 2005

39.1 Specimens of the finished insulated conductor or finished cable with the Use Rating I, are to be evaluated in accordance with the Horizontal-Specimen Appliance-Wire Flame Test, Section 1090 of UL 1581.

39.2 Flame Rating H applies to the finished wire or cable. Insulated conductors in a finished cable are not determined to be rated H unless specifically noted on the tag markings.

40 Vertical Flame Test for Use Rating II

40 effective July 14, 2005

40.1 Specimens of the finished insulated conductor or finished cable with the Use Rating II, are to be evaluated in accordance with Cable Flame Test, Section 1061 of UL 1581.

40.2 Flame Rating V applies to the finished wire or cable. Insulated conductors in a finished cable are not determined to be rated V unless specifically noted on the tag markings.

41 VW-1 Flame Test

41 effective July 14, 2005

41.1 Specimens of the finished insulated conductor and finished cable are to be tested in accordance with 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 effective July 14, 2005

42.1 Specimens of the finished insulated conductor and finished cable are to be tested in accordance with Vertical Flame Test, 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 effective July 14, 2005

43.1 Specimens of the finished insulated conductor and finished cable are to be tested in accordance with Horizontal-Specimen Flame Test for Thermoplastic- and Thermoset-Insulated Wires and Cables, 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.

MANUFACTURING AND PRODUCTION TESTS

44 Test for Continuity of Conductors

44 effective July 14, 2005

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 No. 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.

44.2 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 effective July 14, 2005

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, 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. 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. Wires that have been spark tested are not required to be retested after any of the following operations:

- a) Cutting into lengths shorter than 200 feet (60 m).
- b) Striping with a striping material evaluated for this particular use.
- c) Coating with a coating material evaluated for this particular use.

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.

Table 45.1
Spark test potentials

Voltage rating	AWG sizes	Spark test potential
30 V AC	All	500 V AC
60 V AC	All	750 V AC
90 V AC	All	1000 V AC
125 V AC	All	1500 V AC
150 V AC	All	1500 V AC
250 V AC	All	2000 V AC
300 V AC ^a	All (less than 15 mils of insulation)	2500 V AC
300 V AC ^a	19 and smaller	4000 V AC
300 V AC ^a	18 and larger	5000 V AC
600 ^a – 1000 V AC	24 and smaller	4000 V AC
600 ^a – 1000 V AC	23 – 20	5000 V AC
600 ^a – 1000 V AC	19 – 16	6000 V AC
600 ^a – 1000 V AC	14 – 9	7500 V AC
600 ^a – 1000 V AC	8 – 2	10,000 V AC
600 ^a – 1000 V AC	1 – 4/0	12,500 V AC
600 ^a – 1000 V AC	2135 – 500 kcmil	15,000 V AC
600 ^a – 1000 V AC	501 – 2000 kcmil	17,500 V AC
1001 – 5000 V AC	All ^b	10,000 V AC
7500 V AC	All ^b	15,000 V AC
10,000 V AC	All ^b	20,000 V AC
15,000 V AC	All ^b	30,000 V AC
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

Table 45.1 Continued on Next Page

Table 45.1 Continued

Voltage rating	AWG sizes	Spark test potential
^a 300 V wires complying with Table 3.4 shall be spark tested at 1500 V. 600 V wires complying with Table 3.4 shall be spark tested at 2000 V.		
^b Wires rated above 1000 V are only recognized in 10 AWG or smaller.		

MARKINGS

46 Surface Marking of AWM

46 effective July 14, 2005

46.1 Surface marking is not required for appliance wiring material.

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

- a) Wire/cable designation: "AWM."
- b) Applicable AWM code in accordance with Table 3.1.
- c) Manufacturer's name, trade name, other applicable mark, or file number. When a manufacturer 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.

46.3 For a cable that contains a conductive polymeric shield, the shield shall be black in color, and the surface of the jacket or marker tape shall be marked "Black Material is Conductive Shield," "Contains Black Polymeric Conductive Shield," or equivalent.

47 Markings on Tag, Reel, or Carton

47 effective July 14, 2005

47.1 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.

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

- a) Wire/cable designation: "AWM."
- b) Applicable AWM code in accordance with Table 3.1.
- c) Manufacturer's name, trade name, other applicable mark or file number. When a manufacturer 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

g) Insulation and jacket material and average wall thickness (example: Insulation SRPVC 0.009 inch; Jacket: PVC 0.030 inch).

h) The applicable special ratings or intended applications for cables with the Special Rating S (see Tables 3.1 and 3.2).

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

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

"Optical-fiber portion(s) of cable are for installation only in applications with levels of energy transmitted not exceeding those of Class I laser radiation (Title 21 CFR Part 1040)."

k) 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."

l) For a cable that contains a conductive polymeric shield, the shield shall be black in color, and the following wording or equivalent shall be included on the tag: "Black material is conductive shield" or "Contains Black Polymeric Conductive Shield."

m) For a cable with mixed voltage rating (VM), the voltage rating of each conductor shall be provided.

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.

48 Multiple Markings

48 effective July 14, 2005

48.1 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).

48.2 A cable that complies with the multiple requirements as specified in 48.1 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.

48.3 In 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 wide space.

48.4 In 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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